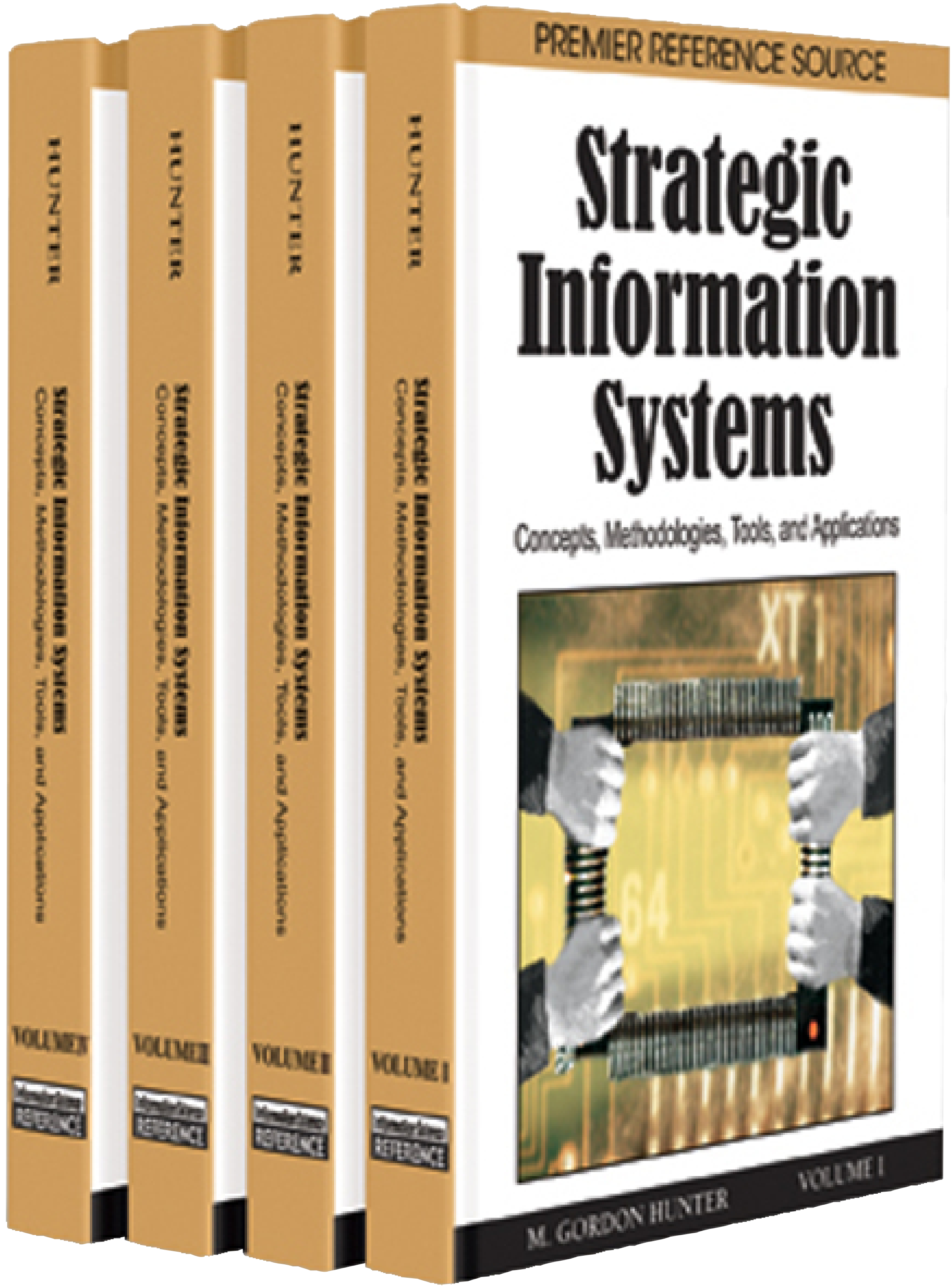

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Strategic Information Systems

Concepts, Methodologies, Tools, and Applications

VOLUME I

M. GORDON HUNTER

Strategic Information Systems:
Concepts, Methodologies, Tools, and Applications

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University of Lethbridge, Canada

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Contents

Volume I

Section I. Fundamental Concepts and Theories

This section serves as the foundation for this exhaustive reference tool by addressing crucial theories essential to the understanding of strategic information systems. Chapters found within these pages provide an excellent framework in which to position strategic information systems within the field of information science and technology. Individual contributions provide overviews of strategic intelligence, strategic decision making, and decision support systems, while also exploring critical stumbling blocks of this field. Within this introductory section, the reader can learn and choose from a compendium of expert research on the elemental theories underscoring the research and application of strategic information systems.

Section II. Development and Design Methodologies

This section provides in-depth coverage of conceptual architectures, frameworks and methodologies related to the design and implementation of strategic information systems. Throughout these contributions, research fundamentals in the discipline are presented and discussed. From broad examinations to specific discussions on particular frameworks and infrastructures, the research found within this section spans the discipline while also offering detailed, specific discussions. Basic designs, as well as abstract developments, are explained within these chapters, and frameworks for designing successful management information systems, data warehouses, and decision support systems are discussed.

Volume II

Section III. Tools and Technologies

This section presents extensive coverage of the technology that informs and impacts strategic information systems. These chapters provide an in-depth analysis of the use and development of innumerable devices and tools, while also providing insight into new and upcoming technologies, theories, and instruments that will soon be commonplace. Within these rigorously researched chapters, readers are presented with examples of the tools that facilitate and support the emergence and advancement of strategic information systems. In addition, the successful implementation and resulting impact of these various tools and technologies are discussed within this collection of chapters.

Section IV. Utilization and Application

This section introduces and discusses the utilization and application of strategic information systems. These particular selections highlight, among other topics, optimizing the relationship between business and information technology, applications of decision making and support systems, and the ways in which strategic intelligence has been applied in society. Contributions included in this section provide excellent coverage of today's strategic environment and insight into how strategic information systems impact the fabric of our present-day global village.

Volume III

Section V. Organizational and Social Implications

This section includes a wide range of research pertaining to the social and organizational impact of strategic information systems around the world. Chapters included in this section analyze organizational knowledge management, e-collaboration, and group decision support systems. The inquiries and methods presented in this section offer insight into the implications of strategic information systems at both a personal and organizational level, while also emphasizing potential areas of study within the discipline.

Section VI. Managerial Impact

This section presents contemporary coverage of the managerial implications of strategic information systems. Particular contributions address firm performance as it relates to IT strategy, the nature of knowledge in the IT workforce, and the effectiveness of strategic implementation. The managerial research provided in this section allows executives, practitioners, and researchers to gain a better sense of how strategic information systems can inform their practices and behavior.

Volume IV

Section VII. Critical Issues

This section addresses conceptual and theoretical issues related to the field of strategic information systems, which include failures and successes in system implementation. Within these chapters, the reader is presented with analysis of the most current and relevant conceptual inquires within this growing field of study. Particular chapters also address service quality in supply chain management, petri nets, and privacy and security in customer relationship management. Overall, contributions within this section ask unique, often theoretical questions related to the study of strategic information systems and, more often than not, conclude that solutions are both numerous and contradictory.

Section VIII. Emerging Trends

This section highlights research potential within the field of strategic information systems while exploring uncharted areas of study for the advancement of the discipline. Chapters within this section highlight advancements in enterprise resource planning, strategic technology planning, and strategic decision making for Green IT. These contributions, which conclude this exhaustive, multi-volume set, provide emerging trends and suggestions for future research within this rapidly expanding discipline.

Preface

Over the past decade, the strategic use of information systems has played an invaluable role in the explosion of information technology. However, adopting a strategic information system is rarely successful without the necessary care and attention. In today's fast-paced, on demand economy, implementation of information systems is a high risk, high reward decision. The impact of a thorough understanding of all vital aspects, ranging from specific mechanics of a system to the theoretical impact and future development, cannot be underestimated when investing in an information system.

Now, with the widespread use of strategic information systems and the efficiency expected by consumers in many industries, there is a call for greater research and development and for efficient systems in an ever widening spectrum of business, governments, and education. To keep up with the demand for newer and better systems, practitioners and researchers must keep abreast of the current research.

In order to provide the most comprehensive, in-depth, and recent coverage of all issues related to the development of cutting-edge strategic information systems, as well as to offer a single reference source on all conceptual, methodological, technical and managerial issues, as well as the opportunities, future challenges and emerging trends related to the development of strategic information systems, Information Science Reference is pleased to offer a four -volume reference collection on this rapidly growing discipline, in order to empower students, researchers, academicians, and practitioners with a comprehensive understanding of the most critical areas within this field of study.

Entitled "Strategic Information Systems: Concepts, Methodologies, Tools, and Applications," this collection is organized in eight distinct sections, providing the most wide-ranging coverage of topics such as: 1) Fundamental Concepts and Theories; 2) Development and Design Methodologies; 3) Tools and Technologies; 4) Utilization and Application; 5) Organizational and Social Implications; 6) Managerial Impact; 7) Critical Issues; and 8) Emerging Trends. The following provides a summary of what is covered in each section of this multi -volume reference collection:

Section 1, **Fundamental Concepts and Theories**, lays a foundation for the extensive research in the following sections. It begins with "The Nature of Strategic Intelligence, Current Practice and Solutions,“ by Mark Xu and Roland Kaye which complements the essential theories in "Strategic Alignment Between Business and Information Technology," by Fernando José Barbin Laurindo, Marly Monteiro de Carvalho and Tamio Shimizu. "Decision Support Systems," by John Wang and David J. Radosevich also provides an important perspective into how DSSs have changed the way business view information technology. Another consideration is discussed in "The Evaluation of Decision-Making Support Systems' Functionality," by Giusseppi Forgionne and Stephen Russell. This chapter includes an important discussion of how to best quantify and assess decision making systems. This section also includes chapters on the concepts underlying the effect of strategic systems with chapters like "Strategic Decision Making in

Global Supply Networks" by Ozlem Arisoy and Bopaya Bidanda, "Leveraging Supply Chain Management in the Digital Economy" by Mahesh S. Raisinghani, and "Information and Knowledge Perspectives in Systems Engineering and Management for Innovation and Productivity Through Enterprise Resource Planning" by Stephen V. Stephenson and Andrew P. Sage. These chapters provide a basis for further research and innovation.

Section 2, **Development and Design Methodologies**, illustrates the fundamental nature of the development stage. Selections such as "Strategic Technology Engineering Planning" by practitioners Tony C. Shan and Winnie W. Hua, "Design Science: A Case Study in Information Systems Re-Engineering" by Raul Valverde, Mark Toleman, and Aileen Cater-Steel, and "Design and Development of a Quality Management Information System," by M. Sakthive, S. R. Devadasan, S. Ragu Raman and S. Sriram, introduce the reader to all of the various facets of developing strategic systems that can ensure success or cripple a project from the start. Other chapters like "Data Warehouse Design to Support Customer Relationship Management Analysis" by Colleen Cunningham and Il-Yeol Song, "Designing Clinical Decision Support Systems in Health Care: A Systemic View" by Wullianallur Raghupathi, and "A Framework for a Scenario Driven Decision Support Systems Generator," by M. Daud Ahmed and David Sundaram provide specific examples of these critical underpinnings. "Challenges in Developing a Knowledge Management Strategy: A Case Study of the Air Force Materiel Command," by Summer E. Bartczak, Jason M. Turner and Ellen C. England, and "A Methodology for Developing Integrated Supply Chain Management System," by Yi-chen Lan and Bhuvan Unhelkar complete this section's treatment of current design and development research.

The chapter "Intelligent Agents in Decision Support Systems" by Gloria E. Phillips-Wren begins the next section, **Tools and Technologies**, with a discussion of how web-based, distributed systems can combine with artificial intelligence techniques to aid decision makers. "Agents and Multi-Agent Systems in Supply Chain Management: An Overview" by Pericles A. Mitkas and Paraskevi Nikolaidou charts the current advances in applying multi-agent systems to supply chain management and is complimented by chapters such as "Beyond Intelligent Agents: E-sensors for Supporting Supply Chain Collaboration and Preventing the Bullwhip Effect" by Walter Rodriguez, Janusz Zalewski and Elias Kirche, "Intelligent Supply Chain Management with Automatic Identification Technology" by Dong Li, Xiaojun Wang, Kinchung Liu, and Dennis Kehoe, and "Supply Chain Management and Portal Technology" by Scott Paquette. Supply chain management is not the only sector affected by the research in this section. Chapters like "An Ontology-Based Intelligent System Model for Semantic Information Processing," by Mark Xu, Vincent Ong, and Yanqing Duan, "A Knowledge Integration Approach for Organizational Decision Support" by Kee-Young Kwahk, Hee-Woong Kim and Hock Chuan Chan, and "Mobile Technologies in the New Zealand Real-Estate Industry," by Eusebio Scornavacca and Federico Herrera, provide perspective into the current tools that are setting trends reaching across many different industries.

Section 4, **Utilization and Application,** introduces research conducted on what is often the crux of any innovation. The actual worth of a system is in its proper use, and chapters like "I-Fit: Optimizing the Fit between Business and IT" by Alea Fairchild, Alea Fairchild, Piet Ribbers, Erik van Geel and Geert Snijder, "Managing Executive Information Systems for Strategic Intelligence in South Africa and Spain" by Udo Richard Averweg and José L. Roldán, and "An Application of Multi-Criteria Decision-Making Model for Strategic Outsourcing for Effective Supply-Chain Linkages" by N. K. Kwak and Chang Won Lee chronicle how best to ensure proper application. This is never more important than in healthcare, discussed in "Nonparametric Decision Support Systems in Medical Diagnosis: Modeling Pulmonary Embolism" by Steven Walczak, Bradley B. Brimhall and Jerry B. Lefkowitz, and "Decision Making by

Emergency Room Physicians and Residents: Implications for the Design of Clinical Decision Support Systems," by Michael J. Hine, Ken J. Farion, Wojtek Michalowski, and Szymon Wilk, and "Decision Support Systems for Cardiovascular Diseases Based on Data Mining and Fuzzy Modelling" by Markos G. Tsipouras, Themis P. Exarchos, Dimitrios I. Fotiadis, Aris Bechlioulis and Katerina K. Naka. In these chapters, and in this entire section, the reader is given a clear understanding of the dynamics involved in applying and using decision support systems.

Understanding and quantifying implementation strategies is an important part of applying strategic systems, but also necessary for understanding the issues created by these systems. Section 5, **Organizational and Social Implications,** presents ways that strategic systems affect the preexisting "human systems." "Supporting Distributed Groups with Group Support Systems: A Study of the Effect of Group Leaders and Communication Modes on Group Performance" by Youngjin Kim, and "Supporting Structured Group Decision Making Through System-Directed User Guidance: An Experimental Study" by Harold J. Lagroue III, both consider how to aid group decision making. Other chapters, including "E-Collaboration Using Group Decision Support Systems in Virtual Meetings" by Jamie S. Switzer and Jackie L. Hartman, "K-link+: A P2P Semantic Virtual Office for Organizational Knowledge Management" by Carlo Mastroianni, Giuseppe Pirrò and Domenico Talia, and "Organizational Culture for Knowledge Management Systems: A Study of Corporate Users" by Andrew P. Ciganek, En Mao and Mark Srite, broach the topic of organizational management. "Organizational Readiness Assessment for Knowledge Management" by Kaveh Mohammadi, Amir Khanlari, and Babak Sohrabi and "Strategic Alliance Capability: Bridging the Individual Back into Inter-Organizational Collaboration" by Christiane Prange, look at two specific issues in organizations, discussing how these systems can affect and enable knowledge management. Lastly, this section includes a look at a number of contexts through chapters such as "SHRM Portals in the 21st Century Organisation" by Beverley Lloyd-Walker and Jan Soutar, "Ethnographic Discovery of Adverse Events in Patient Online Discussions: Customer Relationship Management" by Roy Rada, "The Factors Influence Suppliers Satisfaction of Green Supply Chain Management Systems in Taiwan," by Hsiu-Chia Ko, Fan-Chuan Tseng, Chun-Po Yin and Li-Chun Huang, and "The Strategic Implications of E-Network Integration and Transformation Paths for Synchronizing Supply Chains," by Minjoon Jun and Shaohan Cai.

The next section, Section 6, **Managerial Impact,** delves into the concerns created by and solved by humans managing these systems. The first chapter "IT-Enabled Strategy: Implications for Firm Performance?" by Paul L. Drnevich discusses some of the opportunities that information systems offer to enhance performance, as well as identifying potential pitfalls. "Building the IT Workforce of the Future: The Demand for More Complex, Abstract, and Strategic Knowledge" by Deborah J. Armstrong, H. James Nelson, Kay M. Nelson, and V.K. Narayanan builds on this discussion by exploring the necessary mindsets required by a fully modern business. One of these shifts is the subject of "Managing Knowledge Capabilities for Strategy Implementation Effectiveness" by Sineenad Paisittanand, L. A. Digman and Sang M. Lee, in which the authors researched the effect of knowledge process capabilities on strategy implementation effectiveness. Also included in this section are chapters addressing topics related to customer relationship management, human resources, and financial management, presenting the complete, empirical view of how strategic systems affect the modern management of resources.

Section 7, **Critical Issues,** highlights the reasons for failure and success of system implementation and utilization. The following chapters are an important reference for both researchers and practitioners, featuring case studies and recent developments. The selections "Information System Development Failure and Complexity: A Case Study," by Abou Bakar Nauman, Romana Aziz and A.F.M. Ishaq, "Empirical

Assessment of Factors Influencing Success of Enterprise Resource Planning Implementations” by Fiona Fui-Hoon Nah, Zahidul Islam, and Mathew Tan, and “A Strategic Framework for Managing Failure in JIT Supply Chains” by Jaydeep Balakrishnan, Frances Bowen, and Astrid L.H. Eckstein provide case studies and examples from functioning business and organizations. These selections give real-time problems and solutions that are invaluable when it is necessary to avoid any pitfalls. Chapters like “Information Feedback Approach for Maintaining Service Quality in Supply Chain Management,” by R. Manjunath, “Towards Stable Model Bases for Causal Strategic Decision Support Systems” by Christian Hillbrand, and “Supporting Demand Supply Network Optimization with Petri Nets” by Teemu Tynjala, explore how to approach and solve problems that develop from using strategic information systems. This section also includes chapters addressing more delicate ethical issues, as in “Security Policies and Procedures” by Yvette Ghormley and “Privacy and Security in the Age of Electronic Customer Relationship Management” by Nicholas C. Romano, Jr and Jerry Fjermestad.

Lastly, Section 8, **Emerging Trends**, provides an exciting view of the cutting-edge research currently being conducted. “Enterprise Resource Planning (ERP): Past, Present and Future” by Ronald E. McGaughey and Angappa Gunasekaran is an excellent overview of the present and an insightful look into the future areas of development. Ashley Davis’s contribution, “Enterprise Resource Planning Under Open Source Software,” explores the possibilities and critical factors offered by open source software. The expansion of strategic information systems is the subject of such chapters like “The Dynamics and Rationality of Collective Behavior within a Global Information System” by Jacek Unold, “Toward an Interdisciplinary Engineering and Management of Complex IT-Intensive Organizational Systems: A Systems View” by Manuel Mora, Ovsei Gelman, Moti Frank, David B. Paradice, Francisco Cervantes and Guisseppi A. Forgionne, “Strategic Technology Planning for the Techno-Global Economy: Cities in the Market” by Al D. McCready, and “Enhancing Decision Support Systems with Spatial Capabilities,” by Marcus Costa Sampaio, Cláudio de Souza Baptista, André Gomes de Sousa, and Fabiana Ferreira do Nascimento. Innovation is also taking place where strategic systems are common as shown in “Strategic Decisions for Green Electricity Marketing: Learning from Past Experiences” by Marta Pérez-Plaza and Pedro Linares, “The Future of Supply Chain Management: Shifting from Logistics Driven to a Customer Driven Model” by Ketan Vanjara, and “System Dynamics Modeling for Strategic Management of Green Supply Chain,” by Ying Su, Zhanming Jin, and Lei Yang. This section forms an invaluable aid for spurring on further research and creating new applications to aid all areas of future societies.

Although the contents of this multi-volume book are organized within the preceding eight sections which offer a progression of coverage of important concepts, methodologies, technologies, applications, social issues, and emerging trends, the reader can also identify specific contents by utilizing the extensive indexing system listed at the end of each volume. Furthermore, to ensure that the scholar, researcher, and educator have access to the entire contents of this multi-volume set, as well as additional coverage that could not be included in the print version of this publication, the publisher will provide unlimited, multi-user electronic access to the online aggregated database of this collection for the life of the edition free of charge when a library purchases a print copy. In addition to providing content not included within the print version, this aggregated database is also continually updated to ensure that the most current research is available to those interested in strategic information systems.

Strategic information systems will undoubtedly continue to become increasingly important to all facets of life in a modern society. Therefore, a complete understanding of the concepts and research offered in this book will be instrumental to the achievement of any structured goal whether in business, government, education or even daily life. Although strategic information systems promise to effectively manage all facets of an organization, experience has proved that only through careful and responsive implementation can these promises be fulfilled completely. These volumes are the building blocks to reach the desired functionality.

The diverse and comprehensive coverage of strategic information systems in this four-volume, authoritative publication will contribute to a better understanding of all topics, research, and discoveries in this developing, significant field of study. Furthermore, the contributions included in this multi-volume collection series will be instrumental in the expansion of the body of knowledge in this enormous field, resulting in a greater understanding of the fundamentals while also fueling the research initiatives in emerging fields. We at Information Science Reference, along with the editor of this collection, hope that this multi-volume collection will become instrumental in the expansion of the discipline and will promote the continued growth of strategic information systems.

Strategic Information Systems:
An Overview

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ABSTRACT

This introductory chapter presents an overview of the field of Strategic Information Systems. To begin, the concepts of strategy and information systems are introduced to provide a context for the subsequent discussion. Then themes are identified via a review of existing literature. This review provides further context within which implications for the future are proffered. The chapter concludes with a call to researchers to further investigate this varied and intriguing field of study.

INTRODUCTION

What is the field of study called "Strategic Information Systems" about? Is it about information systems that are strategic? Is it about information systems that support strategy? Is it about how strategy and information systems should be aligned? The answer to these three questions is "yes". This chapter accepts the above myriad of interpretations of strategic information systems and presents a review of the many varied concepts and issues.

A perspective on the interpretation of these terms is that information technology may be used to represent the components of infrastructure, such as hardware and telecommunications. Then, the term information system (which would encompass these infrastructure components) also includes the processes, both manual and automated, which support business operations and eventually, in relation to the organization's strategic direction, contributes to competitive advantage. However, in this chapter information systems and information technology will be used interchangeably, mainly because their use throughout the literature reviewed here is not entirely consistent. That is, in this discussion they will mean the same thing. In general, information systems (and in this chapter information technology) exist to gather data and transform that data into information to support decision making within an organization. These decisions may be made at various levels within the organization. However, the eventual consequence of management decisions will relate to the overall business strategy. Thus, the information systems must provide support for the strategic direction of the organization.

So, whether the information system is strategic or that it supports strategic initiatives it is an important consequence that information systems be aligned with the adopted strategy of the organization.

A REVIEW OF THE EXISTING LITERATURE

The available literature provides a plethora of concepts and themes related to strategic information systems. This section of the chapter will first present a discussion of general concepts which provide a context for strategic information systems. The next part of the chapter will then focus upon themes which emerge from the literature. The research reported here relates to perspectives of overall approaches to strategic information systems. Specific applications are finally presented at the end of this section.

Concepts

The concepts discussed in this section describe various contexts within which information systems functions in relation to strategic initiatives. To begin, the case is made for evaluating information systems relating to their use in infrastructure and business processes. Next, competitive advantage will be facilitated through management of information resulting from information systems that appropriately reflect current business processes. A consideration for aspects beyond financial measures is introduced by the concepts of the Balanced Scorecard. Finally, alignment of information systems and strategy is discussed through the concepts of Six Sigma, Business Architecture, and the generic business model.

Any investment decision by an organization is usually accompanied by a calculation estimating the expected return to be gained. Investments in information systems have been subject to a similar evaluation approach. However, there seems to be issues which are related to information system implementation evaluation. (Brynjolfsson, 1993). With regards to the overall implementation of information systems there is an unclear delay in the period of potential payback from the initial investment. Further, current wisdom suggests that perhaps there should be a consideration for the differentiation between infrastructure investments and those meant to support and facilitate business processes (King, 2007). The infrastructure investments should be considered “table stakes” and are similar to other infrastructure items such as telephones and lighting. So, these investments should simply be considered a necessary part of being in the game. They should provide a minimum level of service in order to be considered successful. The investments in information systems which are related to facilitating business processes should most certainly be evaluated. Indeed, these investments will have important affects on performance and will eventually contribute to the organization’s competitive advantage. This is the perspective that should be taken by the decision makers.

Kadiyala and Kleiner (2005) investigated competitive advantage and present an overview of new developments in information systems. They suggest that information systems have an impact on the competitive advantage of the organization at the strategic level. The use of information systems will support better decision making and improved customer service. Better management of information will result in increased productivity. Overall, more certain strategic decisions will result in competitive advantage. Further, competitive advantage will be facilitated by the existence of current information systems. This means that the information system should reflect the current status of business processes.

The Balanced Scorecard (Kaplan and Norton, 1992) approach to performance measurement incorporates both financial and non-financial measures. The Balanced Scorecard includes four perspectives relating to customers, business processes, learning and innovation, and financial. The use of the balanced Scorecard approach results in a change of focus from achieving business objectives to identifying the information necessary to measure performance. Further, Epstein and Rejc (2005) propose to incorporate the Balanced Scorecard approach when evaluating information systems investments. They suggest this improved rigor will support the justification and evaluation of information system initiatives. Thus, based upon the four perspectives of the original Balanced Scorecard Epstein and Rejc (2005) propose that organizations must develop specific information systems related measurements. It is important, they note, that these measures be aligned with the overall corporate objectives. They conclude by suggesting a method for determining the appropriate measures for a specific organization. Also, the use of the Balanced Scorecard approach for the evaluation of information systems performance is also proposed by Huang and Hu (2007). They propose that through employing this approach alignment may be achieved between business strategy and the necessary information systems processes. They suggest that alignment is not a process but a mindset. Thus, alignment will drive the design, management, and execution of the information system function in concert with the strategic goals of the business. Finally, Hanafizadeh et al (2008) propose the use of the Balanced Scorecard to initially identify strategic business processes and then to ensure alignment of information systems investments with the strategic goals of the business.

The concept of alignment is also presented here through a discussion of the concepts related to Six Sigma, Business Architecture, and generic business model.

Six Sigma is a comprehensive system which contributes to improved business performance (Pande et al, 2000). The value of the method is that its use improves competitive advantage and supports a move to overall business excellence (Lawton, 2004). The Six Sigma application to information systems represents an important strategic initiative (Hsieh et al, 2007). The application of the method to process improvement projects facilitates alignment with the corporate strategic plan.

The Business Architecture concept (Versteeg and Bouwman, 2006) places responsibility over economic activities, or business domains, within an organization. A business domain is a function over which meaningful control may be implemented through appropriate business processes. The establishment of a Business Architecture will facilitate understanding of the business strategy and how the business processes relate to the strategy. In turn, direction will be taken in the design of information systems which will support the business strategy.

Hedman and Kalling (2003) describe components of a generic business model which may be employed to demonstrate the relationship between the business and information systems and to show how information systems relate to the broader business context.

The various concepts presented above serve to outline a number of perspectives regarding the context of information systems and their relationship with business strategy. In general, a strategic goal may be identified to establish and maintain competitive advantage. An important component of this initiative is the information system. The concepts outlined here suggest that alignment of information systems and strategic initiatives will facilitate improved performance and ultimately make a positive contribution to competitive advantage.

Themes

The themes which emerged from the literature about information systems and strategy relate to perspectives on the dynamic environments of both information systems and strategy; about knowledge sharing and knowledge management; and about the generic approach to business process improvement. These themes are presented in the context of ensuring information systems represent necessary business processes and are aligned with business strategy to ensure a positive contribution to competitive advantage.

The environment of both information systems and strategy is dynamic and continually changing. Beeson et al (2002) present a communication and decision making framework to facilitate responding to changing circumstances. This framework supports the linkage of business strategy with information systems development. Further, a close alignment of information systems and the strategy of the business are difficult to attain (Boddy and Paton, 2005). The environment of both information systems and the business is dynamic. While alignment will facilitate competitive advantage, a contingent approach will be necessary. Thus, Boddy and Paton (2005) suggest the use of semi-structures which entails a separate business unit to function in a temporary decentralized form. This autonomous and innovative business unit may be employed to counter the demands of stability for the existing business. In relation to information systems, then it is incumbent upon management to decide which projects reinforce stability and which foster innovation. Also, enterprise agility involves the ability to respond rapidly to environmental change (Overby et al, 2006). Thus an agile business will perform well in changing environments. Effective use of information systems will facilitate enterprise agility. Information systems should be used for both sensing and responding to rapidly changing environments.

Knowledge sharing facilitates strategic planning (Pai, 2006). Knowledge sharing may be enhanced by such organization structures as steering committees and strategic planning teams specifically related to information systems implementation. Knowledge sharing and transfer may be facilitated by such information systems as groupware and web-based applications (Lee and Bai, 2003). Also, knowledge sharing requires activities related to both knowledge contribution and knowledge seeking (Bock et al, 2006). In order to facilitate both contribution and seeking collaborative norms must be established within the business which promotes both of these activities. Knowledge management systems in general and specific systems such as SharePoint provide the platform for knowledge sharing. Further, knowledge sharing is also facilitated through the establishment of electronic knowledge repositories such as expert knowledge, lessons learned databases, and project web sites. (Fulk et al, 2004). Thus, the idea of Knowledge Management attempts to provide sustainable competitive advantage through the development of a strategy for effectively employing knowledge across a business (Barber et al, 2006). Knowledge management is more about connection rather than collections (Dougherty, 1999). That is, the management of corporate knowledge should focus on its transfer among appropriate individuals within the company. It is not sufficient to just gather data. It is necessary to ensure those who need the information are connected in a way that knowledge may be shared. The connection processes can be managed through the use of information systems.

The idea of attempting to improve businesses processes is not new. However, relating the improvement of business processes through appropriate use of information systems is relatively recent. Not too long ago, Hammer and Champy (1993) defined Business Process Reengineering (BPR) as follows:

The fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical contemporary measures of performance, such as cost, quality, service, and speed.

However, according to Ackermann et al (1999) the focus in practice regarding BPR has been on efficiencies such as cost reduction. This focus may be the result of assessing BPR initiatives based upon the bottom line. Thus, Ackermann et al (1999) propose a customer focus which will result in more of a consideration for the effective renewal of business processes.

Wheeler (2002) has proposed a net-enabled business innovation cycle (NEBIC) as a way to determine and evaluate a business' capability to employ digital networks to improve performance through increasing customer value. Hackbarth and Kettinger (2004) have employed NEBIC to evaluate how businesses use technology to support strategy. They determined that businesses follow one of two paths. One path, an incremental strategy employs a gradual approach to business process improvement. The second path, a leapfrogging strategy entails an approach of rapidly exploiting technology to achieve business innovation. When the external business environment is very competitive and the business experiences pressure to respond to market opportunities the second approach, leapfrogging is what firms tend to adopt.

Applications

While many information systems applications may contribute to the strategic initiatives of an organization, this section focuses on enterprise-wide systems which are able to provide a cross functional perspective on business operations and consequently make a contribution to competitive advantage. Thus, to begin, Enterprise Resource Planning (ERP) systems are discussed. Then the major modules within an ERP system are presented. These modules include, Customer Relationship Management (CRM), Supply Chain Management (SCM), and Human Resource Management (HRM). It is noted that these major modules facilitate a strategic emphasis on customers, suppliers, and employees.

Enterprise Resource Planning (ERP)

An Enterprise Resource Planning information system is an, *"information system that supports and integrates all facets of the business…"* (Jessup et al, 2008, p. 414)

It has been determined that 42% of corporate level information systems projects are terminated before completion (Wysocki, 1998). Further, projects involving business process re-engineering technology fail to meet their objectives in over 50% of the documented cases (Stewart, 1993; Roth and Marucheck, 1994; and Rohleder and Silver, 1997). More recently, Ettlie et al (2005) found that the potentially most hazardous information systems projects relate to the purchase and implementation of enterprise systems. They suggest the predictors of positive adoption performance are leadership (introducing learning to the workplace); business processes (adoption of new technology will change the business processes); and acquisition strategy (through the concepts of transaction cost economics potential benefits for adoption may be identified). Thus, ERP systems are both high risk and high reward.

Huq et al (2006) investigated the change management activities of three companies to understand the influence of the use of business process reengineering (BPR) techniques on the ERP endeavor. The authors found that the organizations experienced changes in their structure, organizational culture and management processes as a function of using BPR techniques to support the ERP implementation. Six change management issues:

- Leadership
- barriers to change
- communications
- implementation of change and control
- culture
- change review are important factors of consideration when implementing change

Cotteleer et al. (2006) investigated the degree to which changes in process dynamics affect operational performance. Using longitudinal case study data, the authors found that order fulfillment lead-time, a key performance indicator, demonstrated improvement after ERP system implementation. This suggests that performance enhancements do arise from the implementation of new ERP technologies.

Al-Mashari et al. (2003) developed a taxonomy of ERP critical factors to demonstrate the interrelationship between the uses of technology to support business strategies. In their taxonomy, the authors assert that ERP implementations occur in three stages (setting-up, implementation, and evaluation) with 12 factors of importance across these stages. The taxonomy highlights that ERP benefits are achieved when the implementation approach and the performance measures of the business are closely aligned. The authors suggest that leadership and commitment are the two key elements of ERP success.

Welch and Kordysh (2007) outline a number of aspects that contribute to successful ERP implementation and use. The key aspect relates to harmonization of business processes with the ERP system processes. Information system acquisitions must respond to business needs and consequently support strategic initiatives. Enterprise-wide information systems link the systems and the strategic objectives of the business (Ndede-Amadi, 2004).

Customer Relationship Management (CRM)

A Customer Relationship Management information system supports the, "…*interaction between the firm and its customers.*" (Jessup et al, 2008, p. 412).

Valos et al (2007) reviewed CRM through the lens of Porter's (1980) three generic marketing strategies. The strategies relate to the approach a business takes when dealing with markets and includes product differentiators, cost leaders, and product focus. In all cases, while CRM may be employed in different ways this specific information systems application does contribute positively to the strategy of the business.

Successful CRM systems (Yu, 2001) have common characteristics related to corporate culture (senior management support through major financial commitment); and an emphasis on technology improvement (including alignment between information systems and marketing).

An extension of CRM is electronic customer relationship management (eCRM). This approach employs technology to facilitate the gathering of data and interacting with customers. This strategic initiative has met with success by those companies investigated by Chen and Chen (2004). They determined that success factors for eCRM implementation and use related to similar aspects of successful generic information systems implementation. These factors include leadership; perceived usefulness; alignment; integration; and culture.

Lin et al (2006) support earlier work that suggests eCRM is an important strategy for business. They employ a modified version of Grant's (2003) strategic alignment model to evaluate the strategic impact of eCRM.

Nguyen et al (2007) suggest that a CRM system is not just another information tool. If applied properly, CRM programs can contribute exceptional economic value to the company as well as competitive advantage. They differentiate between CRM, eCRM, and mCRM based upon the use of current and leading edge technology. Implementation issues however relate to those commonly encountered in the implementation of generic CRM initiatives.

Supply Chain Management (SCM)

A Supply Chain Management information system manages the, "… *network of suppliers and subsuppliers that a company interacts with*." (Jessup et al, 2008, p. 421).

Lin and Tseng (2006) demonstrate the strategic importance of integrating operations with suppliers and customers through a supply chain management system. Supply chain management entails the business relationships between suppliers and the company. As more advanced technology is employed in this management process operations become more integrated between the company and the suppliers.

Human Resource Management (HRM)

A Human Resource Management information system provides technological support for the effective management of employees. (Haag et al, 2008).

The practice of Human Resource Management and the use of information systems can contribute to strategic initiatives (Ferratt et al, 2005) of the business. The strategic HRM literature offers three perspectives in this contribution. One perspective, the universalistic approach (Pfeffer, 1998), suggests that "best practices" exist which may be applied across organizations regardless of context. Another perspective, the contingency approach (Youndt et al, 1996) argues that business strategy affects HRM practice. The third perspective, the configurational approach (Doty and Glick, 1994) suggests that patterns of HRM practices exist and they are synergistic sets of practices that are complementary with the strategy of the business. This latter perspective provides the richest link between HRM practice and business strategy because of its incorporation of complex patterns of operation (Ferratt et al, 2005).

Byrd et al (2004) investigated the skill and experience of information technology personnel and the consequent affect on the competitive advantage of the business. They determined that a high level of knowledge and skill on the part of information technology personnel contributed to business competitive advantage.

Mayfield et al (2003) developed a comprehensive model representing the functions of human resource information systems. They determined that these systems are an essential factor in competent, learning organizations. As a consequence, the use of these systems leads to competitive advantage.

IMPLICATIONS FOR THE FUTURE

King (2007) suggests that organizations should focus on their core competencies and outsource other activities to specialist companies. This means that for the information technology organization it is important to identify the necessary core competencies, and retain them within the organization, to support the strategic initiatives of the business.

As Hoving (2007) suggests,

> *The challenges of IT leadership continue to increase. IT leaders need many talents to succeed: 1) innate knowledge of the technologies and natural intuition to know which ones are going to pay off; 2) business acumen and the fortitude to demand measurable returns; 3) the ability to manage a diverse set of internal and external resources within an ever changing set of value propositions; and most import; 4) the IT leader … has to be an executer with a keen sense of what it takes to get the right things done.* (Hoving, 2007, p. 153)

Hunter (2007) in his review of Chief Information Officer (CIO) management experiences suggests,

> *The future entails some exciting times for the CIO. For their business unit the CIO will be investigating the implementation of standards in the performance of duties. Staffing will continue to be an issue. Finding individuals with the necessary skills and ensuring they retain those necessary skills will require continual vigilance as business requirements evolve. Further, as the CIO is recognized within the com-*

pany as a fully fledged member of the senior management team there will be more of a requirement to contribute to the overall goals and direction of the company. The contribution to be made by the CIO and the information systems function will be in the appropriate application of technology in support of the company goals. It will still remain the purview of the CIO and the information systems function to be the source for ideas on the application of new technology. Again, it will be incumbent upon this area to show leadership in the appropriate use of any new and emerging technologies. (Hunter, 2007, p. 245)

CONCLUSION

This chapter has presented an overview of strategic information systems. It is important that information systems be aligned with the strategy adopted by the organization. An information system may be strategic itself or it may simply support strategic initiatives. In any case it is incumbent upon senior management to recognize the vital role played by information systems in relation to the strategic initiatives of the organization.

Information systems must be aligned with and function within the context of strategic initiatives. While post-implementation evaluation of information systems should be conducted, it may be prudent to incorporate non-financial measures into the assessment. Infrastructure components are necessary and should be evaluated based upon required service levels. The implementation of information systems to support business functions may be assessed using traditional financial measures. However, other criteria should also be adopted. These criteria could relate to intangibles such as better customer service; or improved decision making. Another consideration is the assessment of how the information system contributes to competitive advantage.

The current business environment is continually changing. Thus, information systems must be capable of responding dynamically to an elusive strategic target. As the business environment changes so too must the processes that support the business functions. Thus, information systems may be employed to facilitate continuous business process improvement. But information systems must go beyond simply processing data into information, and must facilitate the sharing and management of knowledge.

Further, alignment is the cornerstone of the relationship between information systems and strategy. Information systems must respond to and support the strategic initiatives of the organization.

Finally, this area of strategic information systems is a rich field for investigations. Researchers are encouraged to bring their expertise to the exploration of this topic. As shown above this is a dynamic environment for both information systems and strategic business initiatives. This ever changing field of study contains a plethora of new and interesting topics to investigate.

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Section I

Fundamental Concepts and Theories

This section serves as the foundation for this exhaustive reference tool by addressing crucial theories essential to the understanding of strategic information systems. Chapters found within these pages provide an excellent framework in which to position strategic information systems within the field of information science and technology. Individual contributions provide overviews of strategic intelligence, strategic decision making, and decision support systems, while also exploring critical stumbling blocks of this field. Within this introductory section, the reader can learn and choose from a compendium of expert research on the elemental theories underscoring the research and application of strategic information systems.

Chapter 1.1

The Nature of Strategic Intelligence, Current Practice and Solutions

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ABSTRACT

This chapter discusses the nature of strategic intelligence and the challenges of systematically scanning and processing strategic information. It reveals that strategic intelligence practice concentrates on competitive intelligence gathering, non-competitive related intelligence have not yet been systematically scanned and processed. Much of the intelligence is collected through informal and manual based systems. Turning data into analyzed, meaningful intelligence for action is limited to a few industry leaders. The chapter proposed a corporate intelligence solution, which comprises of three key intelligence functions, namely organizational-wide intelligence scanning, knowledge enriched intelligent refining, and specialist support. A corporate radar system (CRS) for external environment scanning, which is a part of the organizational-wide intelligence scanning process is explored in light of latest technology development. Implementation issues are discussed. The chapter develops insight of strategic intelligence, and the solution could significantly enhance a manager's and a company's sensibility and capability in dealing with external opportunities and threats.

INTRODUCTION

As the business environment becomes more turbulent and competition becomes fiercer, developing foresight about future opportunities and threats, and reacting quickly to the opportunities and threats, becomes a core competency of a wining organization. Companies that can generate competitive intelligence are leaders in their industry (Desouza, 2001). However the increasing demand for strategic information has not been satisfied by the explosive growth in data available. This is reflected in two facets: firstly, computer-based information systems are inadequately implemented at the corporate level for strategic information delivery; secondly, senior managers who go online always feel overwhelmed with the glut of data instead of meaningful, actionable information. Research which applies computing technology to support strategic management activities concentrates on the development and the implementation of computer-based systems for decision support. Systems such as decision support system (DSS), executive information systems (EIS), or executive support systems (ESS) are examples. Strategic management process however is more than an activity of making decisions (Simon, 1965), the process begins with strategic information acquisition, formulating strategic problems, reasoning strategic alternatives, and finally making a decision. There is a distinction between supporting managers with strategic information and supporting making decisions. Information systems tend to emphasize decision-making support more than strategic information support. Senior managers' information acquisition processes have not been adequately addressed in the context of information systems development, except the field of competitive intelligence (Cobb, 2003; Pelsmacker et al., 2005; Patton & McKenna, 2005; Sauter, 2005) and Web-based information searching systems (Chen, Chau, & Zeng, 2002). Supporting strategic intelligence activity with information technology is an area remaining largely unexplored. This chapter aims to address the nature of strategic intelligence and the challenges, and to explore the possible solutions towards improving organizational strategic intelligence process.

DEFINITIONS OF STRATEGIC INTELLIGENCE

The term of strategic intelligence is often used interchangeably with other terms: data, information, intelligence, and knowledge. There seems to be no generally agreed definitions towards these terms, but they are different in the context of this chapter as follows:

Data is the raw material of organizational life; it consists of disconnected numbers, words, symbols relating to the events, and processes of a business. Data on its own can serve little useful purpose.

Information comes from data that has been processed to make it useful in management decision-making. Intelligence in most cases is referred to competitors' information (CI), or competitive intelligence or the totality of external information (Baatz, 1994). Competitor intelligence has often been regarded as a process of collecting and processing competitors' information following a CI cycle, which includes identifying the strategic needs of a business, systematically collecting relevant information on competitors, and processing the data into actionable knowledge about competitors' strategic capabilities, position, performance, and intentions. However, the boundary of competitor's intelligence has always been extended to include not only competitor's information, but also market and environment information for strategic decision. For example, Tyson (1990) defines competitor intelligence as an analytical process that transforms raw data into relevant, accurate, and usable strategic knowledge, more specifically, it includes:

- Information about a competitor's current position, historical performance, capabilities, and intentions.
- Information about the driving forces within the marketplace.
- Information about specific products and technology.
- Information external to the marketplace, such as economic, regulatory, political, and demographic influences that have an impact on the market.

Baatz (1994) refer the term “corporate intelligence” to the collection and analysis of information on markets, technologies, customers and competitors, as well as socio-economic and external political trends. Another term, business intelligence (BI) has been prevalent in the IT industry. Business intelligence is a process that its input is raw data; the data then is evaluated for usefulness to a relevant and reasonably reliable body of information; the analyzed, digested, and interpreted information thus becomes intelligence. The term “strategic intelligence” used in this chapter means strategically significant information to senior managers that is scanned, analyzed, digested, and is meaningful that could affects senior managers’ beliefs, commitments, and actions. The entire process of turning original data from both external and internal environment into intelligence is referred to intelligence activity.

Data, information and intelligence are closely linked to knowledge. Knowledge refers to totality of information related to policy, problem or issue whether it is quantitative or qualitative, data or opinions, judgements, news or concepts. According to Nonaka and Takeuchi (1995), knowledge is “justified true belief”; it is a dynamic human process of justifying personal belief towards the “true.” Information provides a new point of view for interpreting events or objects, which makes visible previously invisible meanings or shed light on unexpected connections. Thus, information is a necessary medium or material for eliciting and constructing knowledge. Information affects knowledge by adding something to it or restructuring it. Nonaka and Takeuchi (1995) further point out that information is a flow of messages, while knowledge is created by that very flow of information, anchored in the beliefs and commitment of its holder.

THE NATURE OF STRATEGIC INTELLIGENCE AND CHALLENGES

Strategically significant information is not a piece of static information that is readily available from certain sources. It is often derived from a sense making process that requires managerial knowledge and judgement. Strategically significant information can be viewed from different perspectives.

Internal vs. External Orientation

Strategic information has an internal or external orientation. Aguilar (1967) suggests two types of strategic information: *External strategic information* is information about events or relationships in a company’s external environment that may change the company’s current direction and strategy. *Internal strategic information* is information about a company’s capacity and performance that significantly affect a company’s strategic implementation. Because strategic decision is primarily concerned with external problems of a firm, the external orientation of strategic information has been emphasized by many researchers. Mintzberg (1973) reports that managers demonstrate a thirst for external information. This is supported by Macdonald (1995), who argues that change in an organization is seen as a process in which the acquisition of external information is critical. Yet, empirical research supporting this notion is limited. In contrast, Daft, Sormunen, and Parks (1988), reveals that senior managers rely as much on internal discussions and internal reports as they did on external media or personal contacts, senior mangers use internal and external source about equally. This view is reinforced by D’Aveni and MacMillan (1990) who found that managers of successful companies pay equal attention to both internal and external environments of their companies, but only during times of crisis, these managers focus more heavily on the external environment, which suggests that there may be a linkage between external information needs and the extent of environmental stability.

We anchor the view on internal-external orientation of strategic information (Xu & Kaye, 1995) by drawing an analogy between a manager navigating his company and driving a car, that is, managers cope with external changes by adjustments to the internal controls. Internal information is vital for controlling the operation, but cannot determine the direction of navigation. External information is of strategic importance, since strategic decisions are primarily long term with a balance towards external focus, whereas operational decisions are primarily short term and have an internal focus. External information is more dynamic and uncertain than internal information, and appears more difficult and costly to obtain than internal information. This poses a challenge of obtaining strategic intelligence from external environment.

Historical vs. Current, Future Orientation

Strategic information is also associated with its historical and future dimension. Information needed for performing routine tasks of daily operation and for short-range decisions will be different from information needed for long-range analysis and planning. Long term planning requires information about the past as well as projections of future conditions. Research (McNichol, 1993) suggests that senior managers demand more future and current information than historical information. This confirms Mintzberg's (1973) argument that managers indicate strong preferences for current information, much of which is necessarily unsubstantiated, and for information on events rather than on trends. Historical, aggregated information from the traditional formal information system provides little help in the performance of manager's monitoring role. Mintzberg's (1973) summarize the information that executives received into five categories:

- **Internal operations:** Information on the process of operations in an organization, and on events that take place related to these operations, comes from regular reports, ad-hoc input from subordinates, observations from touring the organization.
- **External events:** Information concerning clients, personal contacts, competitors, associates, and suppliers, as well as information on market changes, political moves, and developments in technology.
- **Analysis:** Executives receive analytical reports of various issues, solicited and unsolicited, come from various sources.
- **Ideas and trends:** Chief executives develop a better understanding of the trends in the environment, and to learn about new ideas by using a number of means such as attending conferences, glancing at trade organization's reports, contacting with subordinates, paying attention to unsolicited letters from clients.
- **Presses:** In addition to the usual types of information, chief executives receive information in the form of presses of various kinds, that is, from subordinates, clients, directors or the public, with which the chief executives must allocate their time and efforts to deal with.

The issue concerned here is the right balance between receiving historical, current and future oriented information by executives.

Raw Data vs. Filtered, Refined Information

Contradictory views exist towards if executives prefer analyzed information over factual raw data. Bernhardt (1994) argues that managers prefer analyzed information to detailed raw data, as analyzed information adds meaning and makes sense of the data. He believes that managers do not need lorry loads of facts or information; they need an analytical intelligence product, delivered on time, and in a format that can be easily and quickly assimilated. The analytical intelligence product shall be factual, meaningful, and actionable information. It has been revealed (Taylor, 1996) that current information systems produce sheer volume of data but little meaningful information to senior managers. Increasingly providing senior managers direct access to operational data and leaving them to their own devices is a disservice to the organization, as it creates the problem of "data deluge" and the frustrations that arise from time wasted in trying to assemble meaningful information from raw data. Data deluge and information meaningless runs the risk of compromising the advances of colourful, graphic design of an EIS. Even with graphic-interface, high-speed communications, and data-warehousing technology, it is extremely difficult for a decision maker to review thousands of products, hundreds of categories. When adding the task of looking outside, at the world of the competitors, suppliers, customers, and the environment, identifying critical changes becomes a daunting task. Finding the problem becomes the real problem, that is, data can be too much for an executive to spot trends, patterns, and exceptions in detailed data. Thus data may need to be refined in order to be useful. Wright, Pickton, and Callow (2002) reveals that the most common problems in disseminating intelligence is making the information and structure relevant to the audience while being brief yet useful. Wyllie (1993) defines information refining as a social-technological process that enables intelligent human beings to extract and organize systematically the key items of knowledge kept in any given choice of information sources. The purpose of the process is to enable people from executives downwards to be better and more widely informed, while at the same time, reducing the amount of time they have to spend to keep up with headlines on media. The result of the refining process should be to bring about better, more informed decisions.

However, managers' demand for refined information has been questioned. Edwards and Peppard (1993) argue that refined information that reaches the top management team is likely to be distorted. The distortion may not be conscious, but due to the assumptions and knowledge used in handling the information, bring to bear on it. This suspicion is in line with the notion (Daft et al., 1988) that as strategic uncertainty increase, senior managers will want to form their own impression through direct contact with key environmental sources to ensure that data is undiluted and does not suffer from the loss of meaning associated with passing information through intermediaries. Mintzberg (1980) observed that managers clearly prefer to have information in the form of concrete stimuli or triggers, not general aggregations, and wish to hear specific events, ideas and the problems.

The issue concerned is whether strategic intelligence is more likely to be derived from refined data other than from data in its raw fashion. However, the debate is continuing but inconclusive.

Formal vs. Informal Systems

Strategic intelligence may be gathered from formal or informal systems. A formal system for information acquisition is defined as one with a set of procedure to follow, and is systematically used in regular basis, for example, the competitive intelligence cycle. An informal system is in contrast to the formal system that managers do not trace a map route from beginning to the end, and is intuitively used in ad hoc basis. Research suggests that managers often ignore formal systems, and in favour of informal systems for strategic significant information. Mintzberg (1980) argues that as a result of the distinct characteristics in information acquisition, managers often ignore the formal information system, as it takes time to process information. Managers therefore develop their own contacts and establish special communication channels to obtain information. Managers spend most of their time gathering information through less formal systems.

Empirical studies support the speculation that CEOs obtain most information through informal, irregular, human systems. In a study of executives of British Airways, Cottrell and Rapley (1991) found that the majority of executives spend their time in face-to-face or verbal contact (telephone or intercom) with peers and subordinates both inside and outside the organization. Most of the information is received in an unstructured way. Executives spend little of their time in reading or looking at highly structured information in reports or on computer screen.

The tendency towards using informal system by executives for intelligence poses a challenge to developing computer-based intelligence system that has often been regarded as a formal system.

Solicited vs. Unsolicited Intelligence

The terms "solicited searching" and "unsolicited searching" are rooted in social cognition theory regarding whether information scanning is directed by managers' intention or not (Kiesler & Sproull, 1982). In directed search, managers have intentions or objectives, exert efforts to scan information; in undirected search, managers follow perceptual process, which is relatively unaffected by intention and efforts. Aguilar (1967) used the term to appraise the effectiveness of managers' information scanning process, and managers' behavior in information acquisition: that is, whether the scanning is active or passive. If managers obtain most of their information on a solicited basis, their performance could be questioned on the grounds that they are not sensitive enough to valuable information other than what they actively seeking. In other words, solicited information may limited a manager's vision as the manager only knows what the manager wants to know, but not what is needed to know.

Managers appear obtaining more unsolicited information than solicited information. Information from outside sources tends to be largely unsolicited, whereas information from inside sources is largely solicited. This tends to suggest that unexpected information is more likely to be regarded as strategic intelligence than solicited information. If this speculation is substantiated, there shall be a system to proactively feed managers with unexpected intelligence.

Information Specialist Support vs. Managers' Own Scanning

Senior managers may need specialist to support them in information acquisition and processing, because managers' information acquisition pattern tends to be informal and in ad-hoc basis. Schmitz, Armstrong, and Little (1992) revealed that senior managers often lack time which will not allow them the luxury to sit at a terminal and deal with their information needs. They argue that it is still remains primarily the work of staff members to access and decipher the necessary information for senior managers. Langley (1996) cited a managing director, saying "technology on its own could not add value without the input of people who understood the business problems and the meaning of the data." As more information is collected from external environment, information processing becomes more complex, this necessitates the selection of personnel with analytical skills to work with such complex information (Ramaswami, Nilakanta, & Flynn, 1992). Frolick (1994) has taken this view forward and argues that executives need information specialists to support them using EIS. He describes that EIS is no longer for executive use only, rather, many other organizational non-executive personnel use it. For example, the middle level managers who spend a great deal of their time preparing report for executive consumption. The support-staff members include such individuals as the executive's secretaries. Information system does not require hands-on use by executives themselves. The executives would delegate the use of EIS to these individuals and have them bring back printed reports or conveying the message to them by daily summaries, presentations, exception reports, and so forth. EIS increasingly designed to be used by most, if not all, knowledge workers. This raises a critical question as to whether strategic intelligence should be processed by intelligence specialists or solely by executives' themselves?

EMPIRICAL STUDIES ON COMPETITIVE INTELLIGENCE IN PRACTICE

Many empirical studies related to strategic intelligence concentrate on competitive intelligence. Wright, et al (2002) conducted a study to examine how UK companies conduct competitive intelligence through questionnaire and interviews. The study examined the attitude of gathering competitive intelligence, strategies for intelligence gathering, use of intelligence and organizational locations of the intelligence function. Two types of intelligence gathering are identified: (a) easy gathering—firms use general publications and or specific industry periodicals and consider these constitute exhaustive information, and (b) hunter gathering—in additional to easy gathering, companies conduct own primary research on competitors. CI function within an organization are either in ad-hoc location—no dedicated CI unit within the organizational structure, and intelligence activities are undertook on ad hoc basis, typically, by the marketing or sales department, or in designated locations—specific CI function established within the organization with staff working full-time on monitoring competitors and competitive environments. Pelsmacker, et al. (2005) report through a comparative study of CI practice between South Africa and Belgium that companies in both countries are not well equipped with and not active to conduct effective CI, especially in the areas of planning, process and structure, data collection, data analysis, and skills development. CI-activities are not organized in a separate department, and if they are, are mostly done in the marketing and sales department. Sugasawa (2004) adds further evidence by showing that there is a strong interest in CI in Japan, but Japanese companies do not apply any specific analytical methodology to analyze intelligence. Dissemination of intelligence was primarily in written form rather than by electronic means. Computer-based systems are mainly used for intelligence storing and extracting.

In addition to ethic, lawful intelligence gathering by organizations, Crane (2004) suggests that many tactics are currently being used to gather industry espionage. The tactics take forms from clearly illegal, such as installing tapping device, stealing information, to rather more grey areas, this includes searching through a competitor's rubbish, hiring private detectives to track competitor's staff, infiltrating competitor organization with industrial spies, covert surveillance through spy camera, contacting competitors in a fake guise such as a potential customer or supplier, interviewing competitors' employees for a bogus job vacancy, and pressing the customers or suppliers of competitors to reveal sensitive information about their operations. Other means include conventional market research and competitor benchmarking through market scanning, industry profiling, debriefing of managers recruited from competitors.

An earlier study on competitive intelligence systems in the UK was conducted and reported by Brittin's (1991), which shed light on how companies gather and use competitive intelligence. As the findings tend to be comprehensive in terms of the CI cycle, the results are revisited and presented in Table 1.

Brittin's (1991) study reveals that competitor intelligence systems were primarily manual-based in practice. Intelligence gathering relies on managers, data analysts, and sales force. Most intel-

Table 1. Competitor intelligence systems (Source: Brittin, 1991)

	Competitors monitored / Kind of Information	Information sources used	CI Systems	Data analysis	Output / dissemination
Case 1 **A large financial institution**	25 ~ 30 competitors ❶ Financial performance, ❷ specific competitive activities.	Companies house, Stock Exchange, Broker's report, Press Cutting Services, Electronic sources, Consultant, Meetings, Dinner party circuit.	Personnel in the Research Department (manual-based)	Manual-based data analysis and evaluation by the Data Analysts. Hypertext system in Apple Mac is used to store data.	Information disseminating project is to be developed in the form of briefing papers.
Case 2 **A distribution company**	10 competitors 90% ~ 50% external information	Trade and Business Press, Online services (e.g., Dialog, data-Star), Sales force monthly report, Competitor's trade literature, Consult and employees.	Manual-based system by the Marketing Intelligence Manager and one assistant	Use SWOT analysis, but a lot digging and guess work. No computerized database, Data stored in filing cabinet.	❶ Monthly bulletin to managers with analysis. ❷ A spin-off publication for public consumption. ❸ Twice yearly report for managing director. ❹ Ad hoc reports
Case 3 **An engineering company**	About 300 competitors ❶ All aspect of competitor activity ❷ Market information	Published information, Trade journals, statutory company accounts, customers, employees.	Computer-based system in Business information unit	PC-based European competitor database, Mainframe MIS, Computerized data summarizing, and manual-based qualitative data analysis	Newsletters (including solicited and unsolicited information of competitors)
Case 4 **A chemicals company**	500 on a regular basis ❶ Competitors and ❷ Competitive products ❸ Environment	Newspapers, journals, on-line databases (e.g., Dialog) business associations, FT Business Resource Centre Imp/exp. statistics, products literature	Computer aided system in Corporate Information Department	Abstracts have been put into full-text database. Others in filing cabinet. Data is not analysed	❶Daily press scanning report ❷Specific information bulletins ❸Commercial business news bulletin for senior management ❹Ad hoc inquiry reports in various format.
Case 5 **An automotive company**	About 10 competitors ❶ Competitor's strategic intention, ❷ 90% ~95% external information	News-type databases covering the industry, company reports, press releases, promotional materials, trade show	Manual-oriented system in Business Planning Department	Data is analysed, interpreted A lot of intelligent guesswork, but limited data modelling and statistics	Presentations (90%) -computer slides, and hard copies.

ligence is collected from sources both inside and outside the organization. In terms of processing intelligence, very little sophisticated data analysis techniques are used; much of the data analysis is based on intelligent guesswork. Collected data was frequently sent to managers without any degree of analysis and interpretation. Sugasawa (2004) who reported intelligence practice in Japan confirmed a lack of sophisticated intelligence analysis.

Case Study: An Insurance PLC

Bata Insurance Group Plc[1] is a worldwide insurance group operating in many countries with over 100 subsidiaries. In the UK the operating companies are divided by product and includes Beta General Insurance UK Ltd., Beta Life Insurance UK Ltd., Beta Insurance International Ltd., Beta Investment Ltd. The Group Holding Company comprises of several functional departments for example, Legal & Secretarial, Financial Control & Planning, Corporate Relations, International Division, and Strategic Research. The data were collected through action research by the author who participated in a CRM "Client Relationship Management" project in one of the operating companies. The Information Manager of the Group Holdings Company revealed the group's information searching systems for strategic intelligence. Table 2 presents the intelligence searching systems used by the group companies.

The major sources used to scan intelligence include:

- Use the city Business Library and the British Library Business Reference for research projects, and directories and handbooks such as Evandale's London Insurance Market Directory.
- **Subscription for newspapers and industry publications for manager's general information and background reading:** These include daily, weekly and monthly publications such as The FT, The Economist, DYP Newsletters-Europe, DYP Newsletters-Reinsurance, Best's Review—Property/

Table 2. Strategic intelligence systems

The Companies	The Intelligence Searching and Coverage
Beta Insurance Holding Plc	▪ Comparison of main UK competitors from financial results, share price tracking, and press releases ▪ Financial analysis of reinsurance companies from company reports and accounts ▪ Monitoring UK composite insurers from city analyst's reports and a press cutting service
Beta General Insurance UK Ltd.	▪ Press cutting services ▪ PC-based marketing intelligence system, searching extracts from publications (ESMERK) ▪ Data monitor reports on financial services ▪ Networking with competitors
Beta Life Insurance UK Ltd.	▪ Press cuttings ▪ Use of published surveys ▪ Market research association (external)
Beta Insurance International Ltd.	▪ AM Best's on CD ROM ▪ On-line news information services ▪ Competitors financial data ▪ "Soft" information database
Bata Investment Ltd.	▪ Datastream online services ▪ Bloombergs ▪ Contact with external analysts ▪ Track statistics on competitors

Casualty, Best's Review - Life/Health, Insurance Times, FT World Insurance Report, and so forth.

- **Subscription for CD-ROM and online business database:** For example, Datastream
- **Company reports and accounts** collected from city library, Insurance association
- **Economic reports** from banks, stockbrokers, and reports by analysts on the insurance industry
- **Other free publications received by directors and executive staff:** For example, "Insurance Today" (where the advertisements are paying for the copy), giving details of the UK market products and developments. "European Insurance Bulletin" which can keep top management abreast of happenings.
- **The Association of British Insurers (ABI) and the Chartered Insurance Institute (CII) that provide services on insurance statistics, references, and articles on specific topic**
- **Ad hoc intelligence collection by company managers and staff members:** One department of the company also analyzes the financial results of reinsurance companies, periodically reminds the users of the service throughout the group that any "market intelligence" news on reinsurance company being vetted be passed to them. Overseas managers on their UK visits are also asked to set up meetings with them to discuss the local market situation.
- **Computer-based market intelligence system:** Staff throughout the regions is asked to pass on any piece of news they hear about competitors or brokers to central co-ordinators. The database in the UK head office containing news items on competitors, articles from trade magazines, advertisements, and inter-company meetings is being made available over the network to the different areas.

It is reported that most members of the staff do not have the time to read and absorb all the information that is available. Therefore the information service workers look through most publications, mark up the articles of interest for cutting out, and file the data for any enquiry. This service is centralized to serve the whole group. On the other hand, some group executives (e.g., executives for overseas life operations) have made very little use of the research material available to them, as they had good personal contacts with a large number of people in other parts of the group. They naturally adapt at personnel networks for information gathering.

DISCUSSION

The empirical evidence suggests that external intelligence—primarily competitive intelligence and market/industry intelligence as reviewed above, has been addressed by many companies engaged in CI activities. A manager from Bata Group comments that "In today's rapidly changing business world the need for timely and accurate market intelligence will increase. We need to know what our competitors are doing almost before they do." The sources used for intelligence gathering are heterogeneous, but most intelligence tends to be gathered from public domain. Managers' intelligence needs are often fulfilled by using a broad range of approaches, which are characterized as manual-based and unsystematic tendencies. The current intelligence practice exhibits the following deficiencies:

- **Manual based:** Competitive intelligence is collected mainly by managers and information workers from various publications and general information sources. The current method of press cutting and searching is labour intensive. Computer-based intelligence systems are limited to data storage, retrieval, and CD-ROM/online database searching.

- **Intelligence scanning is ad hoc and the process is functionally divided:** Most organizations scanned intelligence irregularly. Scanning is commonly conducted by sales force, and relies on managers' own personal networks. Cobb (2003) argues established organizational CI processes often suffer from holes in data or data integrity causing errors in the interpretation of that data for intelligence purpose, and suggests that scanning activity will be accomplished by a separate, distinct department, unit, or individual that reports directly to the executives in the organization.
- **Lack of Filtering, Refining and Sense Making of Intelligence:** As revealed from the empirical studies, data scanned is not often filtered, processed, and interpreted into meaningful intelligence in required form before reaching the managers, and there is a lack of sophisticated intelligence analysis tools. This affirms Maier et al.'s (1997) assertion that the most common problem in the dissemination phase is making the information and structure relevant to the audience while being brief yet useful. Without data refining, providing increased data access and search facilities to senior managers can exacerbate the problem of data overload. However, filter and interpret intelligence through a systematic system faces great challenges, on the one hand, recognizing which data is of strategic importance needs management knowledge and judgement. Human cognition and intuition process often dominate interpreting, reasoning, and learning that are subtle. On the other hand, technology in semantic data searching, machine learning is limited to structured data analysis, but not to dynamic strategic intelligence. Even with intelligent system and knowledge based expert system, letting computers represent a great deal of human knowledge for data interpretation is still a challenge, since knowledge may not exist in a visible, explicit form for acquisition.

THE SOLUTIONS

Organization-Wide Intelligence Scanning

The way to avoid ad hoc intelligence scanning is to have systematic and organization-wide scanning systems. It is believed that systematic scanning of business environment for strategic information can improve the completeness and quality of strategic intelligence. Huber (1990) assert that the use of computer-assisted information processing and communication technologies will lead to more rapid and more accurate identification of problems and opportunities; and the use of computer-assisted information storage and acquisition technologies will lead to organizational intelligence that is more accurate, comprehensive, timely, and available. Environmental scanning: as defined by Maier, Rainer, and Snyder (1997) is a basic process of any organization, acquires data from the external environment to be used in problem definition and decision-making. The environment consists of all those events, happenings, or factors with a present or future influence on the organization that, at the same time, lies outside the organization's immediate control. The primary purpose of environment scanning is to provide a comprehensive view or understanding of the current and future condition of the five environmental constituents: social, economic, political regulatory, and technological. Scanning invokes a process of externalization, causing the company to expand the focus of decision-making to include the perspectives of outsiders, for example, present and prospective competitors, customers, regulators, stakeholders, and the perspectives of economic condition, political climate, technology development, social and cultural changes. An information scanning mechanism could ensure systematically collection of relevant, important information from various sources available both inside and outside a company.

The current practice of intelligence gathering significantly relies on managers and sales forces. This runs the risk of missing significant intelligence being noticed due to time constraints and limited capabilities of individual managers, and the narrow focus of sales and marketing staff. To maximize the effectiveness and efficiency of environmental scanning, organization-wide intelligence scanning is desirable and possible. Because organization members have wide contacts with a variety of external entities, also they work closely in the front-line to interface with company's customers, hence, a variety of intelligence can be gathered for the attention of senior managers. Organization-wide intelligence scanning should focus on scanning external environment for intelligence. The scanning function can be performed through formal, informal intelligence collecting/reporting systems or third party agency, which are suggested as below:

Intelligence Scanning Through Informal Systems

The informal systems for organization-wide intelligence scanning can include, for example:

- **Sales force report:** Companies can ask their field sales forces to gather up intelligence about competitors, suppliers, and customers, as well as market intelligence.
- **Business trip report:** Business trip report by managers who visited foreign markets. The managers are briefed before the trip by a member of the corporate business intelligence unit, and on their return report back with findings related to the issues and questions raised at the briefing.
- **Intelligence gathering box and online intelligence forum:** Every employee may have something to contribute in terms of competitive intelligence. A company should encourage its staff to contribute information on market, competitors, ideas and suggestions or even rumour, gossip and office grapevines by using an intelligence box or an online forum where valuable intelligence can be collected and rewarded.
- **Friday round tables:** A company can organize a series of round-table meetings in various locations, where a particular topic related to intelligence gathering is discussed. With the aid of a knowledge team facilitator, knowledge for intelligence scanning/processing is articulated, captured.

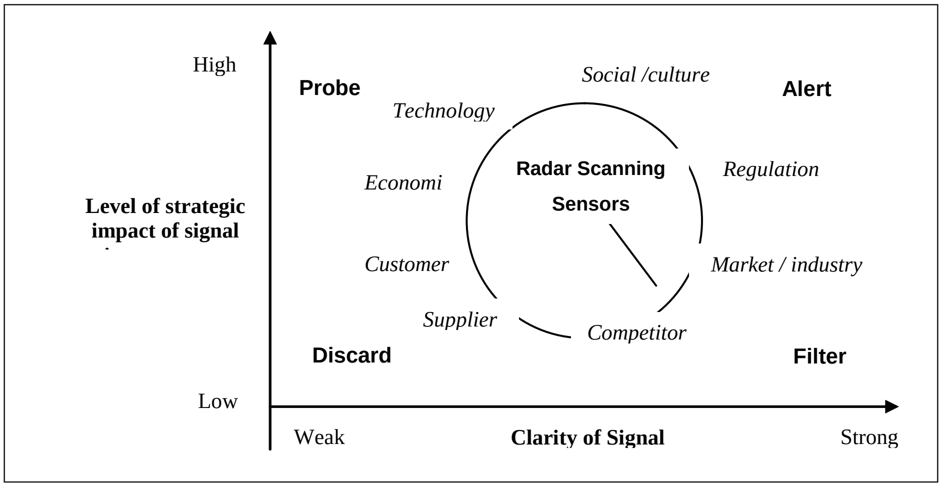
Structured Intelligence Scanning: A Corporate Radar System

Formal methods are needed to systematically collect external information. A company's intelligence centre, and intelligence workers have the responsibilities to fulfil intelligence scanning and analyzing tasks. In addition, computer assisted system shall be considered to enhance intelligence scanning. Business organizations could develop a radar-type system (or function) to continuously but selectively detect significant signals from environment sectors. A corporate radar system for strategic information scanning is depicted in Figure 1.

The radar scanning system works according to two main criteria: the clarity of the signals detected from the environment and the level of strategic significance of the signals. Center to the scanning is the sensor that continually detects all signals emerged from the business environment. Each signal detected will be handled by four distinctive and related processors according to the nature of the signal, i.e.

- **An alert:** If the signal detected is strategically important, and the signal is with strong clarity, that is, message is clearly stated and from reliable sources, the signal will be

Figure 1. A corporate radar system for environment scanning



alerted immediately as hot intelligence to executives.

- **A filter:** If many signals being detected but not all of them are of strategic importance, for example, information regularly received by the company from its environment, the signals have to be selected from a potentially large mass of data, and filtered for relevance. Because most of the signals are less important to derive strategic information, the filter function thus is vital to screen out irrelevant information and to eliminate information overload.
- **A probe:** The radar system may detect a weak signal but it may have potential strategic impact on the organization, the signal thus must be probed and amplified. Information as such is often less structured and not easily to obtain. Much of this type of signal may fall into the "soft" information category, that is, opinions, predictions, hearsay, ideas, rumours, and gossips. The vague signal needs to be verified, and amplified in order to assess its potential impact on the strategic direction of the organization.
- **A discard mechanism:** This is needed to handle large amount of weak signals that are not strategically important or relevant to the organization.

The aforementioned radar sensor, alert, filter, probe, and discard functions can be a computerized or a manual based system. Whatever it is, knowledge needs to be embedded within the system to underpin the operation of the radar system.

It is worthy to note that the environmental sectors for radar scanning may vary from one industry to another. We examined this in a previous study (Xu, Kaye, & Duan, 2003) that the significance of environmental sectors for scanning is industry specific. For example, in the computer industry, customer, competitor, market/industry, and technology sectors are more strategically important than other variables, showing that these sectors have high strategic impact signals. Thus the focus of radar scanning may need to be adjusted to target these environmental sectors. Stoffels (1994) addresses that "the strength of signals is related to the uncertainty of environment, that is, weaker signals are associated the remote environment, and strong signals with the task environment. The environment scanning effort is much required in the remote environment as the visibility of the future diminishes with increasing turbulence, and predictability deteriorates accordingly."

Using Third Parties to Carry Out Intelligence Gathering

A company may choose to use third parties to conduct intelligence scanning. External intelligence firms can be helpful in gathering and analyzing certain information. They can assist in synthesizing monthly intelligence, performing difficult information gathering tasks, and training employees. The third-party status also helps break down any political barriers that may exist within an organization. In this way the third party serves as a catalyst in the process. Tan, Teo, Tan, and Wei (1998) support this notion by asserting that use of external consultants results in effectiveness of environmental scanning. They explained that besides providing and interpreting information, external consultants have helped to equip organization with the knowledge and skills for doing environmental scanning on the Internet. These services include conducting courses on the use of Internet tools and compiling links to potentially useful information sources.

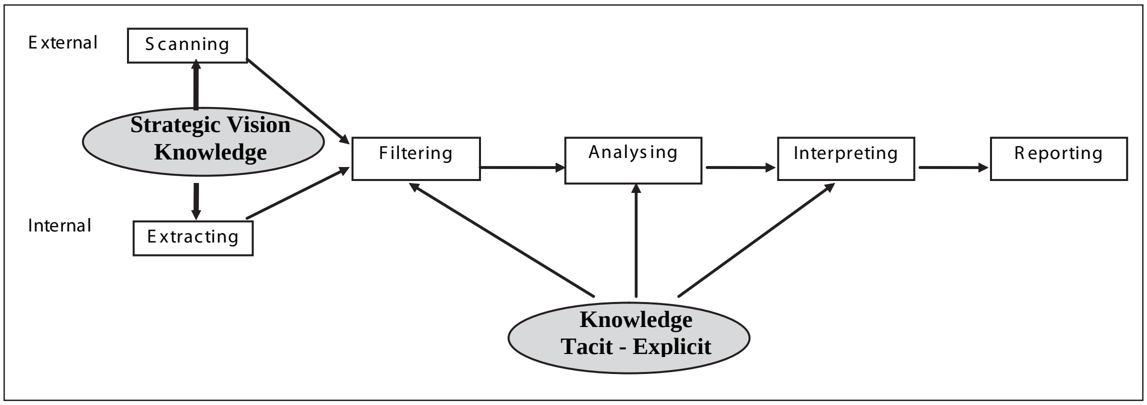
Organization-wide intelligence scanning is envisaged to enhance external intelligence scanning. However, systematically scanning the entire environment is both costly and inappropriate. A manager is interested in the environment that influences his decisions, hence, environmental scanning needs to be selective, yet ensure that sufficient variety is maintained to avoid missing important signals. Auster and Choo (1995) suggest that selecting which environment for scanning is effected by a variety of influential factors, for example, the turbulence of the environment, the difference of industry sectors, or the company's competition strategy. It can be argued from this study that for effective organization-wide intelligence scanning, making knowledge about which environment to scan explicit is vital.

Knowledge-Enriched Intelligence Filtering and Refining

In order to produce analytical intelligence product—meaningful and digestible information, it is vital to filter out irrelevant data and to refine data into meaningful intelligence. The current process of intelligence analysis is a human centred, knowledge intensive process, that is, relies on managers themselves and their knowledge and judgement. Thus the solution to refine intelligence must incorporate managerial knowledge used for intelligence scanning and analysis. Figure 2 shows the intelligence process by highlighting the knowledge enriched filtering and refining function.

As highlighted in the diagram, the intelligence scanning and refining (filtering-analyzing-inter-

Figure 2. Intelligence process with scanning, refining, and supporting function



preting) process should embed strategic vision and human knowledge. This can be achieved by:

- **Using intelligent agent-based system that uses knowledge base, case based reasoning, machine learning, or user feedback and interaction to semantic scanning and analysing intelligence according to user profile:** For example, intelligent agents could base on past information search activities and predefined information needs in "*user profiles*", which is generated by a learning agent, or defined by the user. The user profile can consist of executive's personal profile, executive's information needs and interests, executive roles, and organizational environment profile, which enable software agents to perform domain-specific acquisition, synthesis and interpretation of information. As a result, information processing becomes more personalized to the executive.
- **Creating a knowledge creation and sharing field/culture to turn tacit knowledge into explicit form so that employees**, particularly intelligence staff can be guided to detect and make sense of strategic significant information.

It is envisaged that computer based knowledge enriched intelligence scanning, refining can selectively and systematically scan and categorize, prioritize, and analyze large amounts of data on a continuous basis. Analyzed intelligence will report to, or alert managers to enlarge managers' vision on strategic issues by providing consistent, routine surveillance of a wide range and a variety of data that would not be possible with current management reporting techniques.

Knowledge Workers/Intelligence Specialist Support

Although computer-based intelligence system (scanning, refining) may be developed, it is evident that many senior managers may not wish to use such systems to acquire strategic intelligence due to the nature of managerial work. The advanced systems may be better used by intelligence specialists/knowledge workers, so that analyzed intelligence can be delivered to the senior managers by the specialists. If managers' information requirements can be predefined, the specialist will search necessary databases and the external environment to locate the information as required. If however, managers do not solicit information, the intelligence specialist can continually scan the external environment and proactively report significant intelligence (most of them probably are unexpected) to the senior managers via written or verbal communication channels. Less important information is consolidated, synthesized, and digested to a brief level that managers receive on regular basis. With the support of intelligence specialists, both internal and external data can be systematically scanned, filtered, synthesized, and reported in both regular and ad hoc basis through formal and informal systems.

The challenge however is that intelligence specialists need to possess managerial knowledge and similar judgement that managers use to acquire information. This relies on knowledge sharing. In addition, intelligence specialists need to have rich knowledge of information sources and skills in exploiting, evaluating, and interpreting information.

IMPLEMENTATION

Implementation of the above solution will inevitably require a change of vision, intelligence process, organizational structure and culture. Managers need to develop a strategic vision in order to give a company's intelligence activity a sense of direction. The purpose is to give corporate members a mental map of the world they live in and to provide a general direction as to what kind of intelligence they ought to seek and report. A strategic vision created by senior management helps foster a high degree of personal commitment from middle managers and front-line workers.

A common problem in establishing intelligence functions might be that most companies prefer not to devote resources to such a function until it can prove that the function is necessary and will succeed. Therefore, a visionary leadership is needed, who can perceive the benefits of strategic intelligence and provides support for developing the intelligence function.

What remains critical is how managerial knowledge can be elicited to underpin the radar scanning system, and the refining system. The knowledge spiral model (Nonaka & Takeuchi 1995)—sharing knowledge through socialization could facilitate the process of sharing experiences and turning tacit knowledge to explicit knowledge, for example, in the form of an intelligence gathering event, briefing, club, online discussion forum.

There is probably no one structure that can fit a variety of different organizations. The variety very much depends on the size of the firm, the type of the business, the degree of centralization or decentralization of its activities and decision-making. It is perfectly possible that a centralized intelligence function is established to coordinate organizational-wide intelligence activities and to operate the corporate radar system. This can overcome the data integrity problem that often resulted from functionally divided organizational CI processes.

In accordance with structural change, a knowledge creating and intelligence gathering culture need to be created. Organization-wide intelligence gathering relies on every member's commitment to intelligence activity. Environmental scanning is an essential behavior attribute of culture because scanning provides the first step in a chain that culminates in organizational actions (Saxby, 2002). The briefing on intelligence gathering, incentives, the informal networks form an intelligence culture. Senior managers must continually reinforce the desired culture traits through their own behavior.

CONCLUSION

This chapter reviewed the nature of strategic intelligence and highlighted the challenges of systematically managing strategic intelligence. Strategic intelligence is not a static piece of information that can be easily obtained. What constitutes strategic intelligence is subject to managerial judgement and sense making that requires managerial knowledge. The current process of intelligence activity is either divided by organizational function, or is ad hoc relying on individual manager. Intelligence gather is primarily concentrated on competitive intelligence. Computerized system has played limited role in intelligence scanning and analysis. There is a lack of systematic intelligence scanning, analyzing and intelligence support, and culture.

The solution proposed to improve strategic intelligence activity addresses three significant intelligence functions that constitute a systematic intelligence process. The organization-wide scanning and the corporate radar system will ensure continuous monitoring and scanning of all signals from the market, competitors, and customers, and the far environment. The refining function is enriched with managerial knowledge so as to filter out irrelevant information and ensure meaningful intelligence is reached executives. Intelligence specialists as an organization's knowledge workers will provide complementary support for executives who are not inclined to use formal intelligence systems.

Managing strategic intelligence cannot be subject to sole technical solutions. Enabling technology to assist managers in their intelligence scanning and analysis activities is a challenging task. Therefore, effective managing strategic intelligence will rely much on an organizational approach including illustration of organizational vision, sharing tacit knowledge, establishing an intelligence culture and redesigning the process of intelligence gathering, analysis, and dissemination.

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ENDNOTE

[1] The names of the Plc and the operating companies are fictitious to ensure confidentiality.

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Chapter 1.2

Strategic Alignment Between Business and Information Technology

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INTRODUCTION

Information technology (IT) has assumed an important position in the strategic function of the leading companies in the competitive markets (Porter, 2001). Particularly, e-commerce and e-business have been highlighted among IT applications (Porter, 2001). Two basic points of view can be used for understanding IT's role: the acquisition of a competitive advantage at the value chain, and the creation and enhancement of core competencies (Porter & Millar, 1985; Duhan, Levy, & Powell, 2001).

Several problems have been discussed concerned with IT project results in effectiveness of their management. Effectiveness, in the context of this article, is the measurement of the capacity of the outputs of an information system or of an IT application to fulfill the requirements of the company and to achieve its goals, making this company more competitive (Shimizu, Carvalho, & Laurindo, 2006).

There is a general consensus about the difficulty of finding evidence of returns over the investments in IT (the "productivity paradox"), even though this problem can be satisfactorily explained (Farrell, 2003). Carr (2005) defends the idea that IT in itself has no more strategic value, since it is so widely disseminated that it could not be a source of strategic differentiation anymore.

In order to better use these investments, organizations should evaluate IT effectiveness, which allows the strategic alignment of objectives of implemented IT applications and their results with the company business vision (Shpilberg, Berez, Puryear, & Shah, 2007; Laurindo & Moraes, 2006). Besides, it must be highlighted that if IT applications are associated with changes in business processes, it is possible to notice greater impacts in business performance (Farrell, 2003).

According to Benko and McFarlan (2003), three aspects must be taken into account about IT strategic alignment: IT projects portfolio, business objectives, and the constantly changing situation of business environment.

Thus, the comparison and evaluation of business and IT strategies and between business and IT structures must be a continuous process, since the company situation is constantly changing to meet market realities and dynamics.

THEORETICAL BACKGROUND

Finding Strategic IT Applications

The discussion about the strategic impact of IT applications started in the 1970s, when technology began to provide more powerful alternatives not only for solving companies' problems but also for increasing their business competitiveness (Shimizu et al., 2006).

One of the first important proposals for studying the strategic role of IT was that of *critical success factors* (CSFs), which is still a widespread method used for linking IT applications to business goals, and for planning and prioritizing information systems projects. This method was proposed by Rockart (1979) and states that the information systems, especially executive and management information systems, are based on the current needs of the top executives. These information needs should focus on the CSFs.

Rockart defines CSFs as the areas where satisfactory results "ensure successful competitive performance for the organization." This author states that CSFs' prime sources are the structure of the industry, business (or competitive) strategy, industry position, geographic location, environment, and temporal factors.

Basically, the CSF method includes the analysis of the structure of the particular industry and the business strategy, and the goals of the organization and its competitors. This analysis is followed by two or three sessions of interviews with the executives, in order to identify the critical success factors related to business goals, define respective measures (quantitative or qualitative) for the CSFs, and define information systems for controlling CSFs and their measures (Shimizu et al., 2006).

For Rockart, this process can be useful at each level of the company and should be repeated periodically, since CSFs can change through the time and also can differ from one individual executive to another.

The CSF method had an important impact on managerial and strategic planning practices, even though it was primarily conceived for information systems design, especially management and executive information systems.

Besides the utilization in information systems planning and information systems project management, it has been used in strategic planning and strategy implementation, management of change, and as a competitive analysis technique.

Furthermore, the continuous measurement of CSFs allows companies to identify strengths and weaknesses in their core areas, processes, and functions (Rockart, 1979).

More details of the process of implementation of the CSF method can be found in Rockart and Crescenzi (1984).

Understanding IT Strategic Role in Companies

McFarlan (1984) proposed the Strategic Grid that analyzes the impacts of IT-existent applications (present) and of an applications portfolio (future), defining four boxes, each one representing one possible role for IT in the enterprise: "Support," "Factory," "Turnaround," and "Strategic" (see Figure 1).

- *Support:* IT has little influence in present and future company strategies.
- *Factory:* Existent IT applications are important for the company's operations success, but there is no new strategic IT application planned for the future.
- *Turnaround:* IT is changing from one situation of little importance ("support" box) to a more important situation in business strategy.
- *Strategic:* IT is very important in business strategy in the present, and new planned applications will maintain this strategic importance of IT in the future.

In order to assess the strategic impact of IT, McFarlan proposed the analysis of five basic questions about IT applications, related to the competitive forces (Porter, 2008):

Can IT applications:
- build barriers to the entry of new competitors in the industry?
- build switching costs for suppliers?
- change the basis of competition?
- change the balance of power in supplier relationships?
- create new products?

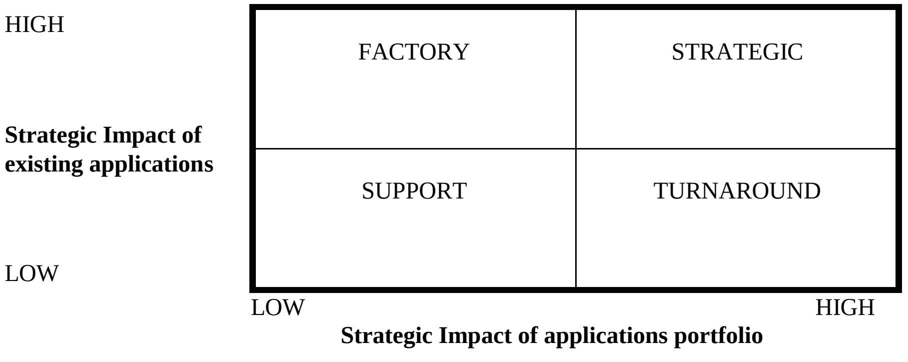
These questions should be answered considering both present and planned future situations.

Thus, IT may present a smaller or greater importance, according to the kind of company and industry operations. In a traditional manufacturing company, IT supports the operations, since the enterprise would keep on operating even when it could not count on its information systems. However, IT is strategic in a bank for business operations, since it is a source of competitive advantage and a bank cannot operate without its computerized IS.

Nolan and McFarlan (2005) have updated the Strategic Grid, changing the two "axes" for "Need for Reliable IT" (instead of "Present Impact") and "Need for New IT" (instead of "Future Impact"). These authors stated that companies in "Support" and "Factory" quadrants adopt a *defensive* approach regarding IT. On the other hand, companies classified in "Turnaround" and "Strategic" quadrants can be considered *offensive* in IT use. They also indicated the right policies in IT governance (Weil & Ross, 2005) for the board of directors' use in each of the four situations of the Strategic Grid.

Porter and Miller (1985) highlight the concepts of the value chain (activities inside the company linked by connections and which have one physical component and another of information processing) and value systems (the set of value chains of an industry from the suppliers to the final consumer).

Figure 1. Strategic grid of impacts of IT applications (McFarlan, 1984)



IT permeates the chains of value, changing the way of executing activities of value and also the nature of the connections among them and, therefore, IT can affect competition:

- by changing the structure of the sector since it has the ability to influence each of the five forces of competition (Porter, 2008);
- by creating new competitive advantages, reducing costs, increasing differentiation, and altering the scope of competition scope; and
- by generating completely new business.

The potential that IT has to make these changes varies according to the characteristics of the process (value chain) and of the product, regarding information needs. The "Information Intensity Matrix" considers the value chain and analyzes "how much" information is contained in the process and the product (see Figure 2). In companies whose products and processes contain a lot of information, information technology will be very important (Porter & Miller, 1985).

In their original article, Porter and Millar did not cite an example for "high information content in the product" or "low information intensity in the process" in the Information Intensity Matrix. However, for Duhan et al. (2001), this would be the case of educational and law firms, for consulting firms would also fit in this same quadrant.

Further according Duhan et al. (2001), an analysis of the value chain would be impaired in the case of knowledge-based companies (such as consulting firms) where it is hard to identify the value that is aggregated to each activity. In these situations, the authors propose that using the essential competencies would be more appropriate to plan the strategic use of information systems.

Henderson and Venkatraman (1993) proposed the "Strategic Alignment Model" that analyzes and emphasizes the strategic importance of IT in the enterprises. This model is based on both internal (company) and external (market) factors.

The authors emphasize that strategy should consider both internal and external domains of the company. Internal domain concerns administrative structure of the company; external domain concerns the market and the respective decisions of the company. Thus, according to this model, four factors (that the authors called domains) should be considered for planning IT:

1. business strategy,
2. IT strategy,
3. organizational infrastructure and processes, and
4. IS infrastructure and processes.

The Strategic Alignment Model brings the premise that the effective management of IT

Figure 2. Information intensity matrix (adapted from Porter & Millar, 1985)

INFORMATION CONTAINED IN THE PRODUCT

INFORMATION INTENSITY IN THE VALUE CHAIN (PROCESS)	LOW	HIGH
HIGH	*Ex: OIL REFINERY*	*Ex: BANKS, PRESS, AIRLINE COMPANIES, TELECOM*
LOW	*Ex: CEMENT*	

demands a balance among the decisions about those four domains above.

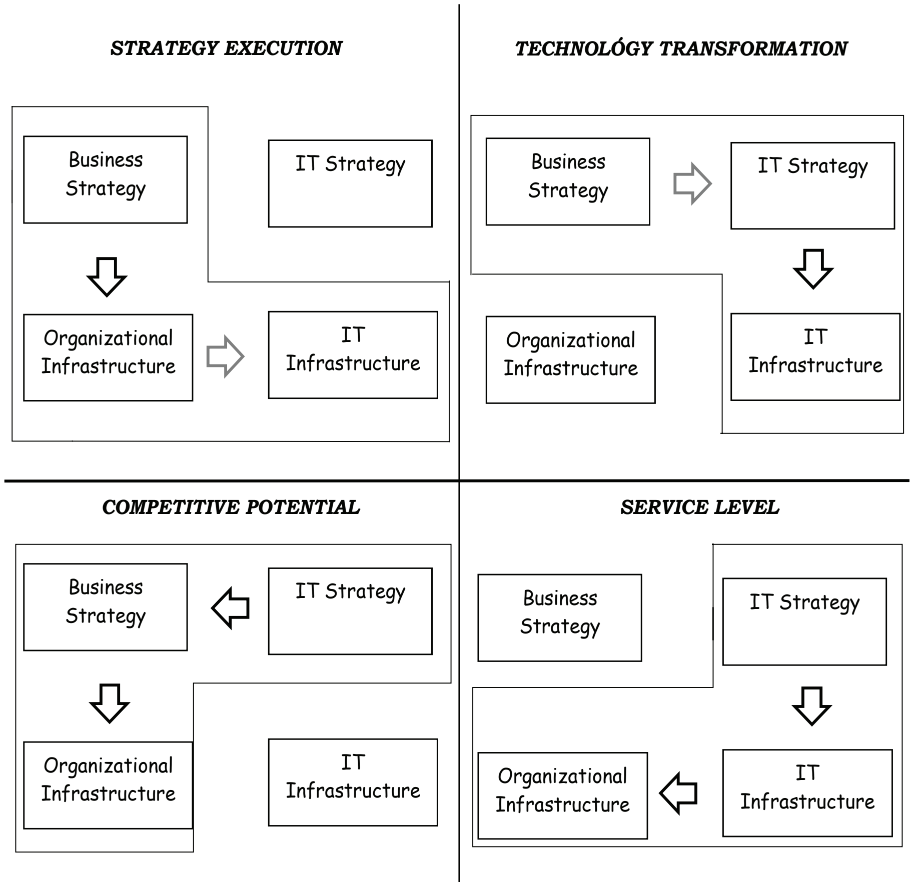
According to Henderson and Venkatraman, there are four main perspectives of Strategic Alignment, through the combination of the four factors, starting from business strategy or from IT strategy, as shown in Figure 3.

One important innovation of this model is that IT strategy could come first and change business strategy, instead of the usually general belief that business strategy comes before IT planning. This planning should be a continuous process, since external factors are in a permanent changing situation. If the company does not follow these changes, it will be in serious disadvantage in the fiercely competitive market. This is particularly true when a new technology is adopted by almost all companies in an industry, passing from a competitive advantage for those that have it to a disadvantage to those that do not use it. Thus, in this sense, the strategic alignment differs from the classic vision of the strategic plan, which does not present the same dynamic approach.

After the proposal of the four perspectives above, Luftman (1996) described four new perspectives that start in the infrastructure domains, instead of the strategies domains:

- *Organizational IT Infrastructure Perspective:*
  Organizational infrastructure → IT infrastructure → IT strategy
- *IT infrastructure Perspective:*
  IT infrastructure → IT strategy → Business strategy

Figure 3. Perspectives of strategic alignment (adapted from Henderson & Venkatraman, 1993)



- *IT Organizational Infrastructure Perspective:*
  IT infrastructure → Organizational infrastructure → Business strategy
- *Organizational Infrastructure Perspective:*
  Organizational infrastructure → Business strategy → IT strategy

Luftman (1996) also proposed that in some situations a fusion of two perspectives might occur. In these cases, two perspectives can be simultaneously assessed and impact the same domain: *IT Infrastructure Fusion, Organizational Infrastructure Fusion, Business Strategy Fusion, IT Strategy Fusion.*

Research has been developed in order to find the enablers of Strategic Alignment. Luftman (2001) listed five of them: senior executive support for IT; IT involved in strategy development; IT understands the business, business-IT partnership; well-prioritized IT projects; and IT demonstrates leadership. The absence or poor performance of these same factors are considered inhibitors of Strategic Alignment.

Some authors, like Ciborra (2004), state the strategic success of IT applications might be achieved through a tentative approach, rather than structured methods of strategic IT planning. These authors argue that frequently the drivers of strategic IT applications are efficiency issues, instead of a result of a strategic IT plan. Some important and well-known successful information systems, with clear strategic impacts, do not present evidence of being previously planned, which seems to be in agreement with this kind of thinking (Eardley, Lewis, Avison, & Powell, 1996).

EFFICIENCY AND EFFECTIVENESS: DIAGNOSING THE ROLE OF IT IN COMPANIES

In this article the importance of focusing on the effectiveness of IT utilization has been emphasized, since frequently analysis is done only from the point of view of efficiency. However, this does not mean that being efficient is not positive; it means that one needs to be efficient in certain areas. In other words, once effectiveness is achieved, increased efficiency can result in important gains and there are many models that help to analyze and improve IT efficiency.

Figure 4 contains a proposed diagram for viewing the situations related to efficiency and effectiveness in the use of IT.

When companies demonstrate low efficiency and high effectiveness, they are in "Chaos"—in a critical situation. The first move to get out of this situation should be to aim at increased effectiveness, to align the IT strategy with the business strategy. If the company has low effectiveness, but high efficiency in the use of IT, it means that it should redirect its efforts, change the focus of its activities, in order to use its good capacity where it can add value to the company's competitiveness.

Figure 4. Efficiency vs. effectiveness in IT applications (adapted from Shimizu et al., 2006)

		EFFECTIVENESS	
		LOW	HIGH
EFFICIENCY	HIGH	*NEED FOR A CHANGE OF FOCUS*	*"ÉDEN" (IDEAL SITUATION)*
	LOW	*"CHAOS"*	*OPPORTUNITY TO IMPROVE PROCESSES*

In the case of a company with high effectiveness, but low efficiency in IT utilization, it is necessary to work to improve its processes, with a view to exploiting to the maximum the focus that is already on the right things, and which can contribute to the success of the company's strategy. Finally, a company that is efficient and effective in the use of IT will arrive in "Eden," the ideal situation, which should be the goal for all.

CONCLUSION

At present there are a series of applications that have captivated the attention of many and have opened up new possibilities. Both Knowledge Management and Customer Relationship Management have been closely associated to IT. In fact, without IT these concepts could hardly have been effectively used in companies. In this sense, one important example is the growing use of business intelligence applications.

Despite the failure of many virtual enterprises (the so-called "dot.coms"), e-business and e-commerce applications seems to have reached a new maturity level, especially B2B (business-to-business—the connection between companies via the Internet).

There are various success stories, and large companies are increasingly investing in this success. According to Porter (2001), the Internet is the IT tool that, up to the present, has shown the greatest potential of being a source of obtaining or stressing strategic advantages. Therefore, an appropriate analysis and evaluation of IT effectiveness can take on a fundamental role, enabling it to really become a powerful tool for competitiveness.

The concepts described above show the importance of a broad view for analyzing IT strategic alignment. Each of the described models (CSF, Strategic Grid, Information Intensity Matrix, and Strategic Alignment) focuses on specific aspect of this issue.

These widespread known models, in fact, have complementary characteristics, and concomitant use of them allows a better comprehension of the role of IT in an organization.

On the other hand, even the use of the three models does not solve the complexity of IT alignment in organizations. As highlighted by several authors, sometimes a tentative and evolutionary approach can be successfully adopted, in circumstances that structured methods do not work properly. By this continuous focus in the IT strategic alignment, the problems of the "productivity paradox" would be overcome.

Further studies would be necessary for a better and deeper understanding of the importance of IT effectiveness for the success of competitive companies. However, this chapter intended to help find a way for this understanding and to provide some tools.

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KEY TERMS

Competitive Forces: According to Porter (2008), the state of the competition in a particular industry depends on five basic forces: new competitors, bargaining power of suppliers, bargaining power of customers, rivalry among current competitors, and substitute products or services.

Critical Success Factor (CSF): One of the areas where satisfactory results "ensure successful competitive performance for the organization," according to Rockart (1979).

Effectiveness: In the context of IT, the measurement of the capacity of the outputs of an information system or of an IT application to fulfill the requirements of the company and to achieve its goals, making this company more competitive. In other words, effectiveness can be understood as the ability of "do the right thing."

Productivity Paradox: The discussion about the lack of evidence about the return of investments on IT in the economy productivity indicators.

Strategic Alignment: The IT Strategic Alignment Model was proposed by Henderson and Venkatraman (1993) and consists of a framework for studying IT impacts on business and understanding how these impacts influence IT organization and strategy, as well as how it enables analysis of the market availabilities of new information technologies.

Strategic Grid: Nolan and McFarlan (2005) and McFarlan (1984) proposed the Strategic Grid, which allows the visualization of the relationship between IT strategy and business strategy and operations. This model analyzes the impacts of IT-existent applications (present) and of an applications portfolio (future), defining four boxes, each one representing one possible role for IT in the enterprise: "Support," "Factory," "Turnaround," and "Strategic."

Value Chain: According to Porter and Millar (1985), the set of technologically and economically distinct activities a company performs in order to do business.

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Chapter 1.3

The Interplay of Strategic Management and Information Technology

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ABSTRACT

The authors trace historical developments in the fields of information technology (IT) and strategic management. IT's evolution from the mainframe era to the Internet era has been accompanied by a shift in the strategic emphasis of IT. In the early days, IT's contribution to the organization was largely information provision, monitoring and control. Current research at the intersection of IT and strategic management increasingly highlights the impact of IT in terms of informing strategic decisions and enabling information flow vis-à-vis all manner of organizational processes. We believe these fields are ripe for research focusing on their complementary impact on organizational performance.

INTRODUCTION

We live in an age in which the value of information and knowledge has far surpassed that of physical goods. Information resources have become a key differentiator of successful businesses. Information technology (IT) and information systems (IS) are now integrated in almost every aspect of business, from planning to analysis and design, operations management and strategic decision making. Even for those businesses not in information industries, information plays a vital role in supporting their business functions, from routine operations to strategizing. John Naisbitt (1982) theorized that information would be the driving force for organizations. Companies that manage information well are more likely to maintain a competitive advantage against their peers. Because information has become a major force in driving business activities, Evans and Wurster (2000) proclaimed that every business is in the information business.

IT and IS have experienced dramatic changes in the last few decades. Their major role in business has shifted from tools to support "back-office" operations to an integrated part of business strategies and the maintenance of core competencies. Strategic management, as the process of business strategy formulation and strategy implementation, is concerned with establishing goals and directions, and developing and carrying out plans to achieve those goals. As organizations evolve, so do their strategies and strategic management practices. In recent years, IT has become increasingly important in strategic management. IT and IT-enabled systems are now indispensable in supporting business strategies. In this chapter, we examine the evolution of information technology and strategic management, and their interplay in the last 50 years. We start with a review of major theories and development in both strategic management and IT, and then explore how IT has become an enabler for strategic management. We also discuss research issues in IT-enabled strategic management, and suggest future directions in this cross-disciplinary research field.

STRATEGIC MANAGEMENT

Strategic management is concerned with managerial decisions and actions that determine the long-term prosperity of the organization. An organization must have a clear strategy and its strategy must be carefully developed and implemented to match its resources and environment in the pursuit of its organizational goals. Two meanings behind the often-used term "strategy," as Lowell Steele (1989) pointed out, are the ideational content of strategy and the process of formulating strategy. The former refers to the array of options that one uses to compete and survive, and the latter refers to the planning that leads to the construction of the strategic plan. Thus, IT-enabled strategic management must address the role IT plays in strategy content options and priorities, strategy formulation processes and strategy implementation processes. Strategic management focuses on identifying the direction of an organization, and designing and instituting major changes needed to gear the organization towards moving in the established direction.

Early research in strategic management started in the 1950s, with leading researchers such as Peter Drucker, Alfred Chandler and Philip Selznick. Drucker (1954) pioneered the theory of management by objectives (MBO). He is also one of the first to recognize the dramatic changes IT brought to management. He predicted in the 1960s the rise of knowledge workers in the information age (Drucker, 1968). Alfred Chandler (1962) recognized the importance of a corporate-level strategy that gives a business its structure and direction; as he put it, "structure follows strategy." Philip Selznick (1957) established the ground work of matching a company's internal attributes with external factors.

In the 1970s, theories of strategic management primarily focused on growth, market share and portfolio analysis. A long-term study aimed at understanding the Profit Impact of Marketing Strategies (PIMS) was carried out from the 1960s to the 1970s. The study concluded that a company's rate of profit is positively correlated with its market share. This is a result of economies of scale (Buzzell & Gale, 1987). As companies pursued larger market share, a number of growth strategies—such as horizontal integration, vertical integration, diversification, franchises, mergers and acquisitions, and joint ventures—were developed. As will be discussed later, those strategies are even more widely used today, with the facilitation of information and networking technologies.

Another shifting of strategic focus occurring in the 1970s was the move from sales orientation towards customer orientation. Researchers such as Theodore Levitt (1983) argued that businesses should start with the customer proposition. The right approach is to find out how to create value for customers and then make the products and services that meet the needs of the customers, rather than trying to sell to customers once the products are created.

In the 1980s, strategic management theories were largely geared towards gaining competitive advantages. Michael Porter (1980, 1987) proposed a number of very influential strategic analysis models, such as the five-forces model of competition, the value chain and generic competitive strategies. Porter suggested that businesses need to choose either a strategy of cost leadership (with lowest cost), product differentiation or market focus. Research has demonstrated that both market share leaders and niche market players may obtain high financial returns while most companies without a coherent strategy did not (e.g., Levinson, 1984). Adopting one of Porter's generic strategies helps a company to avoid the so-called "stuck-in-the-middle" problem. Many of Porter's ideas have been implemented in modern corporate strategic management frameworks. Strategic IS applications, such as supply chain management, are based on efficient value chain management and forming strategic alliances to maintain competitive advantages.

Lester (1989) suggested that companies sustain their strategic positions in the market by following seven best practices: continuously improving products and services, breaking down barriers between functional areas, flattening organizational hierarchies, strengthening relationships with customers and suppliers, effectively using technology, having a global orientation and enhancing human resource quality. Various information technologies have been used to support those best practices.

Hamel and Prahalad (1990) popularized the idea of core competencies. They argued that companies should devote their resources to a few things that they can do better than the competition, and relegate non-core business operations to business partners. This laid the foundation for outsourcing, which has gained in popularity since the late 1990s. The wide spread of information and network technologies has reduced the time and geographic barriers of outsourcing business functions to other companies.

Reengineering, also known as business process redesign, calls for fundamental changes in the way business is carried out. Traditional companies are organized around functional business areas, which often leads to limited communication and cooperation, as well as redundancy due to functional overlap. Hammer and Champy's book, *Reengineering the Corporation*, makes a convincing case for restructuring business resources around whole business processes rather than functional tasks (Hammer & Champy, 1993). IT and IS have become both an impetus and a facilitator for reengineering projects.

In the 1990s, researchers increasingly recognized the importance of customer relationship management (e.g., Gronroos, 1994; Sewell & Brown, 1990). Computer and network technologies have played a key role in making customer relationship management efficient and effective. Along the line of improving value to the customers, mass customization provides competitive advantages (Pine & Gilmore, 1997). Reaching and custom-serving individual customers are only feasible with the proliferation of information and communication technologies.

Peter Senge (1990), in his book, *The Fifth Discipline,* popularized the concept of the learning organization. The rationale in creating a learning organization is that the business environment has become more dynamic and complex. Companies must have the ability to learn continuously and adapt to the changing environment. People in a learning organization need to continuously expand their capacity to become more productive or to maintain their level of competency.

The Greek philosopher Heraclitus said nothing is constant but change. Indeed, Toffler (1970) has recognized that not only is Heraclitus still right, but the rate of change is accelerating. Hamel (2000) believes that all strategies decay over time; thus, organizations need to reexamine their strategies and strategic management practices. Moncrieff (1999) argues that strategic management is a dynamic process. Strategy is partially deliberate and partially unplanned. Recently, many researchers have recognized that organizations are complex adaptive systems in which multiple agents set their own goals, share information, collaborate and interact with one another (Axelrod & Cohen, 1999; Dudik, 2000; Landsbergen, 2005). Two foreseeable trends are: 1) more IT-enabled interactions among human agents in the complex adaptive systems, and 2) agent activities moving from purely human interaction to interactions involving artificial intelligent agents.

THE EVOLUTION OF IT

IT can be defined as technology applied to the creation, management and use of information. Any technology that deals with information gathering, processing, storing and dissemination is considered IT. Earlier examples of IT include pigeon carriers and sending messages by fire and smoke. By definition, IT does not have to be computer-based. However, practically speaking, today's IT is largely built on computer hardware and software applications. Thus, in the following, while we review IT development in the past, we focus on computing-related technologies.

An early and relatively sophisticated computing device was the abacus, invented around 500 B.C. in Egypt. Blaise Pascal invented the first mechanical calculating machine for adding and subtracting in 1642. A milestone in computing machine development was Charles Babbage's difference machine that could perform trigonometric and logarithmic operations. The first electronic computer, ENIAC (electronic numerical integrator and calculator), was developed in 1946. Commercially available computers began in the early 1950s, with IBM as the leading vendor.

One of the milestones in the computer industry was the arrival of the IBM System/360 in 1964. The System/360 was a family of computers running the same operating systems and using the same peripherals. Thus, companies could start with a less capable model and expand the capacity with more powerful models without the need to replace system software and peripheral components. Easy adoption through inter-changeability of hardware and software prompted significant growth of computer system usage in business in the 1960s and 1970s (with later models, such as the System/370). IBM first started unbundling software from hardware by selling software separate from its computer in 1969. That set the stage for the launch of an independent software industry. The fast growth of packaged software applications, in turn, prompted the growth of computer hardware.

The next major event in the computer industry was the birth of personal computers (PCs) in the mid-1970s. Intel introduced the first semiconductor microchip (the Intel 4004) in 1971. However, PCs were not widespread until the early 1980s, when IBM launched its standardized PC (known as the IBM PC). The IBM PC became "Machine of the Year," taking the place of traditional "Man of the Year" on the cover of *Time Magazine* in 1983. Other computer vendors jumped on the IBM PC bandwagon by producing IBM-compatible PCs. During the decade of the 1980s, the number of PCs grew more than 100 fold to more than 100 million (Gantz, 2004).

The continued growth of the PC industry is driven by the well-known Moore's Law, which stipulates that the number of transistors per silicon chip doubles roughly every 18 months; hence, the corresponding performance of the central processing unit—the brain of microcomputers. Gordon Moore, co-founder of Intel Corp., made that stipulation in 1965. Amazingly, Moore's Law has described the state of affairs for the last four decades. The power of exponential growth resulted in dramatic cost and performance improvement of computer hardware. Once scarce and expensive, computer systems are now abundant and inexpensive because of the availability of desktop computer, laptop computers, and even handheld computing devices. Low-cost computing changed organizational computing architecture from centralized computing to distributed computing systems in the 1980s.

In the history of IT, the 1990s is perhaps best known as the decade of Internet booming. The Internet started as the U.S. Department of Defense's ARPAnet, with the aim of creating a distributed computer network that can withstand a nuclear attack. In the 1970s and 1980s, the Internet was used mainly by academics and scientists, and was not accessible largely to the general public because its use, although open, required substantial learning of arcane application protocols. Two major events led to the explosive growth of the Internet. The first was the development of the World Wide Web (WWW or the Web) by Tim Berners-Lee, a researcher at the CERN Institute in Switzerland in 1990, and the second is the arrival of (largely free) graphic Web browsers. The Web made it possible to link information resources all over the world on the Internet. Users could retrieve information without knowing the whereabouts of the information by simply following the hyperlinks (or links). However, initial access to the WWW was text-based; hence, its richness in content and usability were limited. The WWW took off after 1993 when the first graphic Web browser, Mosaic, was released by the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana Champaign. The ensuing Internet growth was unprecedented in the history of technology development. Internet users grew from a few thousand to more than 300 million during the 1990s. As of June 2005, there were more than 938 million Internet users worldwide (www.internetworldstats.com/stats.htm).

The Internet provides a low-cost way of connecting virtually everyone in modern society to an open and shared common network. The wide accessibility of the Internet has created numerous opportunities for businesses and brought fundamental changes to the way businesses operate. The value of a network increases with the square of the number of users connected to the network. This is known as Metcalfe's law, attributed to Robert Metcalfe, one of the inventors of the widely used Ethernet standard and founder of 3Com Corporation (Applegate, Austin, & McFarlan, 2003). The Internet has changed the landscape of competition by lowering the barriers for small- and medium-size companies to reach markets that were traditionally accessible only to large corporations.

Since the late 1990s, mobile computing based on wireless network technologies has gained much momentum. Intelligent appliances, such as cellular phones, personal digital assistants and other handheld computing devices, are becoming a significant part of the IS infrastructure. IDC predicts that the number of mobile devices connected to the Internet will surpass that of Internet-connected computers by the end of 2006. The total number of networked devices may approach 6 billion by 2012 (Gantz, 2004). Ubiquitous computing that allows "anytime, anyplace" access to information resources will bring dramatic changes to the business environment.

The Internet has already created fundamental changes in the business world. The WWW brought the first revolution in our networked society. Many believe that the next major development of the Web may be network intelligence through Web services. The non-profit Internet governing organization W3C defines Web services as the programmatic interfaces for application to application communication on the Web. Web services create a promising infrastructure to support loosely coupled, distributed and heterogeneous applications on the Internet (Nagarajan, Lam, & Su, 2004). Applications based on Web services can be described, published, located and invoked over the Internet to create new products and services based on open Internet protocols such as HTTP, XML and Simple Object Access Protocol (SOAP). The significance of Web services is that system-to-system communications can be automated; hence, building business alliances and virtual organizations becomes much easier than with current Internet technology.

IT AS AN ENABLER FOR STRATEGIC MANAGEMENT

Although strategic management and IS developed in parallel over the last 50 years, the two fields have also had substantial impact on each other. The interaction and co-evolution of the two fields have experienced significant increase in recent years. In this section, we will examine such interaction and co-evolution through the motivations and development of computer-based IS used in businesses.

The short history of computer IT development can be divided into three eras: the mainframe era from the 1950s to the 1970s, the microcomputer era from the 1980s to the early 1990s, and the Internet era from the 1990s to the present. The mainframe era is characterized by centralized computing, where all computing needs were serviced by powerful computers at the computer center. The proliferation of microcomputers led to decentralized computing. Computing resources become readily accessible to more users. This is a period that witnessed improved user performance and decision-making quality. When computer networks became pervasive in the Internet era, decentralized computing evolved to distributed computing, where computing resources are located in multiple sites, as in decentralized systems, but all of the computing resources are connected through computer networks. People in the Internet era are far more empowered than in previous eras, because they have access to not only technology tools as before, but also to shared knowledge from others. Table 1 summarizes the IS and their motivations during those three IT evolution eras. Although IS are separately listed in the three eras, we must point out that the lists are not mutually exclusive. In particular, in the Internet era, businesses are still heavily dependent on systems conceptualized and developed in earlier eras, such as TPS, MIS and DSS.

Clearly, the role of business IS has evolved and expanded over the last 5 decades. Early systems in the 1950s and 1960s were used primarily for dealing with business transactions with associated data collection, processing and storage. Management information systems (MIS) were developed in the 1960s to provide information for managerial support. Typical MIS are report based, with little or no decision-making support capabilities. Decision support systems (DSS) first appeared in the 1970s. They offer various analytical tools, models and flexible user interface for decision support at solving difficult problems, such as planning, forecasting and scheduling. Executive support systems (ESS) are specialized DSS designed to support top-level management in strategic decision making (O'Brien, 2005).

The 1990s saw an increased emphasis on Strategic Information Systems as a result of the changing competitive environment. Competitive advantage became a hot strategic management topic. IT and IS were developed to support business strategic initiatives. The commercialization of the Internet in the mid 1990s created an explosive growth of the Internet and Internet-based business applications. Using the Internet standards, corporations are converting their old incompatible internal networks to Intranets. Also based on Internet standards, Extranets are built to link companies with their customers, suppliers and other business partners (Chen, 2005).

What kind of information systems would be considered strategic information systems? Although strategic support systems are almost exclusively used for top executives dealing with strategic problems, a strategic information system can be any type of IS that plays a key role in supporting business strategies. McFarlan's strategic

Table 1. IT evolution and strategic management relevance (Adopted from Applegate, Austin, and McFarlan, 2003)

	Mainframe Era 1950s to 1970s	**Microcomputer Era 1980s to early 1990s**	**Internet Era 1990s to present**
Dominant technology	Mainframes, stand-alone applications, centralized databases	Microcomputers, workstations, stand-alone and client-server applications	Networked microcomputers, client-server applications, Internet technology, Web browser, hypertext, and hypermedia
Information systems	Transaction processing systems (TPS), management information systems (MIS), Limited decision support system (DSS)	Comprehensive decision support system (DSS), executive support systems (ESS), enterprise resource planning (ERP), business intelligence (BI), human resource management (HRM), expert systems (ES)	Supply chain management (SCM), customer relationship management (CRM), knowledge management (KM), strategic information systems (SIS), multi-agent systems (MAS), mobile information systems
IS motivation	Efficiency	Effectiveness	Business value
Strategic management relevance	Provide information for monitoring and control of operations	Provide information and decision support for problem solving	Support strategic initiatives to transform organizations and markets

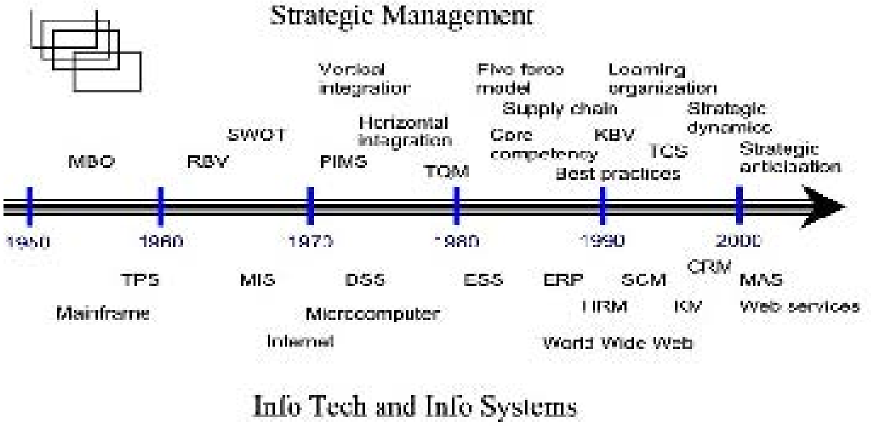
grid defines four categories of IT impact: Support, Factory, Turnaround and Strategic (Applegate, Austin & McFarlan, 2003). When the IT has significant impact on business core strategy, core operations or both, the corresponding IS are considered strategic information systems. Thus, various information systems may be dealt with in strategic management.

Many researchers have written on the strategic importance of information and knowledge in the networked economy. Nasbitt (1982) observed that the world was transforming from an industrial to an information society, and IT would dominate the economic growth of developed nations. Quinn (1992) argued how knowledge- and service-based systems are revolutionizing the economy. Shapiro and Varian (1999) discussed information-based products and services, and how to use information to maximize economic gain.

IT and IS have made it possible to access vast amounts of information easily and quickly. Systems such as enterprise resource planning (ERP) give managers the ability to monitor the operation of the entire organization in real time. Executive information portals have allowed senior managers to take a much more comprehensive view of strategic management than ever before. Tools such as the balanced scorecard (Kaplan & Norton, 1992) give a holistic view of the business performance by integrating factors in multiple business functions.

In the last few years, business process management (BPM) software has been designed with the intent of closing gaps in existing ERP deployments. As companies are increasingly faced with problems associated with incompatible functional systems from different vendors, enterprise application integration (EAI) has become an important research. BPM systems have been deployed to lower the cost and complexity of application and data integration. Another recent development is Web services enabled by standards-based protocols (such as XML, SOAP, UDDI and WSDL). The wide acceptance of Internet protocols also led to the emergence of service-oriented architectures (SOA). SOA focus on building robust and flexible systems that provide services as they are requested in a dynamic business process environment. Instead of being programmed in advance, services are generated, brokered and delivered

Figure 1. Chronology of strategic management and IT development



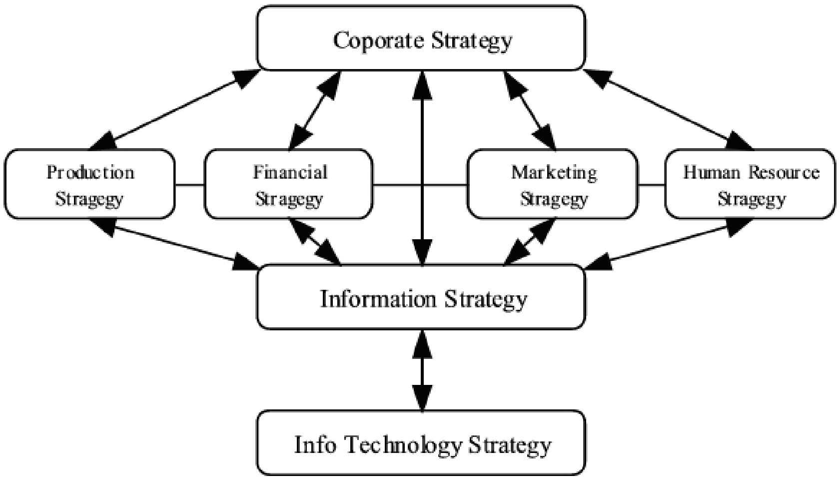
on the fly. Figure 1 presents a timeline that lists major developments in strategic management and IT/IS. Although the two fields have progressed in their separate paths, there are many instances where their paths crossed. As shown in Table 1 and the discussion following it, the motivation of IS has shifted from efficiency to effectiveness, and in the Internet era, to value creation. On one hand, IT is playing a more active and important role in strategic management. On the other hand, strategic management concerns have influenced the development of IS. In many cases, the theories and principles of strategic management led the way of IS development. IT and IS, in turn, have made it more feasible for those theories and principles to be practiced in businesses.

IT ALIGNMENT WITH BUSINESS STRATEGIES

IT in business has evolved and become increasingly integrated with business organizations. Strategic management now encompasses corporate strategy, functional business strategy, information strategy, and IT strategy, as shown in Figure 2. For most businesses, their strategies form a multi-level hierarchy. At the very top is corporate strategy, which sets the direction for corporate-level decision making. Below corporate strategy, there are functional strategies, business unit strategies and operational strategies. Building a comprehensive strategic IT plan that aligns with the business strategy is essential to ensuring the success of the organization.

Numerous researchers have indicated that IT alignment with business strategy is vital to achieve expected results. Sabherwal and Chan (2001) studied the benefit of alignment between business and IS strategies, and concluded that the alignment can improve business performance. They also developed a framework that can be used to analyze the level of alignment between business and IS strategy. Symons (2005) claimed that IT alignment has been one of the top three issues confronting IT and business executives for more than 20 years. Symons reported that a recent poll of CIOs and business executives revealed that the alignment of IT and business goals is their no. 1 or 2 priority. Measuring the degree of IT alignment has been difficult for many businesses. Borrowing the idea from the Capacity Maturity Model (CMM) of the Software Engineering Institute, Symons proposed a strategy alignment maturity model with five distinct levels:

Figure 2. Alignment of information technology with strategies



- At the base level, called Nonexistent, there is IT alignment with business strategy. IT plays only a supportive role of operations.
- At the Ad hoc level, the need for IT alignment is recognized, but there is a lack of systematic approach. IT supports business goals on a case-by-case basis. There is no attempt to measure the success of IT alignment.
- At the Repeatable level, IT alignment is considered at the enterprise level. However, it is only implemented in some business units. Limited measures of IT alignment exist.
- At the Defined process level, IT alignment is systematically implemented throughout the enterprise, with appropriate policies and procedures to monitor and measure the benefits of the IT alignment.
- At the Optimized level, IT strategy is seamlessly aligned with business strategy at all managerial levels and in all business units. IT alignment processes have been extended to external best practices with other organizations. Measures of IT alignment and feedback mechanisms exist to ensure that IT alignment stays at this level.

Obviously, IT alignment is one of the key issues in strategic management. However, IT alignment is more than simply formulating IT strategy to fit the business strategy. Business strategy is future oriented and subject to external forces and environmental uncertainty. IT alignment should build adaptability into IT strategy. Furthermore, for some technology companies, IT may be the driver of corporate strategy (Clarke, 2001).

Strategic management is concerned with the long-term survival and prosperity of organizations. As the environment changes, organizations must also adapt to maintain their viability. Organizations evolve, and so do strategies. Thus, strategic management is also a learning process. There are four basic learning behaviors in strategy formulation; namely, natural selection, imitation, reinforcement and best reply (Young, 1998). In each of the four learning processes, IT and IS are becoming indispensable.

Natural selection stipulates that organizations that use high-payoff strategies have competitive advantages over those using low-payoff strategies. As a result, high-payoff strategies have a better chance to be continued by surviving organizations. Determining the payoff of strategies, thus, is very important in this kind of strategic learning behavior.

Imitation describes how organizations mimic the practices of successful peers in their industry. This is the cause of herding behavior in which the outcome is not clear, but organizations jump on the bandwagon, simply following what many of their peers are doing. A classic example is the dot.com boom during the late 1990s.

Reinforcement is concerned with how organizations monitor their own behaviors and favor the strategies that resulted in high payoffs in the past. In contrast to *natural selection*, *reinforcement* learning is based on one's own experience rather than others' experience.

Best reply is the behavior wherein organizations formulate their strategies based on what they expect their competitors will do. Many of the popular competitive strategies, such as low-cost leadership and differentiation, fall into this category.

RESEARCH ISSUES IN IT-ENABLED STRATEGIC MANAGEMENT

There is no doubt that the application of IT and strategic information systems has aided businesses in gaining competitive advantages. However, the extent to which IT/IS helps businesses to succeed varies, as many other factors also contribute to the long-term performance. Kettinger and colleagues (1994) studied a large number of cases of strategic information systems and found that 40% of the companies had above-average performance in the short to intermediate term, while only 20% of the companies sustained long-term (10 years or more) competitive advantages. Thus, for many of those companies, their strategic investment in IT and IS did not achieve their long-term goals.

In 2003, *Harvard Business Review* published a controversial article titled "IT Doesn't Matter." The author of the article, Nicolas Carr, contends that since IT cost has dropped precipitously in recent years, and now IT is widely accessible to businesses large and small, IT no longer provides a competitive advantage to businesses. Thus, companies should stop investing heavily in advanced IT products and services. Rather, they should spend the resources on reducing operational risks associate with IT (Carr, 2003). Although many scholars and industrial leaders, such as Warren McFalan, Richard Nolan, Paul Strassmann, John Brown, John Hagel and Vladimir Zwass (see Stewart, 2003), have debated Carr's view, and have shown evidence of the strategic importance of IT, it is generally agreed that IT alone is not enough to sustain strategic advantages. Although IT plays an important role, it is only one facet of the comprehensive framework of strategic management. As Clemons and Row (1991) argued, IT's value is not so much in its intrinsic properties, but in how it can be effectively deployed to support business strategies. Although numerous previous researchers have studied IT's importance and its strategic value (e.g., Clarke, 2001; Porter & Miller, 1985), there is a lack of strategic research on integrating IT into strategic management.

In recent years, IT-enabled business changes have become more frequent and more crucial. Prahalad and Krishnan (2002) have surveyed business executives in large companies and found that almost invariably, the executives indicated that the quality of their IT infrastructure fell short of their need and desire for strategic change. In such a case, (existing) IT became an impediment to innovations and other strategic initiatives. Many companies have started large IT projects, such as ERP, CRM and SCM projects, in their effort to revamp their business processes. However, as Prahalad and Krishnan (2002) pointed out, packaged enterprise systems are designed for stability in processes, not ability to evolve. One of the key issues in IT-enabled strategic management is creating an IT infrastructure that offers speed for change and flexibility needed for strategic management.

Understanding how businesses create and sustain competitive value from their investments in IT has been a challenge for strategic management researchers as well as IS researchers. A more comprehensive way of conceptualizing the interplay of IT and strategic management is needed. As more companies are transforming into e-businesses, obviously, information and communication technologies are becoming an integrated part of the organization. However, what is the role of IT in strategic management when computing and network become pervasive and IT becomes invisible? How will emerging IT, such as grid computing, Web services and SOA, change strategic dynamics of organizations? Those questions need to be addressed by both IS and strategic management researchers.

Clearly, the intersection of IT and strategy is ripe for research. Opportunities abound with regard to strategy making and strategy implementation enabled by IT. Research questions falling within the scope of interest could cover a wide range of issues, from various product/market approaches to strategic decision processes to diversification management to corporate governance, to name just a few. For instance, the pursuit of combination, or hybrid, business-level strategies may be more possible now with IT advances. Whereas Porter (1980, 1985) advised organizations generally to pursue one coherent strategy (e.g., the choice between low-cost and differentiation), the advent of flexible manufacturing and highly sophisticated customer database systems may provide more latitude at the business level. A worthy research question is to what extent, and in what contexts, combination forms of competitive advantage can indeed be pursued, and in what ways these strategies are enabled by IT. Likewise, strategic decision processes, such as environmental scanning, analysis and planning, have been aided immensely by the development of executive IS, Internet capabilities and real-time access to business intelligence. These developments enable richer and more abundant information to reach executives, but a key challenge is how to provide relevant information in the proper form and at the right time so the organization can capitalize on opportunities. To what degree might IT advances enable the optimum breadth and depth of information to enter the strategic decision process, given contingencies such as decision makers' characteristics and organizational strategy? These are examples of research questions that would merely begin to scratch the surface.

CONCLUSION

We have explored concepts and issues involving the use of IT as an enabler for strategic management. We discussed the parallel development of strategic management and IT, and their co-evolutions over the last 5 decades. In general, the theoretical research in strategic management has led the way in the co-evolution. IT and IT-enabled IS are developed to support strategic management needs. The fields are at a unique point in their development, enabling cross-disciplinary research of both practical and theoretical interest dealing with a vast array of organization process and performance issues. We hope the succeeding chapters are helpful in providing a start toward fruitful research agendas and in offering practical guidance to those who are responsible for implementation in organizations.

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Chapter 1.4

Enterprise Systems Strategic Alignment and Business Value

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ABSTRACT

This chapter is dealing with the alignment of enterprise systems with business strategy and its impact on the business value that enterprise systems generate. Initially the research on the strategic potential of ICT, which constitutes the basic theoretical foundation of the need for strategic alignment of enterprise systems, is analyzed. Then the previous research that has been conducted concerning enterprise systems strategic alignment is critically reviewed. It is grouped into three basic streams. The first of them is dealing with the conceptualization and basic understanding of enterprise systems strategic alignment. The second research stream aims at the development of models and frameworks for directing and assessing enterprise systems strategic alignment. The third research stream examines the impact of enterprise systems strategic alignment on business performance. Finally, an empirical investigation that has been conducted by the authors concerning the impact of enterprise systems strategic alignment on business performance as a guidance for future research on this topic is described. We expect that this chapter will sufficiently inform on strategic alignment, both researchers and practitioners in the area of enterprise systems, so that they can incorporate this highly important concept in their research and practice respectively.

INTRODUCTION

The strategic alignment of information systems (IS) has been ranked as the most important issue that IS managers face in the two most recent formal surveys conducted by the Society for Information Management (SIM) of USA (www.simnet.org) concerning the key IS management issues (Luftman & McLean, 2004; Luftman, 2005). Also, the strategic alignment of IS has been ranked in very high positions in most of the surveys of the key IS management issues that have been conducted in various countries (e.g. Palvia et al, 2002). Several definitions of IS strategic alignment have been proposed by the relevant literature. According to Broadbent & Weil (1993) as IS strategic alignment is defined the extent to which business strategies are enabled, supported and stimulated by information strategies. Luftman (2000) provides a more detailed definition stating that 'Business-IT alignment refers to applying Information Technology in an appropriate and timely way, in harmony with business strategies, goals and needs. This definition of alignment addresses: 1. how IT is aligned with the business and 2. how the business should or could be aligned with IT' (p.3). Duffy (2002) in an IDC Report states that IT technical people have criticized corporate general management for a lack of interest in the IS function; at the same time general management people have criticized the IT technical people for not understanding the business and for not being profit-oriented, being interested mainly in solving technical problems and not business problems. However, at the same time he remarks that 'However valid both of these criticisms may have been, there is evidence that the gap between the two groups is now narrowing" (p.2), and defines 'IT/Business Alignment' as 'the process and goal of achieving competitive advantage through developing and sustaining a symbiotic relationship between IT and Business' (p.4).

The strategic alignment of enterprise systems consists in the establishment of a bilateral relationship between the enterprise systems planning process and the business/strategy planning processes, which allows:

- The mission, goals, competitive strategy, future directions and action plan of the enterprise, and also the analysis of its external environment (e.g. competition, opportunities, threats) and the analysis of its internal environment (e.g. resources, capabilities, strengths, weaknesses), which are basic elements of its business/strategy plan, to be taken into account for the formulation of its enterprise systems plan,
- And also the capabilities, strengths and weaknesses of existing enterprise systems, the planned enterprise systems, the forms and the extent of information and communication technologies (ICT) usage in the industry and the capabilities offered by existing and emerging ICTs that may interest and influence the enterprise, which are basic elements of the enterprise systems plan, to be taken into account for the formulation of the business/strategy plan.

The basic objective of this bilateral relationship is to exploit ICT in the enterprise in the best possible manner for both supporting and enriching its business strategy, and to take advantage to the highest possible extent of the significant strategic potential of ICT.

This chapter is dealing with the alignment of enterprise systems with business strategy and its impact on the business value that enterprise systems generate. It aims to inform on this highly important issue both researchers and practitioners in the area of enterprise systems, so that they take it into account and incorporate it in their research and practice respectively. In this direction in the following second section of this chapter is reviewed briefly the research that has been conducted on the strategic potential of ICT, which constitutes the basic theoretical foundation of the need for strategic alignment of enterprise systems. Then in the third section the previous research that has been conducted concerning enterprise systems strategic alignment is critically reviewed. In the fourth section is described an empirical investigation that has been conducted by the authors concerning the impact of enterprise systems strategic alignment on business performance, based on the construction of complete econometric models, which are founded on the well-established and validated Cobb-Douglas production function, and using objective measures of business performance and enterprise systems investment, and on. Finally the conclusions and the future trends concerning enterprise systems strategic alignment are discussed.

THE STRATEGIC POTENTIAL OF ICT

There has been for more than two decades a high level of interest of both researchers and practitioners in the alignment between enterprise systems and business strategy, which is founded on the recognition that ICT have a significant strategic potential, i.e. if properly exploited they can have a significant strategic impact on the enterprise and provide valuable competitive advantages. The initial research on this strategic potential of ICT has been based on the work of M. Porter (1980) on competitive strategy, which identifies three generic business strategies: differentiation, cost leadership and focus; also it concludes that organizations use these generic strategies in order to control five basic industry forces, which determine their competitive position and profitability: rivalry among existing competitors, bargaining power of suppliers, bargaining power of buyers, threat of substitute products/services and threat of new entrants. Parsons (1983) applied the above work of M. Porter to the ICT and reached the conclusion that IS can have a significant strategic impact if the are used to change the products, services, markets or production economics of an industry, to affect the buyers and suppliers of the enterprise, to prevent customers from buying products and services from competitors, to preclude new competitors, to alter the degree of rivalry, or to support one of the abovementioned M. Porter's generic strategies. McFarlan (1984) applied the above work of M. Porter to the ICT and concluded that they can have a strategic impact, if they are used in order to build barriers against new entrants, build switching costs, change the basis of the competition, generate new products and services and change the balance of power in supplier relationships. Building on these conclusions Benjamin et al (1984) enriched the perspective of the strategic potential of ICT by concluding that it is not only IS affecting customers or supporting new products and services that can have a strategic impact, but also IS affecting internal operations and supporting traditional products and services can be of high strategic importance as well and provide competitive advantages. Ives and Learnmonth (1984) applied the concept of value chain to the interaction of a customer with an enterprise and concluded that an IS that fits into customer lifecycle and differentiates products or services from those of the competitors can be of high strategic importance. Wiseman (1985) concludes that IS supporting the internal operations or the traditional products and services of an enterprise can have strategic impact if they support its 'strategic thrusts', such as M. Porter's generic strategies, innovation, growth or alliances, in a manner that influences relationships with customers, suppliers or competitors. Important is the contribution of Porter & Millar (1985) on this topic, who identify three basic ways that ICT can affect competition: by altering industry structures, supporting differentiation and cost leadership strategies, and also by spawning entirely new businesses; they also argue that ICT have strategic potential if they can add value to a product or service in at least one of the primary activities (inbound logistics, operations, outbound logistics, marketing and sales, after-sales support and services) or one of the support activities (human resources management, technology development, infrastructure management, procurement) of the value chain. At the same time been many case studies have been published on this topic describing and analyzing 'real-life' IS that have provided valuable competitive advantage (e.g. Earl, 1989; Hopper, 1990; Robson, 1997; Pemberton et al, 2001; Picolli & Applegate, 2003), which validate and prove the practical applicability of the above research conclusions.

Subsequent research on this topic emphasizes the need for combining ICT with other resources of the enterprise in order to have a strategic impact. In this direction Carr (2003) argues that a narrow and exclusively technological focus cannot result in competitive advantages ('IT Doesn't Matter'). Powell and Dent-Micallef (1997) from an empirical study in the retail industry found that ICT alone cannot produce sustainable performance advantages, but such advantages can be gained only by using ICT in order to leverage intangible, complementary human and business resources. Miller (2003) found that sometimes these complimentary resources can be of low value, or even considered as liabilities, until they are they are incorporated in a new ICT-based 'engine of value creation'; therefore ICT can be instrumental in leveraging existing enterprise resources of low value, or even liabilities, into valuable resources that offer (in combination with other resources and ICT) competitive advantage. Another important dimension of the strategic potential of ICT as enablers of 'strategic agility' is proposed by Sambamurthy et al (2003), who argue that the capabilities of ICT can create new strategic 'digital options' for the enterprise and enable it to launch new competitive initiatives and respond quickly and effectively to changes in its environment.

Also, research has been conducted concerning the sustainability of the competitive advantages provided by ICT. Mata et al (1995), based on a resource-based view of the firm, conclude that 'managerial ICT skills' (defined as the ability of ICT management to understand the business needs of other functional units, customers and suppliers, and in cooperation with them to develop IS that cover these needs) is the only ICT attribute of an enterprise that can provide a sustainable competitive advantage. Bharadwaj (2000) adopting also a resource-based perspective and using a matched-sample comparison group methodology found that superior firm-specific ICT resources (ICT infrastructure, human ICT resources and ICT-enabled intangibles) result in superior financial performance. Picolli & Ives (2005) from an extensive literature review identified four basic barriers to the erosion of the competitive advantages provided by 'IT-dependent strategic initiatives': IT resources barrier, complementary resources barrier, IT project barrier and preemption barrier; they conclude that the existence of one or more of these barriers can make the competitive advantages offered by 'IT-dependent strategic initiatives' sustainable for long time.

In conclusion, from the above research considerable theoretical support and empirical evidence has been produced that ICT can provide (usually in combination with other resources of the enterprise) significant competitive advantages, which under specific conditions can be sustainable; it has also been concluded that the realization of this strategic potential is not an easy task and necessitates the establishment of a connection between ICT and the overall strategy of the enterprise.

REVIEW OF RESEARCH ON ENTERPRISE SYSTEMS STRATEGIC ALIGNMENT

The above conclusions gave rise to considerable research in the last twenty years concerning various dimensions of enterprise systems strategic alignment. This research can be grouped into three basic streams: i) conceptualization and basic understanding of enterprise systems strategic alignment, ii) development of models and frameworks for assessing and directing enterprise systems strategic alignment, and iii) investigation of the impact of enterprise systems strategic alignment on the business performance. These three research streams are briefly reviewed next.

Conceptualization and Basic Understanding of Enterprise Systems Strategic Alignment

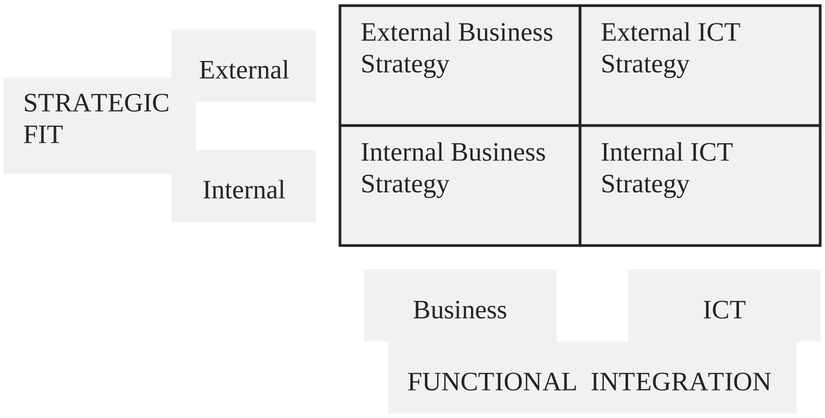
The main objective of this research stream is to conceptualize and understand the strategic alignment of enterprise systems, focusing on the identification of its basic processes, barriers, critical success factors and benefits (King, 1978; Lederer & Mendelow, 1988; Earl, 1989; Jarvenpaa & Ives, 1990; Zviran, 1990; Chan, 1992; Earl, 1993; Luftman, 1996; Reich & Benbasat, 1996; Armstrong & Sambamurthy, 1999; Luftman, Papp & Brier 1999; Luftman & Brier, 1999; Kearns & Lederer, 2000; Reich & Benbasat, 2000; Allen & Wilson, 2003; Campbell et al, 2005; Rantham et al, 2005). Due to space limitations we are going to outline briefly only the most representative publications of this research stream. Lederer and Mendelow (1988) argue that one of the most important barriers of enterprise systems strategic alignment is the difficulty of convincing top management of the strategic potential of ICT, because the top management usually lacks sufficient awareness on ICT strategic potential, regards the use of computers as a strictly operational support tool, perceives a credibility gap, does not view information as a resource, demands financial justification and also is action-oriented; for overcoming these difficulties the authors propose a number of techniques: educate top management, market IS department accomplishments to the top management, have users to do this ‘selling’, promote the business image of the IS department, respond to ‘outside forces’ influencing top managers, capitalize on changes in management and perform highly sophisticated IS planning that necessitate top management involvement. Jarvenpaa & Ives (1991) conclude that the ‘involvement’ of executives in IS activities (i.e. the ‘psychological state’) is more strongly associated with the progressive use of ICT in the enterprise than the ‘participation’ of executives in IS activities (i.e. their ‘actual behaviors’); also executive involvement is influenced by a CEO‘s participation, prevailing organizational conditions, and the executive‘s functional background. Earl (1993) identified five basic approaches that are adopted by businesses for achieving enterprise systems strategic alignment: the business-led approach, the method-led approach, the administrative approach, the technological approach and the organizational approach; each of these approaches has different characteristics and therefore different likelihood of success, the organizational approach appearing to be more effective. Luftman, Papp and Brier (1999) identified a number of enablers of alignment between business and ICT strategies: senior-executive support for IT, IT involvement in strategy development, IT understanding the business, partnership between IT and non-IT units, well-prioritized IT projects and IT demonstrating leadership). Reich & Benbasat (2000) investigated the influence of four factors on the ‘social dimension’ of enterprise systems strategic alignment (defined as the extent to which business and IT executives mutually understand and are committed to both the business and the IT mission, objectives, and plans): shared domain knowledge between business and IT executives, IT implementation success, communication between business and IT executives, and connections between business and IT planning processes; they found that all these four factors influence ‘short-term alignment’, while only the shared domain knowledge influences ‘long-term alignment’. Campbell et al (2005), based on a review of the previous research on enterprise systems strategic alignment, identify two basic approaches in it: the ‘social’ (focusing primarily on the people involved in achieving alignment) and the ‘intellectual’ (investigating mainly the relevant plans and planning methodologies); also, they remark that most of the research on enterprise systems strategic alignment adopts the intellectual approach, and recommend a combination of these two approaches as the optimal approach. Also adopting such a combined approach and based on the analysis of the content from a number of interviews with senior ICT managers they concluded that all of them believed that strategic alignment generally depends upon communication, collaboration, development of trust and shared domain knowledge, as suggested in the relevant literature; however, it was practically problematic to achieve these prerequisites, due to the prevalent culture in their organizations that promoted competition between departments.

This research stream has provided a basic conceptualization and understanding of the strategic alignment of enterprise systems, concerning mainly its basic processes, barriers, critical success factors and benefits. However, more in-depth research is required on these topics, in various types and sizes of enterprises, in various industries and national and cultural contexts, and for various types of ICT, in order to get a deeper and more complete understanding of them.

Development of Models/Frameworks for Directing/assessing Enterprise Systems Strategic Alignment

This research stream aims to support the practical application in 'real-life' of the ICT strategic alignment concept by developing models/frameworks for assisting the technical and the business management in directing and assessing enterprise systems strategic alignment. The most widely used of the models/frameworks that have been developed for directing strategic alignment is the 'Strategic Alignment Model' (SAM) developed by Henderson and Venkatraman (1999). As we can see in Figure 1 it is based on two basic dimensions of required linkage: i) the 'strategic fit' (=linkage between 'external components' (concerning the external environment of the enterprise) and 'internal components' (concerning the internal environment of the enterprise)) and ii) the 'functional integration' (=linkage between the 'business domain' and the 'IS domain'). In the strategic fit dimension the model views strategy as consisting of two components, the 'external' and the 'internal' one, which should be well integrated. In particular, it views ICT strategy as consisting of one component concerning the 'external domain' (=decisions on how the enterprise is positioned in the ICT marketplace, e.g. which of the existing ICT in the marketplace it is going to use, which are their required performance and cost attributes, what kind of relations it has with their vendors, such as outsourcing, strategic alliances, etc.) and one component concerning the 'internal domain' (=decisions on how the internal ICT infrastructure of the enterprise will be configured and managed: ICT architecture, processes and skills), which should be well integrated. Similarly it views business strategy as consisting of two components which should be also well integrated:

Figure 1. The 'Strategic Alignment Model' (SAM)



one component concerning the 'external domain' (= decisions about business scope, distinctive competencies and business relations with other organizations) and one component concerning the 'internal domain' (= decisions about its administrative infrastructure/architecture, business processes and human resources skills). In the functional integration dimension the model views two domains, the business domain and the IS/ICT domain, and proposes integration between them at two levels: 'strategic integration' (=integration between their external domain components) and 'operational integration' (=integration between their internal domain components).

Based on the above dimensions the SAM proposes that the complete enterprise systems strategic alignment consists in the integration between these four domains of strategic choice: business external strategy, ICT external strategy, business internal strategy and ICT internal strategy. Also using this model the authors propose and describe four alignment perspectives: business strategy execution (external business strategy → internal business strategy → internal ICT strategy), technology-based transformation (external business strategy → external ICT strategy → internal ICT strategy), exploitation of ICT competitive potential (external ICT strategy → external business strategy → internal business strategy) and service level improvement (external ICT strategy → internal ICT strategy → internal business strategy).

Smaczny (2001) argues that a major disadvantage of the SAM is that its basic alignment approach is the sequential development of strategies; he states that this approach was the appropriate one for the period in which SAM was developed (characterized by a more stable business environment), but latter, due to major market changes and also due to the increased reliance of organizations on ICT, it has become slow and insufficient (at least for some industries and business contexts). For this reason he proposes a 'fusion' approach instead, which allows business and ICT strategies to be developed and implemented simultaneously. On the contrary Avison et al (2004) used successfully and validated this SAM in a financial services firm, and finally concluded that it has a good conceptual and practical value; also they developed a framework for its practical application, which enables the technology and business management to determine the current level of alignment and to monitor and change it in the future as required. Furthermore, it is worth mentioning another approach that developed by Van Der Zee & De Jong (1999) for planning and setting goals for ICT and evaluating its results based on the business context, which is founded on the concepts of the Balanced Business Scorecard.

Also, a number of models/frameworks have been developed for assisting technical and business management in assessing the level of enterprise systems strategic alignment in their organization. The most widely used of them is the 'Strategic Alignment Maturity Model' (SAMM) developed by Luftman (2000); it is based on six criteria of ICT strategic alignment maturity (Communications Maturity, Competency/Value Measurement Maturity, Governance Maturity, Partnership Maturity, Scope & Architecture Maturity, Skills Maturity), each of them consisting of a number of attributes (sub-criteria), which are evaluated in a five-levels scale (Initial/Ad-hoc Process, Committed Process, Established Focused Process, Improved/Managed Process, Optimised Process). The SAMM enables the evaluation of ICT alignment practices in an organization and also the design of improvements of them. Another IT alignment maturity model has been developed by the IT Governance Institute (ITGI) (www.itgi.org) as part of the CobiT (Control objectives for IT and related Technologies) framework (ITGI, 2005). In particular, CobiT includes a process named 'Define a Strategic Information Technology Plan', which aims to satisfy 'the business requirement to strike an optimum balance of Information Technology opportunities and IT business requirements'; this process includes a strategic alignment maturity model consisting of six levels (0:Non-existent, 1:Initial/AdHoc, 2:Repeatable and Intuitive, 3:Defined Process, 4:Managed and Measurable, 5:Optimized) and also guidance for using it in order to assess the maturity level of an organization. Bleistein et al (2006a, 2006b) argue that ICT strategic alignment is necessary not only at the executive level, but also at the level of the individual IT projects as well; in this direction they propose a requirements engineering framework that addresses the business strategy and the alignment of IT projects' requirements with business strategy.

In conclusion, the research of this stream has produced some first 'high-level' models/frameworks for directing and assessing enterprise systems strategic alignment, which offer some basic guidance, but in general they require further elaboration, evolution and adaptation to the new ICT that are continuously emerging and the new models of their exploitation by modern organizations. Therefore further research is required for the development of 'lower-level' and more practically applicable models/frameworks, which offer a more specific and complete guidance for directing and assessing enterprise systems strategic alignment, and also are adapted to the technological advances and the new globalized and highly competitive business environment; moreover, further research is required for validating such models/frameworks in 'real-life' conditions and situations.

Impact of Enterprise Systems Strategic Alignment on the Business Performance

This third research stream aims to investigate the impact of enterprise systems strategic alignment on business performance or on the contribution of enterprise systems to business performance. In this stream, despite its significance, has been conducted less research work that in the other two. In the following we review the main empirical studies that have been conducted in this direction. King & Teo examined empirically the impact of four types of integration between the business plan (BP) and the information systems plan (ISP) (administrative, sequential, reciprocal and full integration) on the perceived contribution of enterprise systems to various measures of organizational performance and on the perceived extent of various types of ISP problems (organization problems, implementation problems, database problems, hardware problems and cost problems) (Teo and King, 1996; King and Teo, 2000); using data from 157 large USA firms from the Corporate 1000 Book and performing independent sample t-tests and calculating correlations they found that the extent of BP-ISP integration and also its proactive orientation has a statistically significant positive relation with the perceived enterprise systems contribution to organizational performance, and also a statistically significant negative relation with the perceived extent of ISP problems. Chan et al (1997) investigated empirically the impact of enterprise systems strategic alignment on perceived enterprise systems effectiveness and perceived business performance; using data from 164 North-American financial services and manufacturing firms (from USA and Canada) with more than 100 employees from the Dun and Bradstreet directories they constructed a structural equations model (SEM), from which it was concluded that enterprise systems strategic alignment has statistically significant positive contributions to both perceived enterprise systems effectiveness and perceived business performance. Using the same data Sabherwal and Chan (2001) addressed the same research question, but in regard to the business strategy the enterprise follows; they considered three different business strategies: 'defenders', 'prospectors' and 'analyzers' and found that the strategic alignment of enterprise systems affects perceived business performance, only in enterprises following a 'prospector' or 'analyzer' business strategy, but not in the ones following a 'defender' business strategy. Cragg et al (2002) examined the link between enterprise systems strategic alignment and four measures of perceived firm performance (long term profitability, sales growth, financial resources availability and public image & customer loyalty) in the context of small firms; using data from 250 small UK manufacturing firms and performing analysis of variance (ANOVA) they found that the subgroup of firms having higher levels of alignment had also higher levels of all these four measures of perceived firm performance than the ones with lower levels of alignment. Bergeron et al (2003), based on data collected through a mail survey from 110 Canadian small and medium firms, and using cluster analysis found that low-performance firms exhibited a conflictual coalignment pattern of business strategy, business structure, IT strategy and IT structure.

It should be mentioned that all the above empirical studies have used subjective (perceived) measures of business performance and/or enterprise systems contribution to business performance. The only empirical investigation of the impact of enterprise systems alignment on business performance that uses objective measures of business performance has been the one conducted by Byrd et al (2005); based on data from 275 fabricated metal products manufacturing companies from South-eastern USA they constructed econometric models with sales revenue per employee and profit per employee as dependent variables, while as independent variables they used the IT expenditure per employee, a measure of enterprise systems strategic alignment and an interaction term equal to the product of the above two variables. In these econometric models the coefficient of this interaction term was found to be positive and statistically significant, so it is concluded that there is a synergistic coupling (positive interaction) between IT strategic alignment and IT investment with respect to both these measures of firm performance. However, the econometric models constructed in this study did not include some fundamental independent variables, such as non-IT capital and labour, which constitute basic determinants of firm output according to production economics (Nicholson, 2004).

In conclusion, from the research of this stream has been produced some first evidence of a positive contribution of enterprise systems strategic alignment to business performance. However, further research is required in order to understand better the contribution of different types of strategic alignment of enterprise systems to various dimensions of business performance, in various types and sizes of enterprises and in various sectoral, national and cultural contexts, based on objective business performance measures and also on sound theoretical foundations from the area of production economics. Also it is necessary to investigate the dependence of the contribution of enterprise systems strategic alignment to business performance on various external and internal environment factors (e.g. business strategy, competition, etc.) and to identify its main moderators.

AN EMPIRICAL INVESTIGATION

In this section are presented briefly the main results of an empirical study conducted by the authors, which contributes to the third of the above research streams, investigating the effect of enterprise systems strategic alignment on the contribution of enterprise systems investment to business performance. It aims to overcome the two main deficiencies of the previous research on this issue, which have been mentioned in the previous section: use of subjective (perceived) measures of business performance and/or enterprise systems contribution to business performance, and construction of models that do not include all fundamental independent variables.

In this direction our study is based on two objective measures of business performance as basic dependent variables, the value added (=yearly sales revenue minus yearly expenses for buying materials and services) and the labour productivity (=value added per employee), and also on an objective measure of enterprise systems investment. We constructed theoretically sound econometric models for both these business performance measures, which are based on the theory developed in the area of production economics, and in particular on the Cobb-Douglas production function (Nicholson, 2004), and include all fundamental variables. The Cobb-Douglas production function has been successfully used in the past for estimating the contribution to firm output of various firm inputs, including ICT investment (e.g. Brynjolfsson & Hitt, 1996; Stolarick, 1999; OECD, 2003; OECD, 2004). As recommended by this literature we used an extended form of the Cobb-Douglas production function, in which the capital is divided into ICT capital and non-ICT capital:

$$VA = e^{\beta_0} L^{\beta_1} K^{\beta_2} ICK^{\beta_3} \qquad (1)$$

where VA is the yearly firm value added, and L, K and ICK are the yearly labour expenses, the non-ICT capital and the ICT capital respectively, while the $\beta_1 - \beta_3$ are the corresponding output elasticities with respect to these inputs. By log-transforming equation (1) we obtain the following linear model:

$$\ln VA = \beta_0 + \beta_1 \ln(L) + \beta_2 \ln(K) + \beta_3 \ln(ICK) \qquad (2)$$

In order to investigate the effect of enterprise systems strategic alignment on the contribution of the ICT capital to firm value added we added to this model one ‘interaction term’ (Greene, 2003; Gujarati, 2003), which is equal to the product of a ‘strategic alignment factor’ F (=degree of bilateral relationship between the ICT Plan and the Overall Business/Strategy Plan) and the ln(ICK):

$$\ln VA = \beta_0 + \beta_1 \ln(L) + \beta_2 \ln(K) + \beta_3 \ln(ICK) + \beta_4 \ln(ICK) \cdot F \qquad (3)$$

Similar models have been also been constructed for the second business performance measure (dependent variable), the value added per employee, but with all the above independent variables (L, K, ICK) normalised (divided by the number of firm employees N).

For constructing the above econometric models we used data that have been collected through a survey among Greek companies, which has been conducted in cooperation with ICAP, one of the largest business information and consulting companies of Greece. This survey was based on a structured questionnaire, which included questions about the basic financial data of the company (yearly sales revenue, expenses for materials and services, labour expenses, value of capital, value of ICT capital, etc.) and also about enterprise systems strategic alignment. We received completed questionnaires from 281 companies (99 small, 98 medium and 84 large ones) from the 27 most important sectors of Greek economy. Their average yearly sales revenue was 183.7 million Euro and their average number of employees was 493.

Initially for the value added (VA) we estimated the two models of the above equations (2) (basic model) and (3) (model with interaction term) and the results are shown in Tables 1 and 2 respectively.

In the estimated basic model of Table 1 we remark that the coefficients of labour, non-ICT capital and ICT capital are all positive and statistically significant, so we conclude that all these three inputs make a positive contribution to firm value added. These results confirm the conclusion of our previous study (Loukis & Sapounas, 2005), which had been based on a different data set, that ICT investments of Greek companies make a positive and statistically significant contribution to their output, so there is no evidence for ‘ICT Productivity Paradox’ in the Greek context. Also, we can see that the standardised coefficient of the ICT capital is higher than the one of the non-ICT capital, so we can conclude that the investment on enterprise systems contributes to value added

Table 1. Regression model for the impact of labour, non-ICT capital and ICT capital on firm value added

Dependent variable : ln (VA)			
Independent variable	Coefficient	Standardized Coefficient	Significance
constant	2.313		0.000
ln (L)	0.608	0.581	0.000
ln (K)	0.122	0.140	0.002
ln (ICK)	0.235	0.233	0.000
R-squared : 0.723			

Table 2. Regression model for the impact of labour, non-ICT capital, ICT capital and interaction between ICT capital and strategic alignment factor on firm value added

Dependent variable : ln (VA)			
Independent variable	Coefficient	Standardized Coefficient	Significance
constant	2.739		0.000
ln (L)	0.607	0.580	0.000
ln (K)	0.122	0.128	0.004
ln (ICK)	0.196	0.195	0.000
ln(ICT)* STR_ALIGN	0.113	0.112	0.003
R-squared : 0.733			

more than the investment on ‘traditional capital’. In the model of Table 2 we can see that the coefficients of labour, non-ICT capital and ICT capital remain all positive and statistically significant, and that the coefficient of the interaction term is positive and statistically significant as well and also of considerable magnitude; therefore it is concluded the strategic alignment of enterprise systems increases considerably their contribution to value added.

Next we estimated similar models for the labour productivity (=VA/N), but with all the independent variables divided by the number of firm employees N, and the results are shown in Tables 3 (basic model) and 4 (model with interaction term) respectively.

In the model of Table 3 we can see that the coefficients of normalised labour, non-ICT capital and ICT capital are all positive and statistically significant, so we conclude that all these three inputs make a positive contribution to labour productivity as well. The comparison of their standardised coefficient leads to a conclusion similar to the one drawn from the model of Table 1: the investment per employee on enterprise systems contributes to labour productivity more than the investment per employee on ‘traditional capital’. Finally from the model of Table 4 we can see that the coefficients of normalised labour, non-ICT capital and ICT capital remain all positive and statistically significant and also that the coefficient of the interaction term is positive, statistically significant and also of considerable magnitude; therefore it is concluded that the strategic alignment of enterprise systems increases considerably their contribution to labour productivity.

Table 3. Regression model for the impact of normalised labour, non-ICT capital and ICT capital on labour productivity

Dependent variable : ln (LP=VA/N)			
Independent variable	Coefficient	Standardized Coefficient	Significance
constant	3.194		0.000
ln (L/N)	0.551	0.495	0.000
ln (K/N)	0.097	0.126	0.018
ln (ICK/N)	0.201	0.208	0.000
R-squared : 0.376			

Table 4. Regression model for the impact of normalised labour, non-ICT capital, ICT capital and interaction between normalised ICT capital and strategic alignment factor on labour productivity

Dependent variable : ln (LP=VA/N)			
Independent variable	Coefficient	Standardized Coefficient	Significance
constant	3.339		0.000
ln (L/N)	0.551	0.494	0.000
ln (K/N)	0.088	0.113	0.030
ln (CK/N)	0.170	0.176	0.001
ln (CK/N)*STR_ALIGN	0.101	0.151	0.004
R-squared : 0.398			

In conclusion, this empirical investigation contributes to the third of the research streams mentioned in the third section of this chapter and provides sound evidence that the strategic alignment of enterprise systems increases considerably their contribution to both these objective measures of business performance (value added and labour productivity). This evidence is theoretically sound and reliable, since it has been produced based on the construction of econometric models including all fundamental variables founded on the production economics theory (Cobb-Douglas production function), and also using objective measures of business performance and enterprise systems investment. Further research is in progress by the authors for investigating the impact of various types of enterprise systems strategic alignment at different hierarchical levels on the contribution of enterprise systems to business performance, and also on its dependence from various external and internal environment factors.

CONCLUSION AND FUTURE TRENDS

This chapter dealt with the alignment of enterprise systems with business strategy and its impact on the business value that enterprise systems generate. The research that has been conducted on the strategic potential of ICT (reviewed in the second section of this chapter), has generated considerable theoretical support and empirical evidence that ICT can provide (usually in combination with other enterprise resources) competitive advantages, which under specific conditions can be sustainable. This strategic potential of ICT has given rise to considerable research in the last twenty years concerning the strategic alignment of enterprise systems. This research (reviewed in the third section of this chapter) has produced a basic body of knowledge concerning various dimensions of the strategic alignment of enterprise systems, which can be quite useful for both researchers and practitioners in the area of enterprise systems. In particular, it has produced a basic conceptualization and understanding of enterprise systems strategic alignment, and some first 'high-level' models/frameworks for directing and assessing enterprise systems strategic alignment; also it has been produced some first evidence of a positive contribution of enterprise systems strategic alignment to business performance.

However, further research is required in this area and also further practical exploitation by practitioners of the knowledge produced in this research. In particular, further research should be conducted first concerning the strategic potential of ICT and ways of exploiting them strategically in enterprises and combining them with other enterprise resources for achieving sustainable ICT-based competitive advantages. Also, further research is required for understanding better and in more depth the basic processes, barriers, critical success factors and benefits of enterprise systems strategic alignment, and for developing practically applicable models/frameworks, which can offer clear and complete guidance for directing and assessing the strategic alignment of enterprise systems. Finally, extensive research should be conducted concerning the 'value' generated by the strategic alignment of enterprise systems, in order to understand better the contribution of different types of strategic alignment of enterprise systems at different hierarchical levels to various dimensions of business performance; this research, in order to give reliable and practically useful results, and also to allow meaningful comparisons between different types of strategic alignment applied in different in various sectoral, national and cultural contexts, etc., should be based on objective business performance measures and also on sound theoretical foundations from the domain of production economics, such as the Cobb-Douglas production function. In the fourth section of this chapter is described an empirical investigation conducted by the authors that follows these principles, as a guidance for future research on this topic. Also it is necessary to investigate the dependence of the value generated by strategic alignment of the enterprise systems from various external and internal environment factors (e.g. business strategy, competition, etc.) and to identify its main moderators.

At the same time it is highly important that this knowledge on the basic concepts, methods and value of enterprise systems strategic alignment be practically exploited to a larger extent and be incorporated much more in the practice and processes of enterprises.

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KEY TERMS

Business/Strategy Plan: A document describing the mission, goals, competitive strategy, future directions and action plan of the enterprise, which are based on the analysis of its external environment (e.g. competition, opportunities, threats) and its internal environment (e.g. resources, capabilities, strengths, weaknesses).

Cobb-Douglas Production Function: A particular widely used form of production function, which posits that firm output in a particular time period is an exponential function of the capital and the labour employed in this period.

Enterprise Systems Plan: A document with the capabilities, strengths and weaknesses of existing enterprise systems, the forms and the extent of information and communication technologies (ICT) usage in the industry, the capabilities offered by existing and emerging ICTs that may interest and influence the enterprise and also the planned enterprise systems.

ICT Strategic Potential: Capability of ICT to provide valuable competitive advantages and make a significant strategic impact on the enterprise, if properly exploited.

Information Systems Strategic Alignment: The extent to which business strategies are enabled, supported and stimulated by information strategies

Production Function: A function that connects the output produced by an enterprise during a particular time period (dependent variable) with the quantities of the inputs it has used in the same period (independent variables).

Strategic Alignment Maturity Model: A model that aims at assisting technical and business management in assessing the level of enterprise systems strategic alignment in their organization, based on a number of proposed criteria/sub-criteria.

Strategic Alignment Model: A model that aims at directing and assisting strategic alignment in an organization by proposing and describing required steps.

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Chapter 1.5

Behavioral Factors and Information Technology Infrastructure Considerations in Strategic Alliance Development

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ABSTRACT

Since behavioral and cultural factors play a major role in strategic alliances between partners, IT managers must understand the intricacies involved in the development of resultant IT infrastructure in satisfying both business requirements and cultural fit of the aligned partnering units. This paper first highlights the IT-related issues and cultural issues which are important in the process of developing a strategic alliance between partners. Then, a case study involving a major telecommunications organization and several retail electricity organizations is presented to illustrate the IT requirements and human-related considerations. The analysis focuses on the requirements of pre-strategic alliance phase of the negotiation process.

INTRODUCTION

Information technologies (IT) such as the Internet, WWW, EDI, and so forth, have already changed, and are still changing, the way organizations do business today (Housel & Skopec, 2001; Mandal & Gunasekaran, 2003). Significant movement that has occurred relatively recently is the push toward worldwide and national integration of information systems (Dutta, Lanvin, & Paua, 2003; Kumar & van Hillegersberg, 2000; Laughlin, 1999; Palaniswamy & Tyler, 2000; Shore 1996) for organizations to achieve competitive advantages. Since it has become critical for businesses to be able to get to relevant data and information quickly and easily, large information systems such as enterprise resource planning (ERP) systems, supply chain management (SCM), enterprise resource/relationship management (ERM), enterprise application integration (EAI), Web services, and customer relationship management (CRM), have recently grown in importance.

Large information systems are helping organizations to deal with increasing competition. Many organizations can no longer compete effectively by themselves; so, they must consider having partners to cope with the competition. The number of strategic alliances formed between organizations has increased dramatically and are projected to continue to increase in the future. Strategic alliances are a mutual agreement between two or more independent firms to serve a common strategic (business) objective (Bronder & Pritzel, 1992). Alliances have had a growth rate of 25% and are projected to have a value of $40 trillion by the year 2004 (Parise & Sasson, 2002). The "make versus buy" decision is becoming the "make versus buy versus partner decision". Through empirical analysis, Yasuda (2005) shows that the primary motivation of strategic alliances is the access to resources, followed by the shortening of time required for development or marketing.

A successful alliance should not imply an imposition of one organization's culture over another. Rather, it should create a new culture that brings together the best elements of each. Unfortunately, "creation of a new culture" is rarely practiced as alliances are often viewed solely from a financial perspective, leaving the human resource issues as something to be dealt with later and without a great deal of effort. The creation of a new culture involves operations, sales, human resources management, technology, and structure among other issues. It is undoubtedly expensive and time consuming to create a new culture, but, in the end, employees become contented and productive.

For an organization to exploit the benefits of alliances, human factors and information technology (IT) factors must be among the basic components for any analyses and plans. Yet, the literature is poor in this regard. Evidences of failure in the implementation of IT systems due to the lack of considerations of human factors have come to light in recent years, but a comprehensive consideration of human factors in strategic alliance, which is prompted by the possibility of major IT systems alignment, is still rare in IT literature. The main objective of this paper is to highlight the human-related issues in IT-centered strategic alliances. We focus specifically to human-related considerations before the actual negotiations for an alliance and its implementation.

To facilitate the discussion, we have used the case of a telecommunication (TEL) company. TEL identified a new market opportunity as a result of changed market conditions. The company is in the traditional business of telecommunications and information services, but identified a new market opportunity in the retail electricity distribution business that became apparent as a result of market deregulation in the electricity industry. The deregulation of the electricity industry presented TEL with a diversification opportunity. Should TEL enter into an electricity retailing business, or concentrate on its existing communications business, which is increasingly becoming more competitive? TEL's own strength in IT areas, its strong market position, and the opportunities in forming alliances with other business partners in the electricity industry are the main considerations for this strategic move.

The paper is organized in several sections: starting with a brief review of IT and strategic alliance. Cultural aspects in alliances and IT issues in alliances are discussed in the next two sections. The research methodology is presented next. This is followed by a short description of the case study. The cultural issues raised in this case study are discussed before the discussion section.

ISSUES IN STRATEGIC ALLIANCE

Strategic alliance focuses on combining resources of various organizations through acquisition, joint venture, or contracts. The main purpose of an alliance is to create one or more advantages such as product integration, product distribution, or product extension (Pearlson, 2001). Strategic alliances also help in utilization of resources even in small organizations (Gunasekaran & Ngai, 2003). In alliances, information resources of different organizations require coordination over extended periods of time.

Bronder and Pritzl (1992) suggest a strategic alliance exists when the value chain between at least two organizations (with compatible goals) are combined for the purpose of sustaining and/or achieving significant competitive advantage. Four critical phases of strategic alliance are: strategic decision for an alliance, alliance configuration, partner selection, and alliance management. These four phases provide basis for a continuous development and review of the strategic alliance, which increases the likelihood of the venture's success.

Typically, the first phase of a strategic alliance is the strategic decision. Phase I answers the question: Is this strategic alliance justified? Phase II (Configuration of a Strategic Alliance) focuses on setting-up the alliance's structure. Phase III (Partner Selection) is one of the most important success factors of the strategic alliance. Considerations such as fundamental fit (do the company's activities and expertise complement each other in a way that increases value potential?), strategic fit (do strategic goal structures match?), and cultural fit (is there a readiness to accept the geographically and internally grown culture of the partners?) are some of the concerns in this phase. The final phase, Phase IV, is concerned with managing a strategic alliance; how do partners continually manage, evaluate, and negotiate within the alliance to increase the odds of continued success?

According to Currie (2000), there are three major forces that are influencing the formation of alliances between organizations: globalization, deregulation, and consolidation. But, before organizations commit to strategic alliance, they should have a management plan on how to deal with human behavior aspects of the new organizational unit. Once a strategic alliance is a "done deal", the organizations must manage the alliance. Parise and Sasson (2002) discuss the knowledge management practices organizations should follow when dealing with a strategic alliance. They break the creation of a strategic alliance down in to three major phases:

- *Find* — making alliance strategy decisions and screening and selecting potential partners.
- *Design* — structuring and negotiating an agreement with the partners.
- *Manage* — organizations should develop an effective working environment with the partner to facilitate the completion of the actual work. This phase includes collecting data relating to performance and feedback from both partners on how they think the alliance might is progressing. Managing relationships and maintaining trust are particularly critical during the Manage Phase.

Knowledge management techniques are especially important for a successful alliance (Parise & Sasson, 2002). They discuss the need to develop a systematic approach for capturing, codifying, and sharing information and knowledge, a focus on building social capital to enable collaboration among people and communities, an emphasis on learning and training, and a priority on leveraging knowledge and expertise in work practices. They also state their study indicates easy access to information and knowledge is a recurring theme in successful alliances.

Parise and Sasson (2002) provide a list of the building blocks of alliance management. Four of their building blocks relating specifically to human behavior factors are:

- *Social capital.* Building trust and effective communication with the partner are necessary ingredients for an effective relationship.
- *Communities.* Communities of practice allow for the sharing of personal and experiences and tacit knowledge based on a common interest or practice. Communities can be realized using electronic meeting rooms and forums or more formal alliance committees.
- *Training.* Companies that rely heavily on strategic alliances should have formal training for managers and team members.
- *Formal processes and programs.* Alliance know-how should be institutionalized. An example of this is Eli Lilly, a leading pharmaceutical firm, created a dedicated organization, called the Office of Alliance Management, responsible for alliance management.

Company's that use alliance management techniques that stress knowledge management are more successful than those who do not. Leveraging knowledge management across a company's strategic alliance is a critical success factor for partnering companies. Strategic alliance is a management issue. Both cultural and information technology aspects play a significant role in strategic alliance, which is the topic of discussion in the next two sections.

CULTURAL ASPECTS IN ALLIANCES

As discussed in the preceding sections, alliance among firms naturally would result in many organizational changes. Leavitt (1965) concluded there are four types of interacting variables to consider when dealing with organizational change, especially in large industrial organizations: task variables, structural variables, technological variables, and human variables. He proposed structural, technological, and people approaches to organizational changes, which derive from interactions among the four types of variables mentioned earlier.

The earlier-mentioned four variables are highly interdependent so that a change in any one variable usually results in compensatory changes in other variables. The introduction of new technological tools — computers, for example — may cause changes in structure (communication system), changes in people (their skills and attitudes), and changes in performance and tasks. Therefore, it is imperative to consider all areas that might be affected when a company plans to introduce change to an organization.

Pre-existing, people-related problems at a target company often cause many alliances to fail to reach their full financial and strategic potential. Numerous case studies report failure of alliances due to lack of consideration for the potential impact of behavioral and structural aspects (Brower, 2001; Numerof & Abrams, 2000). To build an effective alliance, institutions must pay particularly close attention to cultural, personality, and structural incompatibilities. Leaders from alliance institutions need to recognize the personality differences in their managers as well as the demands required by the life cycle stage of their organizations (Segil, 2000). It has also been demonstrated that successful alliance partners share many strong similarities regarding performance and relationships (e.g., people skills) (Whipple & Frankel, 2000). Understanding potential incompatibilities gives institutions contemplating alliances a solid foundation on which to explore the feasibility of joint projects. It also increases the likelihood that the alliance will operate successfully (Whipple & Frankel, 2000).

Successful alliances are impeded when the culture of one or both associations highly differ in value. "High control value" is inconsistent with the toleration for ambiguity and the "willingness to compromise" often required for strategic alliances.

Maron and VanBremen (1999) suggests the use of William Bridges' Organizational Character Index (OCI), which can be a useful tool for analyzing the cultural differences between two associations to determine how well they might work together. It promotes better understanding between two associations; fosters an appreciation for what both partners could bring to an alliance; and identifies underdeveloped qualities in both associations that could inhibit the success of an alliance.

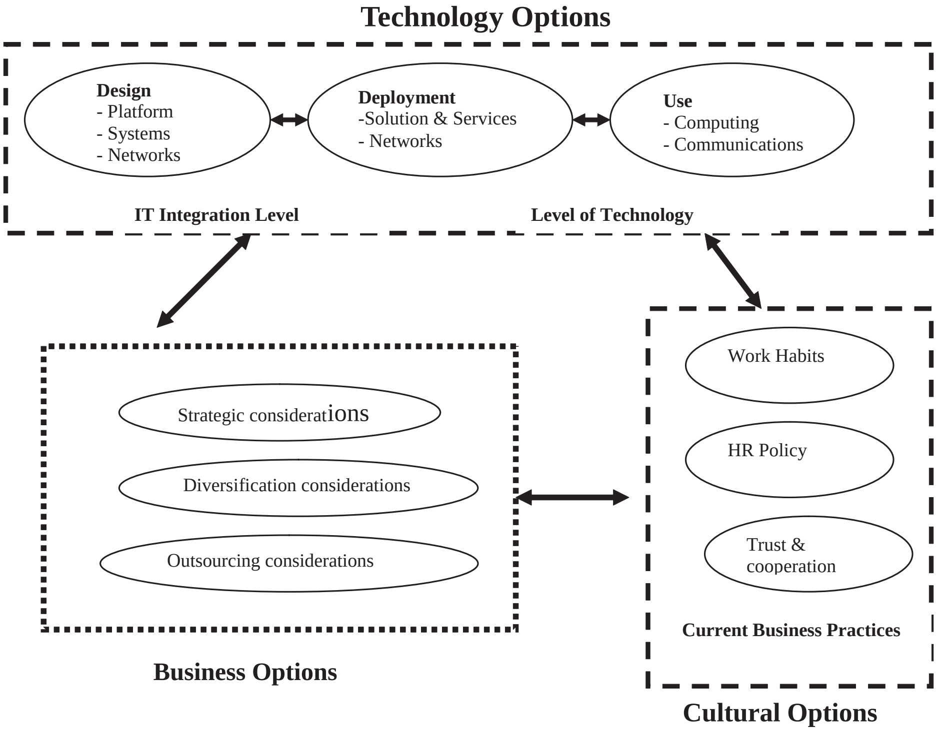
IT ISSUES IN ALLIANCES

Long-term IT considerations, such as IT architecture, is a major consideration. A strategic consideration, such as new alliances, would require visioning of a different IT architecture. Applegate, McFarlan, and McKenney (1999) view IT architecture as an overall picture of the range of technical options as well as business options.

> *Just as the blueprint of a building's architecture indicates not only the structure's design but how everything — from plumbing and heating systems, to the flow of traffic within the building — fits and works together, the blueprint of a firm's IT architecture defines the technical computing, information management, and communications platform.* (p. 209)

Figure 1 brings out the dynamic nature of the IT architecture development process. The technology part, shown by dotted oval, is concerned with design, deployment, and how it is used. This part is the core of IT architecture and a huge proportion of IT professionals' time is devoted to these activities. Consideration of business options, which feed to various technology options, are higher level activities in the IT architecture development process. Business options, such as strategic alliances, mergers and acquisitions, outsourcing, diversification, and so forth, are

Figure 1. Forces affecting overall IT architecture



influenced by major internal as well as external factors, such as current business practices, business opportunities, and organizational strategy. There is a direct link between technology and organizational strategy. The technology (with its operational and technical settings) exerts a strong influence on the organization's future strategic direction. Thus, one can observe (as shown in Figure 1 through connecting lines), a close link between technical and other business factors, and, like ever-changing business, the IT architecture is a dynamically evolving phenomena.

An alliance can exist between any types of organization. For example, a telecommunication organization could form an alliance for international joint ventures, or an alliance can be established between a banking organization and an IT supplier. The notion of developing a strategic alliance suggests an organization's performance can be significantly improved through joint, mutually dependent action. For a strategic alliance to be successful, business partners must follow a structured approach to developing their alliances and should include as part of this process, strategic planning, communication, efficient and effective decision-making, performance evaluation, relationship structure, and education and training.

Strategists have often suggested that organizations should consider entering into similar or somewhat-related markets sectors to broaden their product/service portfolios (Henderson & Clark, 1990; Markides & Williamson, 1997). Both the dimensions of market (customer and product) in a related market can easily be identified and strategies formulated for deployment. The main advantage of adopting such a strategy is that an organization can easily use its competencies and strategic assets in generating a strategic competitive advantage (Markides & Williamson, 1997). Determining the design and the requirements of a new information system (IS) is a relatively simple task. In contrast, diversification into a significantly different market for an IT/IS organization is a very challenging task, which needs considerable evaluation of IT infrastructure and human relations.

RESEARCH METHODOLOGY

The focus of this research has been to understand the complexities that may arise in an alliance, particularly when an ICT organization *moves away from its traditional business activity arena*. From practitioners' point of view, this research aims to provide guidance in four avenues while an organization is negotiating various terms and conditions of strategic alliance with partners:

1. to define the new environment for the organization and its partners;
2. to highlight the complexity and complementarities in the alliance;
3. to provide details of technical strengths and limitations for the new situation; and
4. to provide an assessment of human-related strengths and limitations for the new situation.

There has been limited published research that has examined the pre-strategic alliance structures, particularly in the telecommunications industry. Thus, a case study approach was used to gain an in-depth understanding about the way in which the organizations went about examining the strategic alliance structure. A case study is basically a "methodology based on interviews, which are used to investigate technical aspects of a contemporary phenomenon with its real life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used" (Yin, 1994). Thus, a case study approach may lead to a more informed basis for theory development. It can provide analytical rather than pure statistical generalizations. Thus, "theory" can be defined as a set concepts and generalizations.

A theory can provide a perspective and a way of seeing an interpretation, which ultimately leads to understanding some phenomenon (Benbasat, Goldstein, & Mead, 1987). In this case, the technical and human factors that need to be considered when forming a strategic alliance.

Interviews were conducted with CEOs of electricity operating agencies and market regulating organizations. IT managers in some of these organizations were also contacted to get an appreciation of how transactions and information flows take place within the electricity industry. The duration of each interview was approximately 40 minutes, where every interview was conducted on a one-to-one basis, so as to stimulate conversation and breakdown any barriers that may have existed between the interviewer and interviewee.

Information for this research was also collected from various sources such as government publications, industry reports, trade publications and informal/formal discussions with industry experts. WWW and the Internet were also a good source of information.

THE CASE STUDY

The telecommunication organization (TEL) provides services to its customers through its own telecommunications network and would like to improve its customer base by forming a strategic alliance with the retail electricity distribution organizations. TEL is a Fortune 500 company with annual revenue over $14.5 billion. TEL provides a full range of services in telecommunication markets to more than 10 million fixed line and 6 million mobile subscribers. Many experts believe that a handful of global power companies will soon provide the majority of the world's energy needs (Brower, 2001), and TEL aspires to be one among them. As large telecommunication organizations exhibit structural inertia, generating a competitive advantage in a new market poses an enormous challenge (Henderson & Clark, 1990). An organization must make a distinction between a new product and the means to achieve that new product. The recent merger between America Online and Warner Publishing clearly demonstrates that it is not too difficult for an IT organization to offer new products in an existing market. Considering this point, strategic alliances and partnership could be a way out for an IT organization to enter into a completely new product market. From a systems development perspective, alliances may result in the development of new interfaces to the existing ISs or alternatively a new integrated IS.

As per the deregulation rules, a retail distributor must make financial settlement with other suppliers of the electricity industry supply chain. This needs to cover the cost of electricity from the wholesale electricity market, tariffs for distribution of the same by the transmission and distribution service providers, and meter data collection from meter providers (MPs) and meter data agents (MDAs). The processes and systems therein must be able to interface with retail energy distributors accounting and billing, service activation, and service assurance processes and systems.

To conduct business as a market participant TEL must purchase wholesale electricity and services for the physical delivery and metering to the customer. There are two clear options available to TEL to purchase electricity:

- By *direct participation* and trading in the national electricity market (NEM). This means that TEL would perform all electricity trader functions, including the act to bid and settle wholesale purchases in the national electricity market from its own resources and carry all market and prudential risks and responsibilities.
- By *engaging an existing specialist energy trader.* This means that TEL would form a close and long-term relationship with one (or more) existing trader(s) who would operate all market trader functions and processes on

> TEL's behalf. This would be an outsourced supply arrangement. The sharing of risk and responsibilities is a matter for specific agreement with the trader.

The management of TEL must first realize the complexity and limitations of the IT infrastructure before they venture into the new business. TEL follows a standard procedure called PDOM (product development operational model) for any IT product development and this procedure was also applied in developing its IT architecture design. PDOM is very similar to standard SDLC (systems development life cycle).

Figure 2. Relationships between TEL and third parties

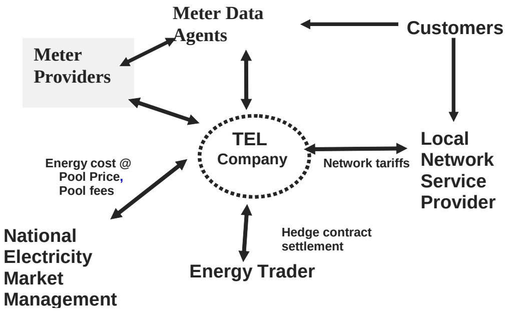


Figure 2 shows the relationship between TEL and third parties that it must reconcile.

Reconciliation with these third parties is critical to ensure that the following items are accurate for customers: charges, dates (i.e., customer's start and end dates), rates, services received, usage, and loss factors. Reconciliation is also necessary to ensure that payments are settled for the correct dollar amount and are on time. The third parties with whom TEL will be required to settle with are NEMMCO (National Electricity Market Management Company), LNSPs (local network service provider), MDAs, MPs, energy traders, and other retailers.

For the proposed alliance to become effective, TEL will be required to develop a number of third party relations with electricity retailers. These relationships are shown in Table 1.

To forge a meaningful alliance TEL would be required to make a number of major business decisions, which would influence the overall IT architecture. These decisions would form the core of the IT system and partnership relations and are presented in Table 2.

Table 1. Electricity retailers and third party relationships

Retailers	**Relationships**
Electricity sourcing	TEL will need to contract energy traders to purchase electricity in the national electricity market. TEL will be required to settle periodically with these organizations for services rendered.
NEMMCO	Tel will be required to settle periodically with National Electricity Market Management Company (NEMMCO) for wholesale electricity purchases. NEMMCO will provide billing reconciliation data.
MDA	TEL will contract with NEMMCO accredited MDAs for the collection and provision of customer electricity usage data for billing purposes. TEL will be required to settle periodically with MDAs for services rendered
MP	TEL, as an RP, will have a relationship with MPs in the provision and maintenance of meter installations, and TEL will be required to settle periodically for services rendered
LNSP	TEL will enter into service agreements with each local network service provider (LNSP) for the use of their distribution network and for the connection and supply of electricity. TEL will be required to settle periodically with LNSPs in terms of distribution fees for network use.
NEMMCO and State Regulators	TEL will pay fees to NEMMCO and state regulators for operating licences and other regulatory charges
Generators	TEL may contract with generators (outside of the spot market) for long-term energy requirements.
TEL Partner sales commissions	TEL could potentially enter into sales partnerships and pay appropriate commissions.

Table 2. Major business decisions TEL must make

Decision
TEL will require a customer-signed application form before the retail transfer process can commence.
TEL will not enter into and conduct a customer transfer under the BETS process.
The company will negotiate contracts with a LNSP, which will ensure that LNSPs will connect customers to their network at a customer-nominated date and time or within a reasonable time. Noteworthy each LNSP will perform service location work for the electricity connection.
TEL will appoint only registered to read meters at agreed customer start date and times.
An MP will install and remove electricity meters only with company's written instructions.
Each LNSP is responsible for fault rectification and maintenance of their electricity distribution network in their local area. TEL will hand off to the appropriate LNSP for fault calls made to TEL. TEL will pay the relevant service fee, but if the customer is culpable for the fault, the onus will be on the LNSP to recover costs.
MDAs are to provide all customer electricity usage to the retailer for billing purposes, typically daily overnight for smart meters. MDAs will employ manual meter readers to read SIMs at a minimum interval of monthly regardless of the billing cycle.
TEL will settle with MDAs, LNSPs, MPs, energy traders and the pool for electricity energy cost of goods sold.
TEL must provide energy forecasts to energy traders so they can determine the amount of energy to hedge.

If these alliances are to eventuate, the existing processes and systems will be used to generate reports to partner sales and commissions. TEL would be required to provide a lot of technical support to potential strategic partners, since partners in the electricity retail business in general do not have well-developed information systems. In fact, most electricity retailers had manual settlement systems. This would be a serious limitation to full-scale system integration.

CULTURAL FIT BETWEEN TEL AND ITS PARTNERS

Table 3 shows that there are significant differences between TEL and the other partners. A strategic alliance in this situation would require a careful evaluation of the strengths and weaknesses of each firm, and detailed planning of what the reorganized alliance would look like. The IT architectural planning would not only present the overview of future challenges, but would also provide the chief information officers (CIOs) a summary of the nature of human-related activities they would be faced with once the alliance became a reality.

Before companies agree to participate in the strategic alliance, they should first determine if their organizations can work together harmoniously. To determine whether they can work well together, each company should attempt to determine what type of organization it is, that is, does an organization have a certain personality

Table 3. Structural and behavioral differences

Factors	TEL	Partners
Company organizational structure/size	Very complex and large in sales volume (Annual revenue $14.5 billion, Assets $24.9 billion)	Small to medium size, relatively simple structure (revenue in the order of million $)
Employee work habit	Flexible work hours	Relatively rigid work hours
Customer relations	Good relations with existing customers — excellent customer services	Indifferent to customer complaints
Employee training	Good opportunity for skill upgrading (formal training department)	Reasonable opportunity to technical skill development
IT system compatibility	Highly developed IT system	Manual or primitive IT systems
Employee satisfaction	Highly motivated, well paid work force.	Competent, but low paid work force.
Employee turn over	High turn over	Relatively low employee turnover.

or culture? As shown in Table 3, both TEL and its partners exhibit a different cultural setting, this suggests the need for further investigation to make the proposed alliance effective.

The cultural differences between TEL and potential industry partners are so high, as evident from Table 3, that one might suggest the proposed alliance is a recipe for disaster. Unless there is a higher authority to ensure compliance, this alliance is likely to head for a failure. The perception of relational risks plays a dominant role in strategic alliance. As uncertainty regarding partner's future behavior and the presence/absence of a higher authority to ensure compliance dominate strategic alliance considerations, it seems to be that the relational risks are very high in this case. Delerue (2004) suggests that informal contextual factors have more influence on relational risks than the formal contextual factors.

There are three important reasons related to human behavior factors that might lead to partnership failure in this situation. The reasons are (as per Dixon & Marks, 1999): *inattention to the human resources issues; failure to plan for other human resources issues such as benefits, loyalty, identity, etc.; and poor communication*. In addition, it would be necessary to build a new culture and learning environment.

DISCUSSION AND FUTURE SCOPE

In today's competitive business environment, new methods of evolution from independence to interdependence are continuing to unfold; strategic alliance is one of those methods that can be used to achieve competitive advantage. In the process of developing a strategic alliance, IT infrastructure and human factors play important roles. In addition to considering the projected information systems the organization will require, information officers should focus on the human factors of its organization to increase the odds that an alliance will be successful. IT planning highlights major weaknesses and incompatibilities with information systems of various parties within an organization. Those incompatibilities, however, can intensify further due to operational and work practices in partner organizations. The development of an IT system and the serious consideration of human issues would lead to practical improvements in the way most organizations approach strategic alliance development planning.

As further enhancement in analysis of human-related issues, the author advocates the deployment of organizational character index (OCI) tool (Bridges, 1992), mentioned earlier in the paper. To determine whether partners should work together on possible strategic alliances, the American Society of Clinical Pathologists (ASCP) and the College of American Pathologists (CAP) suggest the use of the OCI tool (Maron & VanBremen, 1999). Bridges (1992) explains how OCI can be used to categorize organizations, similar to the way the Myers-Briggs Type Indicator describes the characteristics of the individual. OCI, a public domain tool, consists of a written questionnaire that takes 10 to 15 minutes to complete. Bridges stresses that there are not right or wrong types of organizations; it merely brings out organizational personalities. OCI categorizes organizations for the following types (Maron & VanBremen, 1999):

- its orientation or source of energy (extroverted or introverted);
- how it gathers information or what it pays attention to (sensing or intuitive);
- its way of processing information, how it judges situations, and how it makes decisions (thinking or feeling); and
- how it deals with the external world (judging or perceiving).

The OCI tool was most useful in its ability to stimulate constructive discussions about the two company's cultural differences. Using the OCI tool, ASCP and CAP accomplished the following objectives:

- it promoted better understanding between the two associations;
- fostered an appreciation for what both partners could bring to an alliance; and
- identified "underdeveloped" qualities in both associations that could inhibit the success of an alliance.

The OCI provides valuable insights into difficulties organizations with certain characteristics might face in a joint venture such as a strategic alliance. It also highlights the underdeveloped qualities of an organization. These qualities might then be improved. Improving on the qualities can increase the likelihood that a joint venture will be successful.

Maron and VanBremen (1999) stress that the "OCI is not a definitive diagnostic tool. It is best used as a way to stimulate discussion, largely because it helps potential partners better understand and articulate their own, and each other's values and expectations." To use the OCI tool, the following set of simple steps could be followed:

- Administer the OCI questionnaire.
- Tabulate the responses.
- Use the results as the basis for discussion by volunteer leadership and staff.

The OCI could assist the organizations in determining whether their organizational cultures might work well together, but there are other human factors to consider. Burrows (2000) stresses the importance of understanding the "people situation at the target company," if a successful long-term relationship is to result. Burrows (2000) argues that most companies misunderstand or ignore "pre-existing people problems", and once the joint ventures are created, man problems reveal themselves, which undermine value-creation opportunities, jeopardize relationships with customers, and reduce productivity.

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Chapter 1.6

Developing and Analyzing Core Competencies for Alignment with Strategy

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ABSTRACT

Although it is widely accepted that alignment of knowledge with corporate strategy is necessary, to date there have been few clear statements on what a knowledge strategy looks like and how it may be practically implemented. We argue that current methods and techniques to accomplish this alignment are severely limited, showing no clear description on how the alignment can be achieved. Core competencies, embodying an organisation's practical know-how, are also rarely linked explicitly to actionable knowledge strategy. Viewing knowledge embedded in core competencies as a strategic asset, the paper uses a case study to show how a company's core competencies were articulated and verified for either inclusion or exclusion in the strategy. The study is representative of similar studies carried out across a range of organisations using a novel and practically proven method. This method, StratAchieve, was used here in a client situation to show how the core competencies were identified and tested for incorporation or not in the strategy. The paper concludes by considering the value of the approach for managing knowledge.

INTRODUCTION

Many companies have developed or adopted various knowledge management (KM) initiatives to try to surface and differentiate what they do know from what they need to know and also to identify the location of their knowledge gaps. Processes and tools that support efforts to capture knowledge are well known and widely used, such as expertise directories, intranets, communities of practice, knowledge audits, discussion forums, knowledge maps, building and documenting knowledge based and expert systems, storytelling, benchmarking, and the like. These efforts serve the strategy functions of organisations, aligning capability and know-how with strategic objectives.

Although the importance of strategic alignment is recognised, what is less understood is the practical means to determine what knowledge is strategically important and how this knowledge can be incorporated into the corporate strategy. Zack (1999) for example suggests that companies may have unique ways of doing this, (itself a competitive advantage) using techniques such as SWOT analysis. Zack's work, while providing a framework and some high-level questions, is light on actionable detail, and is silent on how the output of such efforts can be strategically assessed with sufficient reach to be implemented. The available literature on knowledge strategy alignment is generally very limited: although many documents refer to these issues, few go beyond noting the desirability of alignment, and even fewer provide any detailed methodological guidance. Few empirical studies appear to exist, and whilst academic comparison across unique cases is not always appropriate, the study reported in this paper describes a generic method that has also been used in several other organisations. The approach described here addresses *what* organisations know, and how it aligns with their wider strategy.

All organisations need to "know what they know" (and know what they don't know) to make strategic decisions on (for example) sourcing, customer satisfaction, recruitment and training, investment, and in identifying areas for process re-engineering, market development, or innovation. The familiar saying, "If only we knew what we know" is, however, flawed because it presumes that what exists as knowledge in organisations is always useful and needs to be formalised and actioned. More appropriate is to say "If only we knew what we need to know". This means that organisations must also know what they no longer need to know because it no longer has a sufficient impact on the corporate objectives. Similarly, organisations must know what knowledge is most important and determine whether they already have this knowledge or need to acquire it. Apart from the rather limited SWOT analysis, or proprietary methods (e.g., AMERIN, n.d.) that may or may not include tools that help identify knowledge gaps, there are few clear statements on how, in practice, strategy may be structured in actionable alignment with organisational knowledge.

Organisations must structure their strategy so that strategic decisions and actions can be made on a variety of fronts, such as retaining and growing profitable customers, selling the right products to the right market, and recruiting and developing staff. To achieve this, organisations must manage their knowledge effectively to ensure it is directly translatable into strategic actions. Without knowing how to effectively manage their own stock of intellectual capital, such decisions cannot be actioned nor can the company be properly valued[1].

When turnover or loss of key staff is potentially a consequential threat, failure to manage the implicit knowledge assets underpinning this value may be seen as negligent. Intellectual capital is the main source of value creation (Edvinsson & Malone, 1997) and thus strategically linked directly to the organisation's future. In larger organisations especially, formalisation of this activity is required, not only for internal purposes, but also externally, such as shareholder value creation and outperformance of competitors. Identifying, securing and managing the various forms of intellectual capital (human and structural) within an organisation has thus become a central theme for knowledge management research as well as for knowledge valuing and reporting.

KM initiatives typically centre on the personnel who embody and can apply their knowledge in project or other business activity settings, and often entail recording or abstracting from the traces of their contextualised activities. Such KM initiatives implicitly recognise the centrality of the competencies of individuals and groups in transacting the strategic aims of the organisation at operational levels, and in potentially identifying the specific knowledge and abilities that give comparative advantages. Rarely, however, are such initiatives directly linked to corporate strategy and are (often inappropriately) typically designed and implemented through the organisation's IT support function (Berkman, 2001). A focus on the competencies related to strategic objectives and alignment with operational competencies is vital and is addressed in the following case study.

If organisations are centrally reliant on their knowledge for their survival, value and prosperity, their knowledge management strategies must be fully congruent with wider corporate strategy. Hackney, Burn, and Dhillon (2000) note, however, that comments on implementing such congruence have been few, and there remains a "prevalent disconnect between (business) and IT strategies". Their analysis of contemporary business strategy implies a reappraisal of the conventional and rational assumptions implicit in strategic IS planning (SISP) and where installing an IT "solution" is insufficient without coherent linkage to business strategy.

Hackney, Burn, and Dhillon (2000) cite research suggesting a necessary relationship between innovation and organisational *competence* and see assessing organisational competencies as a critically relevant challenge for SISP. The terms *competences* and *competencies* are both used in the literature to refer to such organisational abilities: we prefer to use *competencies* in this paper. The knowledge embedded in organisational competencies can be a key strategic asset, and conversely, strategy emerging from inherent capabilities and competencies provides flexibility and responsiveness. Identifying such competencies is prerequisite to their assessment, valuation, and incorporation into strategy. These competencies, which are typically knowledge based, can form the essence of a knowledge strategy embedded within a wider corporate strategy that is not simply cast in terms of KM technologies over some planning period.

A company's core competencies (Prahalad & Hamel, 1990) are the areas in which it has competitive strength and thus form a platform for its strategic thrusts. Not knowing or appreciating these means its strategies may fail and compromise proper valuation of a company's knowledge assets underlying the support, adaptation, and maintenance of its activities. Core competencies are the "cognitive characteristics of an organisation, its know-how…" (Hatten & Rosenthal, 2001, p. 50), that is, an organisation's collective (functional) expertise. Built on the skills and experience of individuals and teams, they are housed in characteristic business functions: examples Hatten and Rosenthal (2001) cite include McDonald's HR competency in recruiting, hiring, training, and retaining part time labour and Intel's technology competency in state of the art design of microprocessor chip families. Although such functions are not necessarily unique to an organisation, the know-how and processes involved in them may well be, thus conferring advantage.

Core competencies are necessarily part of a knowledge strategy which itself is part of the overall strategy. A focus on competencies (which implies active and generative abilities) rather than the knowledge traces itself is preferable, since in times of change, accumulated knowledge may be a hindrance to new thinking: what Leonard-Barton (1995) has called "core rigidities". To give a sustainable strategic advantage, competencies should be valuable, rare, hard to imitate or substitute, and ideally will confer a dominating ability in their area. Bollinger and Smith (2001) view the knowledge resource as a strategic asset, with the "collective organisational knowledge, (rather than that) of mobile individuals", that is the essential asset. This suggests a focal shift towards organisationally understood activity and process, not merely data and record storage requiring leverage by particular individuals for effectiveness.

In the knowledge based view, nicely contrasted with the conventional rational view of strategy by Carlisle (1999) the strategic focus is on value *creation* arising from uniquely effective internal capabilities and competencies, rather than value *appropriation*, which emphasises "optimisation" activity in imperfect markets. Although over time advantages may be eroded, organisations with developed "capabilities for managing knowledge creation and exploiting (its value) are better able to adapt by developing new sustainable core competencies for the future" (Carlisle, 1999, p. 24). Dawson (2000, p. 323) also notes "It is far more useful to think (about developing) dynamic knowledge capabilities than about knowledge as a static asset …to be managed".

The theoretical literature on core competencies does not however generally relate their development to concepts of knowledge management operation, nor to strategy implementation. Nor, although recognising that some competencies are more important than others, does it distinguish strategic from operational core competencies. Although the literature does not imply that strategic competencies arise from operational ones, we find it useful in practice to differentiate these since the only way strategy can be realised is at the operational level, by competent people performing activities that achieve strategic goals. For this to occur, an explicit linkage between strategic goals and operational activity, between strategic core competencies and their implementation (and reciprocally between operational competencies and strategic objectives) must be articulated. This theoretical claim is demonstrated in the present case study.

Since contemporary thinking on strategy emphasises ability to respond to environmental changes quickly at all levels rather than planning in a controlled environment, an embedded knowledge strategy will act as the medium through which these levels can be brought into alignment and allow for emergent strategy to be developed across the organisation.

Klein (1998) asks the question "But how does a firm decide what set of operating-level initiatives would best meet its strategic goals?" and goes on to identify the "challenge of linking strategy with execution at the knowledge level" (p. 3) by a focus on various activities around intellectual capital. As an open research question however, specific implementation guidance is not offered, and associated literature (e.g., Graham & Pizzo, 1996) often notes only generic steps (identify strategic business drivers, determine business critical knowledge characteristics and locations, construct knowledge value chains, and find competency gaps).

Apart from private ownership tools, which may lack academic evaluation or an underlying original research base, there are few existing public domain management tools that offer help in modelling the different aspects a comprehensive knowledge-centric strategy development entails. These candidates include the "enterprise model" (Hatten & Rosenthal, 1999), later renamed the "action alignment (AA) model" and extended in Hatten and Rosenthal (2001); and more recently strategy maps (Kaplan & Norton, 2004). These generally provide broad areas for consideration, but give little or no guidance on strategy development or implementation beyond a flimsy structural outline. For knowledge strategy evaluation in financial terms, the KM valuation methodology of Clare and Detore (2000) applies, but this starts from a developed business strategy or KM project proposal.

The AA (Action Alignment) model is essentially a grid showing classical business functions (e.g., HRM, IT, and so on) crossed with business processes (e.g., order fulfilment) allowing visualisation of core junctures or problem (misaligned) areas, with supplementary tools to assess the fit or otherwise between customers and organisational capabilities and competencies. This appears to be essentially reactionary to the need for cross-functional alignment occasioned by new economy realities, but problematises the issue within an assumed industrial-era organisational structure of functionally defined silos, and without highlighting the knowledge activities required. The AA model has various other serious limitations in a knowledge-based view, in which traditional "Balkanised" organisational structures are considered obsolescent, and not conducive to the strategic planning and development of intangible assets and associated capabilities (Chatzkel, 2000).

The Balanced Scorecard (Kaplan & Norton, 1996) is a widely used performance measurement tool and has evolved since its origination in the early 1990s to more explicitly focus on strategy. Originally it aimed to address aspects of a company's performance not covered in simpler measures oriented primarily to financial performance. A customer perspective, an internal business perspective, an innovation and learning perspective, and a financial perspective provide a set of measures indicating aspects of performance relevant to various stakeholders. The strategy maps and supporting theory outlined in Kaplan and Norton (2004) are however very sketchy and conventional in relation to the knowledge based view — competency is effectively equated with job description (p. 225 et seq), and the references to the concepts of knowledge and KM are very shallowly treated. Furthermore, although the strategy maps show some linkages, the map's theoretical formulation is silent about the detailed linkages between these giving no guidance as to how the knowledge embodied in them can be identified, related to strategic competencies and leveraged with respect to achieving financially quantifiable targets such as market share, net profit or shareholder value, or other non-financial performance measures. Tools such as Kaplan and Norton's strategy map thus do not explicitly address knowledge-centric strategy development and indeed a series of google searches in mid 2004 yielded few hits relevant to this aspect.

Yet an organisation's ability (or otherwise) to knowledgeably enact and leverage corporate processes and technologies is the essence of strategic competency. In a view of strategy that is not purely top down, but is essentially enacted dynamically by the knowledgeable activity of people in the "middle", it is crucial to reify these competencies in relation to strategy formulation. Current tools do not go far enough in guiding this, nor do they provide explicit methods for systematic engagement at this level.

THE CASE STUDY

Overview

We offer an approach addressing this by using a case study embodying action research techniques, beginning with a brief description of the organisation, its strategic position and the context of the fieldwork. A case study approach has been chosen since contemporary phenomena are being investigated in their real life context, with multiple variables of interest and converging sources of data; where the boundaries between the phenomena and the context are unclear and where the researcher has little control over behavioural events (Yin, 2002). The case study approach allows depth of understanding across many variables to occur. In this research an interpretivist position is adopted in which the organisation's own meanings and their negotiation are prioritised.

The case study reported here is of a UK accountancy company, and entailed the elicitation and reification of its hitherto poorly understood core competencies. The knowledge strategy was developed within a comprehensive corporate strategy overhaul and was built around the knowledge audit of its core competencies embodied in people and processes, supported by relevant technology.

The paper proceeds as follows. Having identified the need to provide detailed guidance on reifying an organisation's core competencies and to relate those effectively to knowledge strategy, we outline processes that address this weakness and show how they can be implemented within more generic strategic planning processes.

We illustrate these in the case study context to show how the organisation systematically identified its core competencies, as well as determining the core competencies that are no longer of strategic importance. In the process, learning that the company not only did not have the strategic competencies it thought it had, but that it had knowledge assets which it had not realised, provided the capability to explicitly incorporate the competencies into the strategy.

The result was an articulation of what the company "knew" as well as what it did not know but needed to know, both strategically and operationally. This enabled the company to consciously leverage its strengths but also identify areas in which it was deficient and therefore strategically vulnerable. The case study concludes by showing how the company had achieved a strong competitive position from which to strategically value its knowledge and other intangible assets in an informed manner for forward planning and reporting to shareholders and others. The detailing of this valuation is part of our ongoing research.

The Organisation

The UK accountancy company featured in this case study is involved in a broad range of financial services to a wide variety of customers, both large and small. For purposes of this paper, the company shall be called Target Accountancy. The company has 56 employees and has been existence since 1987. Staff turnover is low as a result of high loyalty and good conditions of employment.

Target Accountancy had never produced a formal strategy plan but realised it could not achieve the success it wanted without one. The saying "if you don't plan your company's future, it won't have one" was very pertinent in their case. The company possessed a rich abundance of talent but this was tacitly held in the minds of individuals; it wanted to be the formal owner of its capital knowledge. One of the aims of Target Accountancy was to verify whether the competencies it thought it possessed were being successfully engineered to generate the required competitive differentiators. There was thus a strong need to strategically specify and test the impact of its core competencies, to determine which were the most productive and identify gaps where new competencies were required.

The StratAchieve Method

One of us (Sawyer) was the external facilitator. The StratAchieve method[2] was chosen because of its proven capability in over 400 organisations to create and achieve strategies. Other tools currently on the market are geared either for helping to produce a strategy plan or to conduct project management, but not both. StratAchieve produces and combines the two, enabling iteration between the plan and implementation to take place.

The method is supported by software produced by Alpha Omega, which is used throughout the change programme. During a workshop session, a map is projected onto a screen and interactively developed through discussions, suggestions and learning from workshop delegates. An important aspect of the approach is its ability to integrate the various types of organisational strategies, such as customers, financial, HR, marketing, product, IS, and (crucially) knowledge, into a single, coherent corporate strategy.

The method enables organisations to determine, construct, legitimise, and achieve their strategy and conduct monitoring and controlling during implementation and provides the structure for all organisational strategic actions to be integrated. Thus, marketing, HR, finance, IT, and knowledge strategies are all holistically integrated into one coherent and comprehensive strategy. This will become apparent in the examples that follow.

The Strategy Tree provides the theoretical framework of the method (Sawyer, 1990) consisting of four or five layers of verb-fronted activities, logically related through *Why* and *How* connections. These Why and How relations provide a path that simultaneously justifies a given action at a higher level, whilst specifying an operational activity that achieves higher level aims. In discussions any given statement can be explored in either direction. For example rationale for the expressed operational competency "*Keep in regular contact with all clients*" was explored. The next higher-level activity was determined by asking, "why should we *Keep in regular contact with all clients*"? which elicited the response, because we want to "*Maintain excellent personal relationships with our clients*". A further Why interrogation on this activity produced the parent, "*Retain our current clients*" and a further Why activity resulted in the parent "*Increase our revenues*". A final Why activity generated the high-level statement "*Increase our gross margin*" linked directly to strategic mission. In this example, a set of Why interrogations produced the higher-level activities which linked to the pre-set vision (increase our gross margin). Conversely, How statements can be elicited by starting with a high-level aim, and identifying child activities that follow from it, as reversing the previous example shows. Turning a competence into verb-fronted form emphasises a capability focus for knowledge, and leads eventually to activity based costing and specific required operational actions. The software tracking the map thus developed shows what must be done, when, how, why and by whom through specific supporting functions, and aids dynamic strategy construction.

Workshop Preparation

The process was initiated through a one-day workshop, attended by all senior members of Target Accountancy together with a range of staff from a variety of departments.

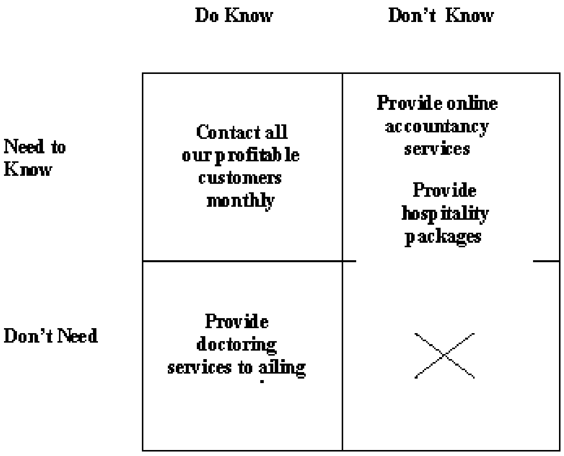
The Knowledge Positioning Matrix (KPM)

The KPM was developed to accommodate the core competency dimensions, as shown in Figure 1. The four quadrants provide a means for noting the knowledge that is strategically needed, and is already known; the knowledge that is required, but is not known; knowledge that is known, but not strategically required; and gaps in knowledge that do not bear on strategy anyway. Target Accountancy wanted to know whether its current set of core competencies were sufficiently robust to maximise their competitive performance. The company thus wanted to know what it *needed* to know (i.e., if only we knew what we needed to know) as opposed to the familiar saying "if only we knew what we know", to identify gaps in required knowledge, and to identify areas of knowledge that were no longer required. In other words, the company wanted to know which core competencies should be modified, deleted and created.

The StratAchieve Structure

The method naturally provides the structure and operations for the Knowledge Positioning Matrix.

Figure 1. The Knowledge Positioning Matrix showing examples from the workshop



	Do Know	**Don't Know**
Need to Know	**Contact all our profitable customers monthly**	**Provide online accountancy services** **Provide hospitality packages**
Don't Need	**Provide doctoring services to ailing**	✕

Figure 2 shows a four-level map. The *vision* is the prime focus of the organisation's strategy. Each successive level below the vision provides increased detail about the vision — what it is, what it means and how it can be achieved. The mechanism that does this is through top-down *How* and bottom-up *Why* explorations and checking.

The top-most activity of the tree represents the vision in the case of a company-wide strategy or the key objective of a department, division, or sub-strategy such as a marketing or a finance strategy. The levels below the top-most activity increase in specificity so that the day-to-day actions can be specified and actioned. There is thus full alignment between the vision and the day-to-day operations.

The second level of the StratAchieve Map is occupied by the Critical Success Factors (CSFs). CSFs are the vital factors that must be successfully actioned if the vision is to be fully achieved. The third level has the core competencies which in turn must successfully produce the CSFs. Traditionally, the number of organisational core competencies is suggested as five or six (Robson, 1994) at the maximum.

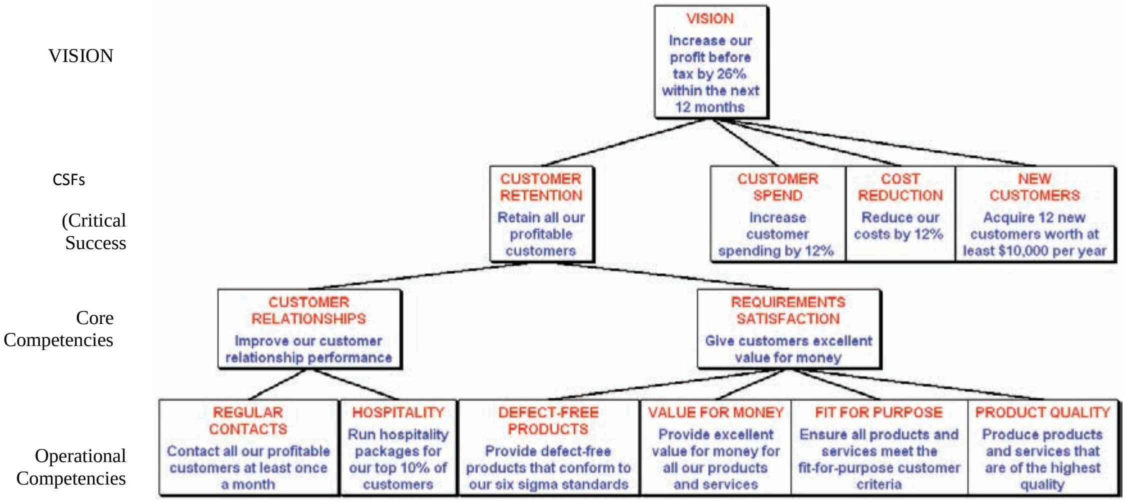
The top-down *How* and bottom-up *Why* structuring also provides the all-important alignment from the vision to the operational competencies on the lowest level of the StratAchieve Map. Only through this logical connectivity can alignment be achieved. This also provides a clear understanding to the fourth-level operational competencies. This also provides a clear understanding of what operational competencies must be actioned to achieve the core competencies, the CSFs and the vision. The process then provides for detailed operational specification of the requirement.

Knowing What We Need to Know

As mentioned, organisations need to "know what they need to know" (and know what they don't know) to make strategic decisions on various fronts. The first task in actioning the Knowledge Positioning Matrix is thus to establish "what needs to be known". From this capture, what is known and not known can then be determined.

To establish "what needs to be known", a set of core competencies was logically produced from the CSFs (top-down Hows) and verified through the operational competencies (bottom-up Whys).

Figure 2. A four-level StratAchieve Map showing all four company CSFs and two of the core competencies



A fourth level of operational competencies were initially produced through logical How unpackings from the core competencies. Figure 2 shows two of the core competencies identified at the workshop, namely Customer Relationships and Requirements Satisfaction.

Although it would have been competitively desirable for Target Accountancy to action every operational competency, in practice this was not feasible through resource and time constraints.

In the course of establishing "what we need to know", it was found that two of the competencies were not distinct but instead were linked in a parent-child relationship. Figure 3 shows that two core competencies, namely Value for Money and Product Quality, share two child operational competencies. The more children that share the same two parents indicate the amount of overlapping of the parent activities. As a consequence of producing the StratAchieve Map, it was found that Product Quality should be a sub-set of Value for Money. Figure 4 shows how this competency structure was re-configured to account for the family resemblance.

Figure 5 shows two core competencies, Customer Satisfaction and Product Quality. Each has a set of identical sub-activities. This duplication of sub-activities indicates that the two seemingly different core competencies are actually the same because they share exactly the same competency children. The degree of similarity between competencies is thus verifiable through the amount of shared sub-activities. Where there are no shared sub-activities, the core competencies are distinctly separate. The workshop delegates wanted to Product Quality to be featured on the StratAchieve Map and therefore showed it as a sub-activity. Alternatively, they could have eliminated the activity, and shown its two sub-activities under Customer Satisfaction.

Need to Know and Do Know

Once the set of core competencies were identified (need to know), the next stage was to identify which core competencies were known (available expertise) and those that were unknown (unavailable expertise). Figure 2 shows how the CSF, *Customer Retention* was unpacked, first into

Figure 3. Product Quality shares child competencies fully with Value for Money which means Product Quality is a sub-competency

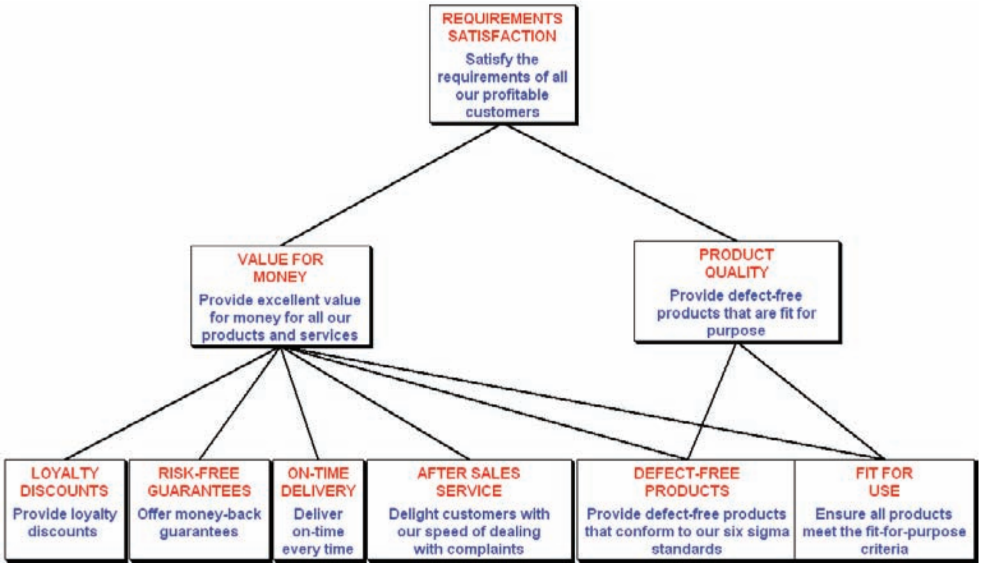


Figure 4. The revised structure showing Product Quality is a sub-set of Value for Money

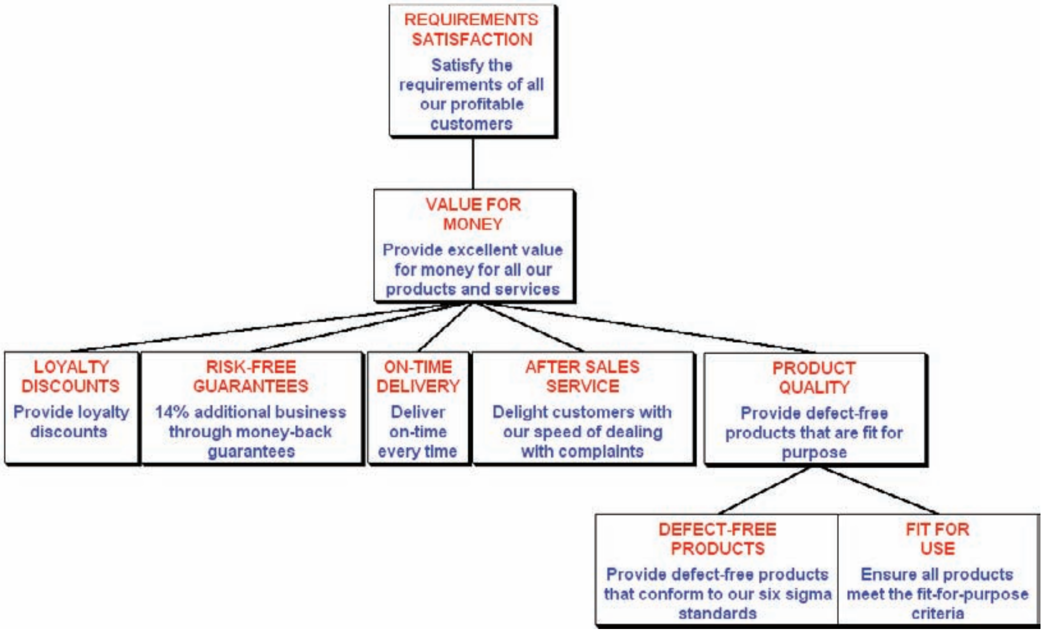
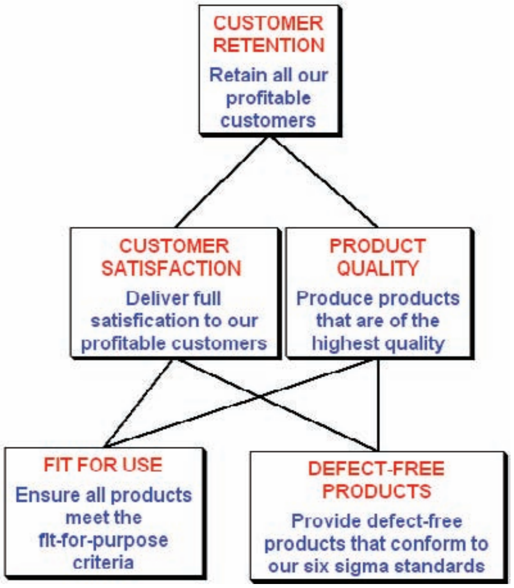


Figure 5. Product Quality and Customer Satisfaction are semantic duplications



the respective core competencies, and then into operational competencies.

At the workshop, delegates were asked to produce a knowledge map showing their key actions. A comparison was then made between the logically derived core competencies using StratAchieve and those competencies actually held by the individuals. Several competencies were matched while others were unmatched. Examples are shown in Figure 1.

Need to Know and Don't Know

The StratAchieve Why and How creations and connections produced the activity "use the Internet to increase sales". It was agreed that this activity was important enough to be regarded as a potential core competency, where new skills would be needed. The exercise thus identified a knowledge gap, identifying what should be possessed as expertise and what was lacking.

The logical operational competency "operate hospitality packages" was created from the core competency "improve our customer relationship performance". The workshop delegates agreed that this activity (operate hospitality packages) was an important competency that needed to be included in the strategy as part of the core competency "improve our customer relationship performance".

A further action the company took after the workshop was to determine which competencies they lacked and needed to purchase through recruitment and consultancy. The core competencies were also prioritised, based on agreed criteria such as contribution impact on the CSFs, resource demands (cost implications) and risk quantification. Through this process, it was possible to weight the core competencies and produce a ranked order of importance. Although supported within the method, this is not detailed further here.

Don't Need to Know and Know

The Knowledge Positioning Matrix shows "provide doctoring services to ailing companies" as a known competency, but one that does not have any impact on the current company-wide CSFs. Thus is because there is no logical Why connection into the newly formed CSFs. For example, there is no *Why* connect to Customer Retention since once the customer's company has been restored it will cease to be a customer. With no logical connection for this in the developed map, it was thus excluded.

Don't Need to Know and Don't Know

It follows that not knowing what we do not need to know is a null set and therefore is left blank in the Knowledge Positioning Matrix.

CONCLUSION

This paper described the importance of core competencies and demonstrated the utility of the StratAchieve method for testing the validity of knowledge-laden core competencies for strategic goals. It has shown how to test core competencies for logical compatibility with the strategy plan as well as to identify core competencies that are essential for strategic success. The software support links these logically, and through separate functionality relates them to timescales, costing, human resources, and progress indicators for subsequent monitoring. In doing this, we needed to unpack the meaning of the word "know". For example, in the phrase *do we know what we need to know*, two uses of the term can be discerned, namely know-what and know-how respectively. Both relate to awareness, not necessarily the skills available.

The case study has demonstrated the formulation of a corporate strategy from a consideration of the core operational activities and associated knowledge competencies forming the organisation's intellectual capital resource. Meanings of the operational and other activities that produce the emergence of achieved strategic objectives have been systematically elicited, negotiated, and agreed within a multi-stakeholder framework, which explicitly links the strategic requirement to the necessary activities and identifies the knowledge requirements for each strategic objective.

Although simplified and indicative examples only have been shown here, linked and cohesive *Strategy Trees* for major business functions have been produced in a form that translates directly into actionable specifications, with a motivated logic chain of abstraction upwards towards, or implementation downwards from, strategic activities and competencies. Core strategic competencies, such as "contact all our profitable customers monthly" have been illustrated to show the alignment of activities, and how a competency at one level can provide an advantage at another. Equally less advantageous competencies, without strategic import, are highlighted by the method. An emphasis on the terminology and meanings understood within the company, and its reporting norms, helps strategy ownership and implementation. A sort of "mediated objectivity" applies, which explicitly links the strategic requirement to the necessary activities and identifies the knowledge requirements for each one.

By expressing the required activities in the structure the focus is shifted towards dynamic strategy achievement through knowledge capability, rather than merely managing the organisational resources and by-products of business activity. Evaluation of the strategy is provided for within the method, though beyond the scope of this paper to describe. Monitoring, activity based costing, resource allocation, and progress and performance indicators are all linked explicitly to the strategy model developed. During the case study, each core competency was analysed to determine its value and hence impact contribution on the company's goals and vision. This core competency valuation and ranking method has been the subject of ongoing research.

The case study reported in this paper is one of several conducted over a 15-year period with organisations large and small, public and private and whilst the case is unique, the methods involved are considered generic and stable. Individual studies such as this one lie within a "declared intellectual framework of systemic ideas, ultimately allowing general lessons to be extracted and discussed" as recommended by Checkland (1991, p. 401).

Although a case study does not aim at generalisation rich, contextual understanding and utility value are indicated. Apart from the direct pragmatic value to the organisation, the "story told" in reporting the notion of mediated objectivity may help convey insights that transfer to the understanding of similar situations. Results from action research studies can provide rich and useful descriptions, enhancing learning and understanding which may itself be abstractly transferable to other organisations, or provide an underpinning to future inductive theory development. This potentially allows further contextualisation of the work in the more nomothetic terms implicit in multiple case study research designs.

This case study has shown the development of strategy: further action research with the company will evaluate its impact and value. In general through work with this, and with other organisations we aim to develop a competency valuation method so that the value of operational competencies in relation to strategy may be assessed.

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ENDNOTES

[1] The valuation of intellectual capital is significant: the most authoritative estimates typically suggest that around 75% of a company's value lies in its intangible assets (Handy [cited in Edvinsson & Malone, 1997; Kaplan & Norton, 2004, p. 4]).

[2] StratAchieve™ is a registered mark of Keith Sawyer.

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Chapter 1.7
Strategic Alliances of Information Technology Among Channel Members

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ABSTRACT

This chapter explores novel ways of improving flexibility, responsiveness, and competitiveness via strategic information technology (IT) alliances among channel members in a supply chain network. To gain competitiveness, firms have to constantly update their operational strategies and information technologies through collaborative efforts of a "network" of supply chain members rather than the efforts of an individual firm. In sum, the foci of this chapter are: (1) an overview of supply chain management (SCM) issues and problems, (2) supply chain coordination and integration, (3) the latest IT applications for improved supply chain performance and coordination, and (4) strategic IT alliances. This chapter concludes with a discussion of business implications and recommendations of future research.

INTRODUCTION

Supply chain management (SCM), characterized by interorganizational coordination (Hill & Scudder, 2002), deals with how each company in a supply chain coordinates and cooperates with its business partners. Along the supply chain, most business activities are integrated for effectively supplying products and services to customers via a continuous, seamless flow. Drawing on the concepts of value chain and value system (Porter, 1985), SCM inherits the viewpoint of "process." In a value system, simply a series of integrated processes is insufficient to support a supply chain and offer fully synchronized operations of all supply chain partners (Williamson, Harrison, & Jordan, 2004).

Recently, it has been realized that information technology (IT) plays an important role in supporting systematic integration and synchronization by providing automatic information flows throughout the entire supply chain. More and more SCM researchers have emphasized the need to embrace the enabling information technologies and explore the essential capabilities of effective information management for supply chain integration (Dai & Kauffman, 2002a). Kopczak and Johnson (2003) stated that the synchronization in a value system required a sophisticated information system (IS) to foster real-time information processing and sharing, coordination, and decision making by the entire supply chain. In line with Kopczak and Johnson's research, other researchers (Dai & Kauffman, 2002b; Gunasekaran & Ngai, 2004) have utilized a systematic study to classify the landscape of emerging online business-to-business (B2B) marketplaces.

In addition, Internet technology is then conceived as an enabling tool for effective integration of the information-intensive SCM processes via ubiquitous availability of timely information (Boyson, Corsi, & Verbraeck, 2003). Information transfer via Internet facilitates more interactive partnerships in multi-directions as opposed to the traditionally linear movement of information within a supply chain (Boyson et al., 2003). This information sharing from multiple directions has boosted the power of process integration and synchronization as well as effective collaboration among the supply chain members.

The remainder of this chapter is organized as follows. First, an overview of issues and problems existing in SCM (such as free-riding phenomenon, negative externalities, and bullwhip effects) is presented. Next, it describes the importance of supply chain coordination and integration, followed by a discussion of the latest IT applications that improve supply chain performance and coordination. The following sections focus on (1) the importance of supply chain portal (SCP) in term of e-collaboration between firms, and (2) the "spillover" effect of IT investments.

With these two foci, the authors attempt to classify the differences between supply chain management systems (SCMS) and SCP in terms of major functions, applications, performance matrices, and the like. Two forms of strategic IT alliances for effective SC coordination are then discussed in detail, including technology similarity or geographic proximity. A typology of competitive advantage positions in terms of alliances and spillovers is also presented. In In addition, the researchers intend to emphasize a new selection of IT, namely, SCP, and a different perspective of SCM, namely, a "spillover" effect of IT investments and a strategic alliance of IT. Last but not least, this chapter attempts to find an innovative way to improve a company's flexibility and responsiveness in terms of competitiveness. Finally, the last section concludes this chapter by discussing a number of business implications and recommendations for future research.

SUPPLY CHAIN COORDINATION PROBLEMS AND ISSUES

Free-Riding Phenomenon

A noticeable "free-riding" phenomenon has become more prevalent in a multichannel supply chain (Wu, Ray, Geng, & Whinston, 2004). With the occurrences of free riding, a channel member may acquire relevant sales data from one upstream member but actually purchase the products or receive the services from other vendors, possibly at a lower price. In other words, one channel member carries out the final sale transactions, while another channel member debuts the activities that are required to sell the products/services. In practice, a number of advanced information technologies, particularly the Internet, have increased supply chain channel members' caliber to access a wide range of handy information at a much modest cost. Without doubt, companies that sell their products through multiple-channel sales and distribution are often concerned about the free-riding phenomena for fear that the downstream retailers would have less incentive to promote their products.

Another problem with the free-riding phenomenon is likely to arise when additional efforts made by one channel member bring about increasing revenue that is shared by other channel members in a supply chain. As a consequence, a member may be inclined to work less and enjoy a free ride of improved financial rewards realized by other member(s) in the supply chain. One way to alleviate this problem is to implement an incentive program to motivate the channel members to bring forth adequate contributions in order to receive the comparable compensation. On top of that, a monitoring system should be constructed to measure the effort of each member and to ensure the financial gains of each individual member match their contributions.

Negative Externalities

An effect of externality occurs in a supply chain when a business decision or action results in costs or benefits to members other than the member actually making the decision or carrying out the action. In other words, the decision maker does not bear all of the costs or reap all of the gains from the action. On the other hand, the spillover costs, or negative externalities, may be imposed on a certain channel member without compensation from other parties. For example, a delivery delay caused by the vendor will spill superfluous production costs or excessive inventories over to the manufacturer or other downstream member(s) in a supply chain. Mostly, inferior decisions or deficient data can cause subsequent spillovers on invoices and shipment notices, which will, in turn, lead to incorrect shipments, delays, and costly reductions.

The Bullwhip Effect

In a supply chain, demands can be distorted by members attempting to achieve local optimization. This phenomenon of information distortion on demands is referred as the "bullwhip" or "whiplash" effect (Lee & Padmanabhan, 1997). This phenomenon may occur in many echelons where the variability of demand increases at each stage of the supply chain (Kopczak & Johnson, 2003). In reality, the bullwhip effect may exist in various industries at different levels of a supply chain network. This effect can also cause unnecessary costs and excessive inventories in production, distribution, logistics, and intermediaries.

SUPPLY CHAIN COORDINATION AND INTEGRATION

Horizontal vs. Vertical Coordination

In earlier SCM studies, the adoption of IT was mainly on the use of advanced planning systems to reduce uncertainty of the demand side and to optimize flows (Kumar, 2001). Integrated supply chains strive to achieve not only "horizontal coordination" but also "vertical coordination" (Kumar, 2001, p. 61). Horizontal coordination refers to communication and process synchronization within an industry, while vertical coordination is across industry or firms. Vertical coordination can be further explored from the aspect of transaction costs in a supply chain (Williamson, 1995). With vertical coordination, the possible costs (e.g., the investment costs, spillover costs, or "free-rider" costs) should be properly applied to all the business transactions for each participating channel member in a supply chain during the movement of a product and/or a service, business transactions. Enhanced by the "transaction costs" point of view, Jap, Bercovitz, and Nickerson (2005) argued that the level of expected cooperative exchange norms (i.e., joint transaction-specific investments) could be beneficial to interorganizational performance.

In addition, Williamson (1993) further indicated that the partnership entails the willingness to realize some risks, which imply the uncertainties between partners. To resolve the uncertainties among members, the "trust" relationship may evolve over time under a certain governance structure (Kogut, 1988) and information-sharing mechanism for safeguarding against potential risks or certainties. Upstream members are often characterized as "power asymmetries" (Subramani & Venkatraman, 2003, p. 46) compared to downstream members. The investment costs among supply chain members may be shared under contractual agreements or long-term alliances. The former is a "close, fast-developing, short-lived exchange" relationship (Lambe, Spekman, & Hunt, 2000, p. 213), whereas the latter are equity based or strategic resources alliances (Colwell & Vibert, 2005). As far as effective information sharing goes, both horizontal cooperation and vertical cooperation would require a well-structured information communication technology (ICT) platform to carry out such an operation (Kumar, 2001).

Positive Externality: IT Investment Spillover Effect

In contrast to negative externality, there is a positive externality (or beneficial externality) existing in a supply chain, especially the spillover effect in IT investments. The effect of spillovers from a channel member's IT investments is well documented in the literature (Harhoff, 1996; Lambertini, Lotti, & Santarelli, 2004; Mahajan & Vakharia, 2004; Owen-Smith & Powell, 2004; Rosenkopf & Almeida, 2003). Typically, the spillover costs in IT investment exist in a supply chain when there is a more powerful upstream member who covers some or the majority of costs. As a result, spillovers were mainly studied from a perspective of upstream supply chain.

Utilizing mathematical modeling, Mahajan and Vakharia (2004) developed two strategies that underpinned the IT investment decisions from the supplier perspective: (1) myopic strategy, making the IT investment solely on maximizing its own gain, and (2) global strategy, resulting in gains accruing to the entire value chain. According to their research results, the "global strategy" is a comparably better decision than the "myopic strategy." Furthermore, the "global strategy," with or without a distributor's own investments in IT accruing to the entire supply chain, was tested with better results as well. Based on their results, it is apparent that some free riders may exist among the IT investments from the upstream members, such as distributors and other downstream members. However, overall spillovers or positive externalities can still offer a competitive advantage to a firm or a supply chain in a marketplace at times.

Another aspect of spillover is related to R&D investments. According to Harhoff (1996), the R&D investment can be specific to a firm's product and production methods. As a result of the supplier's R&D contribution, the outputs in the downstream can be greatly expanded and enhanced (Harhoff, 1996). Additionally, on the supplier's side, the demand is shifted to a higher level, and its R&D expenditure is furnished with a higher profit gross. In a sense, a higher profit gross indicates a higher return on investment that is one of important performance metrics for evaluating the outputs of IT investment (Gunasekaran & Ngai, 2004). About a 1% upsurge in IT investments in manufacturing industries will trim down the labor intensity of their suppliers by about 0.01%. In time, investments in IT appear to have spilled over through the supply chain. Other research data show that increasing IT investments in manufacturing industries by 1% will boost the supplier investments by 0.6%, and customer investments by 0.3% (Gorman, 2005).

In sum, the spillovers from the upstream supply chain can add value to the entire supply chain. To reap the global benefits of positive externalities, a control over spillovers (Lambertini et al., 2004) or intentional spillovers (Harhoff, 1996) may be necessary. However, according to the results of empirical studies by Lambertini et al., the extent to which the firms can endogenously control the spillovers is low. Instead, the tight cooperation between the firms can embrace a higher level of spillovers because of increasing information sharing across the firms.

Information Sharing and Integration in a Coordinative Environment

To a great extent, effective information sharing is indispensable due to the efficiency required from each channel member in a supply chain. Defined by Ganeshan, Jack, Magazine, and Stephens (1999, p. 851), information sharing "specifies schemes for coordination" that apply to the efficient operation in a supply chain. Srinivasan and Yeh (1991) supported that some state-of-the-art information-sharing technologies, such as electronic data interchange (EDI), could significantly improve the suppliers' shipment performance in a just-in-time environment. Furthermore, the research showed that performance of the production and logistics can be dramatically enhanced by accurate and timely information through the facilitation of EDI.

Going beyond information sharing, Kulp, Cohen, Hau, and Ofek (2004) emphasized "information integration," which is similar to Lee and Padmanabhan's (1997) concept of "decentralization" in a supply chain. To better support SCM, Kulp et al. combined the methods of vendor-managed inventory (VMI), new products/services, and reverse logistic systems, along with effective information integration and sharing on customer needs, inventory levels, and so forth. In their research, the task of information integration was empirically tested with significances to improve the supply chain performance at different levels. To further assess other supply chain performance measures, information sharing was associated with higher manufacture performance, while collaboration of new products/services was positively related to intermediate performance. The uncertainty resulting from fluctuating customer demands will, in turn, require seamless information integration for better decision making in a more timely fashion.

IT for Improving Relationship-Specific Investments

Williamson (1995), a transaction cost economist, has pointed out that relationship-specific investments have notably contributed to value creation in a supply chain. The relationship-specific investments can be specifically interpreted as customized business processes catering to the requirements of a particular buyer (Subramani, 2004). According to Subramani and Venkatraman's (2003) field study, the companies that possess intangible, relationship-specific assets are usually capable of imposing an enhanced value creation over those competitors operating without such assets. In light of supplier investments, Subramani (2004) identified two types of intangible asset specificity—business-process specificity and domain-knowledge specificity. Business-process specificity refers to the development of relationship-specific routines or standard operating procedures for efficient task execution. On the other hand, domain-knowledge specificity arises from an understanding of cause-effect relationships that facilitate effective actions and provide resolutions of ambiguities in task planning and execution. By emphasizing IT-mediated buyer-supplier interactions, a firm creates and retains value of domain-knowledge based on the combination of transactions-cost and resource-based views (Subramani, 2004).

The investments of IT within a firm create a resource-based view, whereas the transactions-cost view occurs when the investment "spills over" its supply chain members. Spilling over the

IT investments from suppliers to their distributors (Mahajan & Vakharia, 2004) is one field of research, whereas the IT investments from a R&D perspective is another important area of research (Harhoff, 1996; Lambertini, Lotti, & Santarelli, 2004; Rosenkopf & Almeida, 2003). Having conducted a case study involving the ship repair industry, Chryssolouris, Makris, Xanthakis, and Mourtzis (2004) demonstrated how modern IT could promote effective communications among different partners and enable seamless information flows within value-added chains. The IT investments can lead to enormous benefits from an efficient product life cycle, a shorter lead-time, better product quality, or simply cost reductions.

IT IN SUPPLY CHAIN MANAGEMENT

According to Kumar (2001), three factors have contributed to the needs of effective supply chain management. On the demand side, more sophisticated customers are increasingly demanding a customized value from the supply chain. On the other hand, suppliers are increasingly embracing IT to obtain a forward-looking perspective of the entire supply chain and, in turn, to optimize the processes for meeting the demands. Finally, on both the demand and supply sides, the emergence of global markets has stretched a supply chain to a longer distance. These longer chains—along with the accumulated demands of variability, uncertainties, costs, distances, and time lags—make SCM vulnerable yet in great need of advanced information technologies.

From an enterprise-centric perspective, SCM is considered an extension of enterprise resource planning (ERP) (Kumar, 2001) and has evolved into numerous interwoven information-intensive networks focusing on improving the coordinating and collaborative relationships among supply chain members. Along the line, the trend of a modern supply chain is to fulfill uncertain demands with an array of variety and desired product quality in a timely fashion at the least possible cost (Kumar 2001). If the products and/or services can be delivered by a supply chain with sufficient value at a lower cost than other competitive supply chains, then it has a competitive advantage. Kumar (2001) stated that an innovative use of IT could dramatically increase the competitive advantage via changing the cost and value equation in a supply chain. In the following sections, a number of cutting-edge SC coordination practices and information technologies are described.

EDI, ECR, CPFR, and VMI

Electronic data interchange (EDI) was once used just for transferring information (Hill & Scudder, 2002). Lately, many SCM practitioners have increasingly embraced a number of emerging SCM practices, such as efficient consumer response (ECR), collaborative planning, forecasting and replenishment (CPFR), and cross docking, to facilitate improved coordination among channel members. Launching in the United States, the ECR movement was initiated in 1993 as a result of modern consumers who are more sophisticated and increasingly demand higher quality, more product variety, and better services for less money and less lead-time. ECR responds to tailor products through continuous improvements, focusing on both the demand and supply sides.

CPFR, first adopted by companies like Wal-Mart, Pillsbury, and Procter and Gamble, is an emerging SCM initiative that pursues greater profits through improved operational efficiencies and better collaboration and information sharing between trading partners. By embracing the CPFR technology, Wal-Mart's retailing is able to establish a solid information-rich relationship with most of its customers and suppliers (Gottfredson, Puryear, & Phillips, 2005), which has dramatically strengthen its coordinative capability with its business partners and greatly enhanced its fundamental economies of scale in distribution

(Moore, 1993). Different levels of coordination have led to a lower inventory level and lower operating costs, successfully sustaining Wal-Mart's dominance and superior bargaining power.

In supply chain operations, inaccuracy in the information flow may significantly hold up inventory levels and undercut production rates. Addressing this issue, the participating supply chain members need to acquire necessary information about sales forecasting and replenishment to improve the deficient product throughputs. To satisfy this need, CPFR can be used as a novel way of sharing and disseminating information in a supply chain network. With CPFR, participating supply chain partners are required to collaborate and share information throughout the entire design and production life cycle, from planning to execution (Esper & Williams, 2003).

Addressing the bullwhip effect mentioned previously, Lee and Padmanabhan (1997) analyzed the sources of the bullwhip effect and called for cooperation and coordination among members to lessen its negative effects. For example, by using CPFR with the philosophy of vendor-managed inventory (VMI), channel members can share forecast and demand information and further streamline replenishment, which leads to significant reduction of the bullwhip effect (Kopczak & Johnson, 2003). To achieve better coordination and diminish the phenomenon of demand distortion, more and more companies have started sharing point-of-sales (POS) information throughout the supply chain (Steckel, Gupta, & Banerji, 2004).

Cross Docking

Between 1972 and 1992, Wal-Mart went from $44 million in sales to $44 billion, partially because this retailing giant has been capable of optimizing its distribution and logistics (Hammer, 2004) by adopting the so-called "cross docking" technique. Cross docking refers to a logistic process whereby the goods transported to a distribution center from the suppliers are immediately transferred to the stores (Hammer, 2004). In other words, cross docking is a process of taking a finished good from the manufacturing plant and delivering it directly to the customer with little or no handling in between. Simply put, the cross-docking process means receiving goods at one door and shipping them out through the other door almost immediately, without ever putting them in storage. As a result, the step of filling a warehouse with inventory before shipping it out can be virtually eliminated. In practice, implementation of the cross docking process requires seamless coordination of products transportations among different suppliers, distribution centers, and retail stores in a timely fashion.

Internet Technology for SC Coordination

The Internet and its associated technologies (e.g., intranet and extranet) provide enormous opportunities for companies to make significant improvements in managing and optimizing their supply chains through efficient and effective information flows (Boyson et al., 2003). Shared information enabled by the Internet helps break down functional barriers. Further, Internet technology can help supply chain members to develop a common understanding of the marketplace (Boyson, Corsi, Dresner, & Harrington, 1999). With effective use of the Internet, the entire network of a supply chain allies as a whole instead of just a single member or chain to compete in the marketplace. As an example, Dell responds to supply-demand imbalance by changing its price options or price bundling to steer demand by making the most of Internet. Dell's marketing scheme—Sell What You Have—would not exist without Internet technology (Kopczak & Johnson, 2003) because price elasticity can be managed easier online. For example, the price changes at the Dell site can be seen by all participating members. As a result, there is no need for Dell to inform any of its channel members via paper invoices that slow down the business processes.

Stretching the use of the Internet, Johnson and Whang (2002) divided Internet-enabled e-business and e-supply chain technologies into three categories: e-commerce, e-procurement, and e-collaboration. According to their definitions, e-commerce helps a network of supply chain partners identify and respond quickly to changing customer demands captured over the Internet. E-procurement allows companies to use the Internet for procuring direct or indirect materials as well as handling value-added services like transportation, warehousing, customs clearing, payment, quality validation, and documentation. E-collaboration facilitates coordination of various decisions and activities beyond transactional operations among partners, suppliers, and customers over the Internet.

Internet-Enabled Supply Chain Portal for Heterogeneous IT Environment

Transmitting information electronically reduces errors and increases reuses of information. However, each supply chain member may not adopt the same standards and/or systems to communicate with each other during the business processes. Addressing this issue, a Web-based supply chain portal (SCP) is one of Internet technologies that can be used to solve the problems associated with different standards and systems in SCM. Examining recent business practices, the SCP has actually taken SCM in an electronic form to a new level. Managed and designed by an organization, a SCP can support any business processes in supply chain management (Boyson et al., 1999). The portal is also capable of supporting collaboration among business partners on related business processes. In practice, the collaborative partners are not limited to suppliers and sellers/retailers but can also include customers downstream in a supply chain. On the demand side, a typical SCP solution facilitates an e-commerce, front-end interface for promoting products or services and processing transactions. On the supply side, a portal streamlines and coordinates internal business transactions and interorganizational operations in a real-time mode (McCormack & Johnson, 2001).

A portal can manage many peer-to-peer relations as well as simplify numerous business processes (McCormack & Johnson, 2001). Unifying supply chain partners in a single portal will make the transactions easier for the buyers and, in the meantime, more efficient for the suppliers despite different standards and communication technologies throughout the whole supply chain. With the use of SCP, any authorized partner in a supply chain can bypass excessive security procedures, such as log-on access, and immediately retrieve the relevant information (McCormack & Johnson, 2001). With SCP, the user's access privilege in a portal depends upon his or her level of security clearance. Meanwhile, information on a portal can be updated in real-time from multiple sources.

In terms of the functionality and practicality of SCP, McCormack and Johnson (2001) summarized that the SCP can be adapted to:

- provide a unified format and middleware platform;
- use real-time messaging to assure supply chain operations within optimal inventory level parameters;
- personalize portal views based on user requirements and security/access classifications;
- distribute field-based data gathered from scanners, PDA devices, and other information appliances to multiple users; and
- construct a seamless grid of information on key operational performance areas.

Supply Chain Management Systems

Evidence provided by Subramani (2004) showed that IT-enabled electronic integration technologies, such as supply chain management systems

(SCMS), could create and retain greater value for each channel member in a supply chain. According to Subramani, there are two major functions of SCMS: automating and informating. These functions are further distinguished in two different perspectives, namely, exploitation and exploration. Exploitation is the extension or elaboration of old certainties, whereas exploration is the method of pursuing new possibilities (Subramani, 2004). More precisely, exploitation refers to using the system to perform structured, repetitive tasks, while exploration is meant to use SCMS for unstructured tasks that may seek or create new business processes and/or opportunity (Subramani, 2004). In general, exploitation can be a supplement to exploratory uses of SCMS.

Derived from several research studies, Table 1 summarizes the differences between SCMS and SCP in several categories including major functions, functionalities (Johnson & Whang, 2002), communication, channels, applications (Boyson et al., 1999), performance metrics (Otto & Kotzab, 2003), and their drawbacks. Performance metrics in an organization perspective are represented by transaction costs, time to network, flexibility, and density of relationships (Otto & Kotzab, 2003). The density of relationships is then evaluated by the density of a relation based on the distance of "social, technological, cultural, geographical, and time" (Otto & Kotzab, 2003, p. 315).

IT ALLIANCES FOR EFFECTIVE SC COORDINATION

Transitioning from controlled spillovers to strategic alliances of IT investments reveals a new, promising aspect of knowledge sharing for seamless coordination among supply chain members. Essentially, IT alliances between channel members are formed to search for "new capabilities" and interdependencies within lim-

Table 1. Comparison of SCMS and SCP

	SCMS	SCP
Major functions	Automation Information sharing	Information sharing Knowledge sharing Interoperation
Functionalities	e-Procurement e-Commerce	e-Procurement e-Commerce e-Collaboration
Communication	Hierarchical Sequential Difficult to update	Open Multi-directional Easy to update
Channels	Business-to-business Business-to-consumer (limited)	Business-to-business Business-to-consumer Consumer-to-consumer (limited)
Applications	EDI VMI CPFAR ECR	Search engine KM repository Data mart Data warehouse Index/category filter Information push Information mining
Performance Metrics: *Transaction coast* *Time to network* *Flexibility* *Density of relationship*	 High Long Easily change Low density	 Low Short More easily change High density
Drawbacks	Disconnection Broken channel links Lack of interoperation	Vulnerable to malicious attacks Trust & commitment issue among trading partners

ited social networks (Rosenkopf & Almeida, 2003, p. 753). These limited social networks are the clusters close to each other in some way. Alliances of IT-related R&D facilitate the growth and/or profit of a supply chain because alliances offer great accessibility to essential business and SCM-related knowledge. In a study of the semiconductor industry, Rosenkopf and Almeida (2003) illustrated overall knowledge flows across supply chain networks, while the firms allied and worked together as networks of networks. Further strategic IT alliances can be formed by either technology similarity or geographic proximity among participating members.

Technology Similarity

When firms form alliances, they are more likely to cooperate with other companies that have similar technologies. In other words, the firms that maintain similar positions in constructing their technological landscapes will build their allied relationships upon the knowledge stock of the firms' core competencies. For example, common patent citations are used to form alliances in a semiconductor industry (Stuart & Podolny, 1996). Using a secondary data analysis, Kalaignanam, Shandar, and Varadarajan (2005) provided some insights about information technology industry. They found that the alliance scope contributed to financial gain in large firms, while the alliance type (scale or link alliance) contributed to financial gain in small firms. Evidently, the sizes of firms matter to the IT alliances strategically.

Geographical Similarity

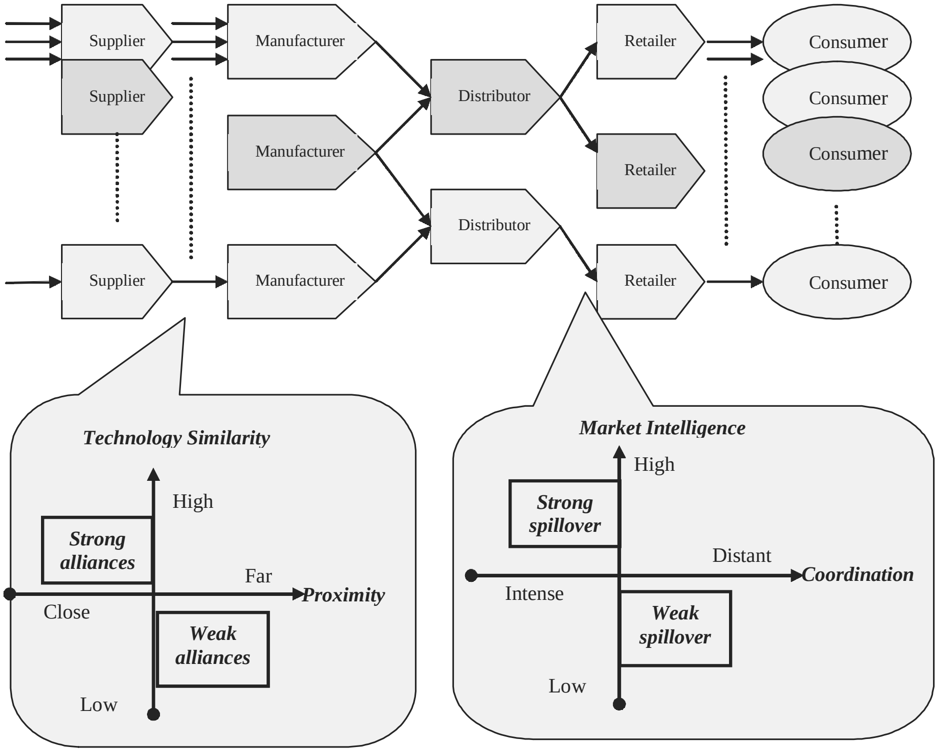
Silicon Valley is a good example of strategic alliances in a geographical cluster. Having conducted a social network analysis, Owen-Smith and Powell (2004) documented alliances as knowledge flows among the firms within the Boston region. According to the analysis results, the local links can be formal, that is, a strategic alliance, or informal, such as a social network that recognizes each other via professional courtesies in a region. Rosenkopf and Almeida (2003) suggested that geographic proximity should reduce costs and increase the frequency of personal contacts in a regional network. The more frequent contacts occur among firms, the better alliances they can organize. Therefore, the knowledge can easily flow among the allied members while geographic local searches can be reciprocally stimulated. The local searches, then, reinforce the organizational and/or regional establishment in terms of technology alliances.

Owen-Smith and Powell (2004) suggested that the spillovers resulting from proprietary alliances were a combination of the institutional commitments and members' practices in the network. Specifically, they made an attempt to capture any possible links by utilizing social network analyses. Between information spillovers and the strengths of regional networks, Owen-Smith and Powell found that contractual linkages along with physical proximity represented relatively strong alliances (Figure 1).

The strengths of alliances are embedded in a mechanism of a rich ecology and a regional labor market. Similarly, while studying technology-based alliances, Stuart (2000) also found that strong alliance increased innovation rates in the semiconductor industry. However, he discovered that those affiliations depended strongly on partner characteristics in terms of IT alliances. Also, Colwell and Vibert's (2005) study illustrated that firms were likely to be satisfied to collaborate with those with whom they had engaged in a satisfying partnership previously. Therefore, commitment and trust are embedded in a longer term of partnership.

One typology, developed by Tapscott, Ticoll, and Lowy (2000), and further interpreted by van der Vorst, van Dongen, Nouguier, and Hilhorst (2002), defines four different types of e-business initiatives based on economic control and value integration. This typology represents the value-added IT alliances into four categories:

Figure 1. Strong vs. weak alliances among upstream vs. downstream channels (Rosenkopf & Almeida, 2003; Lancioni et al., 2003b; van der Vorst et al., 2002; van der Vorst, Beulens, & van Beek, 2000)



- E-marketplaces that facilitate the exchange bring together sellers and buyers.
- Information chains that provide the transparency of information through the value chain and focus on the demand-driven information for monitoring customers' demands and behaviors.
- Virtual enterprises (or alliances) that play a role as a broker who leads a network of community to collect knowledge for every participating member.
- Value chains or "extended enterprises" (van der Vorst et al., 2002) that are represented as a form of "supply chain integration" (p. 133).

According to van der Vorst et al. (2002), "virtual enterprises" and "value chains" are different in terms of economic control. Every member in virtual enterprises has been empowered to access, create, and update the knowledge in the network, whereas "value chains" are controlled by a hierarchy that dominates the supply chain. Jap and Anderson (2003) have illustrated goal congruence as a powerful governance tool in alliances. In reality, the breadth and intensity of the relationship between alliances will either grow or discontinue over time (Dyer, 1997). For example, opportunists in a supply chain may eventually be dropped out of the cooperation for lacking commitment or contribution. The alliances may grow if the IT investments have added benefits to each channel member throughout the supply chain in addition to the harmonious relationships among the allies. Two potential benefits—short-term operational efficiency and longer-term new knowledge creation (Clark, 1989; Malhotra & Gosain, 2005)—may be generated in allied relationships.

To configure supply chain capacity, Malhotra and Gosain (2005) presented "structure" and "cognitive" impacts for alliances in electronic business (p. 31). The structural impact is the adoption of standardized interfaces for linking potential partners in a timely fashion, while the cognitive impact stands for the uses of new knowledge to reduce managers' cognitive loads (Malhotra & Gosain, 2005). The quick coordination between partners increases the capacity to create market intelligence that, in turn, enhances decision-making processes. Figure 1 presents such a model demonstrating that coordination and market intelligence may result from the IT alliances in the upstream.

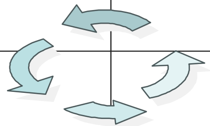
Despite the importance of technology similarity and proximity, economical control, or value integration, Toyota has switched to a system of "dynamic learning capability" to encourage suppliers' involvement, promote knowledge sharing, and prevent free riders in its supply chain (Kim & Im, 2002). Doz (1996) explored alliances as a learning process that could occur in several dimensions, such as environment, tasks, processes, skills, and partner goals. The "dynamic learning capability" has led a whole supply chain to its competitive advantage. The value-added functions are distributed across the participating members who are interactively coordinated. The interactive coordination is indeed facilitated by a knowledge-sharing network known as "virtual enterprises," as mentioned above. According to Kim and Im (2002), the knowledge-sharing network facilitates a supply chain in three ways: (1) saving in procurement and transaction costs; (2) alleviating the bullwhip effect and lowering inventory; and (3) allying the R&D support and co-engineering.

In light of Otto and Kotzab's (2003) performance metrics (i.e., time to network, flexibility, and density of relationship), this chapter intends to incorporate the performance metrics to the downstream spillovers that are created from the upstream investments. Figure 1 shows such an effort. Future research is required to investigate how the spillover effect (resulting from either strong alliances or weak alliances) can add value and benefits to the supply chain as a whole. The researchers classify the possible spillovers outcomes with two determinants—market intelligence and coordination. The downstream spillover effect depicted in Figure 1 can be interpreted by a "technology similarity" that may make possible more knowledge sharing while "proximate" alliances lead to a better coordination in a supply chain. The knowledge sharing and coordination can also be explained by Malhotra and Gosain's (2005) "structure" and "cognitive" impacts.

The transaction costs may decrease or the values may increase while the spillover effect (mainly resulting from the IT investments in the upstream) moves to the downstream. Derived from value chain (Porter, 1985), transaction cost (Williamson, 1993, 1995), resource-based view (Barney, 2002) principles, and resource-advantage theory, Table 2 summaries a typology of competi-

Table 2. The typology of competitive advantage positions in terms of alliances and spillovers in a supply chain

	Downstream Weak Spillovers	*Downstream Strong Spillovers*
Upstream Weak Alliances	1. Money Pit	3. Competitive Advantage without Sustainability
Upstream Strong Alliances	2. Possible ROI in a Longer Term	4. Competitive Advantage with Sustainability



tive advantage positions in terms of alliances and spillovers.

The four arrows in the table represent the emergent competitive advantage positions that synchronize with the market changes. These four positions of the typology are described in detail next.

Position 4: Competitive Advantage with Sustainability

Strong alliances in the upstream supply chain are likely to engage more sturdy spillovers that will lead to a more sustainable competitive advantage. Prior to reaching this phase of affiliation, the alliances between upstream members may have previously formed their partnership with satisfaction (Colwell & Vibert, 2005). The partners have learned from each other on how to work with each other (Jordan, 2004; Kim & Im, 2002). Therefore, they can team up with great ease, comfort, and trust. The more satisfied the partnership is, the more likely the firms are to ally repeatedly. While robust alliances can support stronger spillovers and sustain a better position in competitive advantage as a whole, the long-term relationships may collapse because of economic situation, market changes, consolidations, or conflicts of new alliances. The strength of upstream alliance diminishes and this sustainability could retreat to the third position.

Position 3: Competitive Advantage Without Sustainability

This position is characterized by the mixture of strong downstream spillovers and weak upstream alliances. The strong spillovers may support the supply chain with a competitive advantage; however, they may not be able to provide sufficient sustainability in competitive advantage. The argument here is that the competitive advantage may have been generated from the strong spillovers derived simply from weak resources, namely, less innovative technology, lack of coordination, or short of investment effort. From the perspective of resource-advantage (R-A) theory, this position is similar to Hunt's (2000) "Cell 6" of competitive position matrix. In Hunt's research, the competitive position matrix contributing to the thrust of R-A theory represents nine possible competitive positions based on the combinations of a firm's resource-produce value and relative costs for producing such value. The "Cell 6" represents an "effectiveness" advantage because "their parity costs produce superior value" (Hunt, 2000, p. 139). Simply put, Position 3 can be effective but not sufficient to sustain a competitive advantage over time. It is possible that it would recede to Position 1 or move to Position 4, depending on the fact that alliances become stronger or spillovers become weaker. To assume pessimistically, Position 3 is more likely moving towards to Position 1.

Position 2: Possible Return on Investment (ROI)

In this position, the ROI will take a longer time to evolve to stronger spillovers that will show beneficial impact to the supply chain. Jap et al. (2005) presented the "overshooting the target" situation to illustrate the long-haul investment in partnerships. Some R&D alliances may range from three to 10 years. Therefore, commitment and trust need to be established in addition to a governance structure. With strong upstream alliances, the downstream spillovers should be increasingly strengthened to move forward to Position 4. Nevertheless, there always are some possibilities that R&D may not be able to completely follow through. If that is the case, Position 2 can then turn into Position 1. However, with strong alliances or previous satisfying cooperation experiences, the spillovers in the downstream will eventually come around and cause the state of competitive advantage to move towards Position 3.

Position 1: Money Pit

This position represents a combination of weak alliances and weak spillovers that is likely to dangle the firms over the precipice of a potential money pit. Jordan (2004) has stressed that alliance success depends on the combination of a high level of cooperation and knowledge/information sharing. If the allies fail to learn or share from one another, then the supply chain's ability to compete may be compromised (Jordan, 2004; Kim & Im, 2002). Therefore, the investments may not realize a return. However, as the allied partners' learning experience becomes more satisfying, futile partnerships will eventually evolve to partnerships that are more favorable. Therefore, it is possible that Position 1 can swing towards Position 2. In this case, stronger downstream spillovers may come about due to increasing coordination and knowledge sharing.

CONCLUSION

As there are multiple channels, there are multiple combinations in grouping a supply chain (refer to the gray shaded areas in Figure 1). In other words, the reconfigurations continuously evolve as long as there is a change of trading partners in a supply chain or one of the trading partners changes the way of dealing with businesses. For example, if Wal-Mart switches to CPFR, then all of its distribution partners must change their business processes accordingly.

For most firms, their IT investments still remain in the upstream of the supply chain for better performance, more efficient throughput, shorter lead time, and improved customer satisfaction. Nevertheless, as IT improves the upper channels, it will be highly likely to enhance the performance for the entire chain because of the "spillover" effect. Hence, the spillover effect has been recognized as a viable enabler to turn the supply chain into a sustainable competitive advantage as a whole.

Furthermore, there is an increasing emphasis on the R&D investments in a supply chain in terms of strategic alliances in IT investment. In most cases, similarities in technology and geographic proximity are the two ultimate factors for forming such IT alliances. In reality, IT investments can be very costly. If a firm can strategically plan out the investments and properly spread out the costs among the trading partners, it can acquire a better marginal benefit and return on investment.

Since the late 1990s, Internet technology has introduced different aspects of innovative processes, such as mass customization, real-time inventory management, and, most importantly, the diminishing of intermediaries (Porter, 2001). Not only does the Internet move businesses from "brick and motor" to "click and play," it also facilitates the companies to fundamentally reengineer their businesses. Internet technology makes business processes among suppliers, customers, intermediaries (if they exist), and business partners more efficient and effective because of its real-time, ubiquitous capabilities. Nowadays, Internet technology has changed the landscape of SCM in almost every aspect, including business process integration, coordination, collaboration, and information/knowledge sharing.

Several issues on strategic alliances of IT among supply chain channel members have been illustrated in this chapter. However, there are a number of limitations needing to be addressed in future research. First, in extension of the typology of van der Vorst et al. (2002), Gunasekaran and Ngai (2004) introduced a framework for the development of IT for effective SCM. The framework includes such integral components as strategic planning of IT, virtual enterprise, e-commerce, IT infrastructure, knowledge management, and IT management and implementation. Making it more complete, it is suggested that the framework should include the study of organizational issues related to IT establishment as one of the future research activities.

As far as strategic alliances of IT investments are concerned, another important area of future research is to investigate how the spillovers can be properly incorporated into a firm's strategic planning needs (Mahajan & Vakharia, 2004). From a longer term perspective, a firm's R&D investment introduces a firm's specific capabilities. In line with a firm's investment in R&D, there are two important issues that ought to be in the spotlight for future research: (1) how the knowledge-sharing network can enhance its "dynamic learning capability" (Kim & Im, 2002), and (2) how the knowledge-sharing network fits into the landscape of the whole supply chain in a rapidly changing business environment.

In Mahajan and Vakharia's (2004) article, it was mentioned that the accruing benefits from each channel member may help increase efficiency and productivity of the entire supply chain. To assist investors in figuring out more financial measures beyond just ROI, some performance metrics should be in place. In light of this need, Otto and Kotzab (2003) offered a complete list of performance metrics of SCM, along with associated problems and suggested solutions. Furthermore, to prevent the free-riding phenomenon in a supply chain, the "fee-for-use" of IT was tested by the mathematical models developed by Mahajan and Vakharia (2004, p.681). Extending from Mahajan and Vakharia's research, examination of how much or how often to subsidize or charge the participating members in a supply chain is recommended.

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Chapter 1.8

Strategic Positioning and Resource-Based Thinking:

Cutting Through the Haze of Punditry to Understand Factors Behind Sustainable, Successful Internet Businesses

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ABSTRACT

This article synthesizes and leverages two strategic frameworks when analyzing the true nature of strategy and the Internet: (1) the concept of strategic positioning, and (2) the resource-based view of the firm. When considered together, these approaches create a powerful tool for understanding the factors determining the winners and losers among Internet businesses. Several examples of the applied framework are demonstrated. These frameworks also help challenge broken thought around many of the postbubble assertions regarding strategy and the Internet. This analysis is based on a series of case studies, with information drawn both from secondary sources as well as over 60 field visits with senior managers at technology firms in Seattle, Silicon Valley, and Tokyo conducted from 2005-2006.

UNDERSTANDING COMPETITIVE ADVANTAGE

Strategic Positioning

To understand strategic positioning it is important to first recognize what it is not. Many firms claim to have crafted a sustainable strategy, only to realize that their competitive position is vulnerable and will be eroded over time. Vulnerable business models are often the result of relying on operational effectiveness. Operational effectiveness involves "performing *similar* activities *better* than rivals perform them" (Porter, 1996). Being operationally effective is critical for sustained business. Firms must strive for improved quality and design, lower costs, and increased efficiency. However, operational effectiveness alone is almost never sufficient enough to determine winners over the long term. This is particularly true of Internet-based businesses where technologies are highly replicable (Shapiro & Varian, 1998).

Technology-based competition leveraging operational effectiveness often pushes firms to improve quality and lower cost. However, given that the steps taken are readily replicable, firms engaged in this sort of hyper competition often see profits decrease rather than increase (D'Aveni, 1994; Wiggins & Ruefli, 2005). There are many examples illustrating the challenges relating to the intensity of competition among Internet firms. For example, Gallaugher and Downing (2000) demonstrated that among leading Web portal firms, leadership in feature innovation played no role in achieving market dominance. Rivals engaged in a rapid response feature war in which the average first competitive response matching a pioneering technical innovation was only 1.5 months. Forrester and Gomez rankings of the user experience among online brokerage firms reveal a similar pattern over time, with firms that have ranked last in one quarter's reports subsequently moving up in less than a year to obtain top honors. Also consider the fate of many firms that are recipients of the Webby Awards. The Webbys, awarded by an international committee of 500, are considered by many to be the oscars of user interface design. Yet despite being recognized for excellence, dozens of prior winners of the Webby Awards have gone bankrupt, had their stocks delisted, or dramatically scaled back operations (Wired, 2003). Design and feature innovation are vital and too many firms have failed in execution due to poorly conceived user experiences; however, design excellence alone is not enough to build a sustainable online winner.

So how do firms succeed? Proponents of strategic positioning suggest sustainable advantage is achieved through differences. Strategic positioning refers to "performing *different* activities from rivals' or performing similar activities in *different ways*" (Porter, 1996). To return to the case of discount brokerages, while the various online discount brokerages have jockeyed for position in usability rankings, one firm, Schwab, has achieved consistent and sustainable competitive advantage, ranking #1 in market share leadership since first going online in the mid 1990s. Schwab's differences are not attributable to easily matched advantages such as lower fees or superior interface, but rather to difficult-to-acquire assets including the nation's largest branch network and the strong Schwab brand. A full 70% of new Schwab members open accounts through the branch network, while the vast majority of these new customers are immediately migrated to electronic trading channels for subsequent interactions (Myers, Pickersgill, & Van Metre, 2004).

Proponents of strategic positioning argue that organizational *differences* can help a firm avoid the self-inflicted wound of hyper competition by insulating a firm against competitive convergence enabled by the rapid diffusion of best practices (Porter, 2001). Firms are advised to choose strategies that confront competitors with tradeoffs that these rivals are unable or unwilling to efficiently undertake. Such trade-offs would result in competitors straddling markets, often resulting in rivals attempting to deploy business models with divergent capital structures, alternate margin and volume demands, and nonsynergistic assets (Porter, 1995). The classic nontech example of straddling is the response of major carriers to Southwest Airline's position. By eschewing hub and spoke systems, tiered service classes, meals, travel agents, and flying one fleet of aircraft, Southwest has built a value chain that is so efficient that competing carriers would need to cut roughly 20% of their cost structure to attain comparable margins. Many firms, including Continental with

Continental Lite and British Airways with Go, have attempted to emulate Southwest's model, but failed due to straddling. Most recently, Delta announced the folding of Song after losing a reported $13 million in a single year on the effort (Serwer, 2004; Mullaney, 2005).

Tech and the Resource-Based View of the Firm

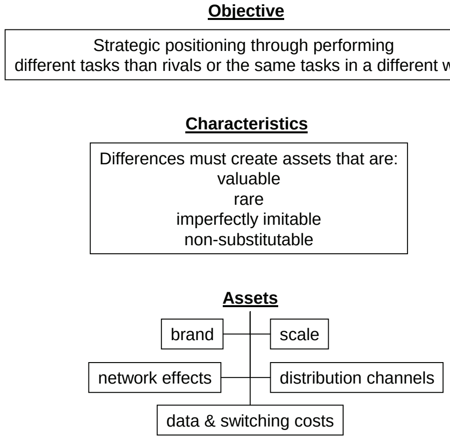
The strategic positioning perspective, however, is limited in that it does not clearly articulate the types of differences that a firm should pursue. The resource-based view (RBV) of competitive advantage (Barney, 1986, 1991; Wernerfelt, 1984) is particularly useful in helping to shape thinking regarding strategic positioning. In the resource-based view, firms are seen as having the potential to earn sustainable returns ahead of industry rivals if and only if they have superior resources that are protected by some form of isolating mechanism preventing their diffusion throughout the industry (Barney, 1991).

In an earlier analysis, Mata, Fuerst, and Barney (1995) examined four variables: capital requirements, proprietary technology, technical IT skills, and managerial skills, and identified that of these, only managerial IT skills could provide sustainable advantage. However this analysis ignores assets that are created or enabled by information technology (Smith, Vasudevan & Tanniru, 1996). While technology can be copied, oftentimes the resources *created* or *enabled* by technology cannot be. This goes beyond the process view espoused by Smith and Fingar (2003) and recognizes that technology is not only a component of most modern strategic processes, but further, strategic technology implementation can create assets that satisfy the four characteristic criteria of the resource-based framework. In this sense, it isn't the technology that is the advantage. It is what a firm does with the technology. The capability to conceptualize and deploy technology that can create or reinforce strategic assets is critical (Bassellier & Benbasat, 2004; Clemons & Row, 1991).

Considering this in the context of Internet firms, a set of key strategic resources emerges. Unlike the picture painted by Porter (2001) in which low barriers to entry erode competition and margins, eliminating profitability and sustained advantage, the opposite seems to be taking place. Strategic resources seems stronger online than in the physical world. There are winners—large consistent winners—among online firms. Perhaps what is most interesting is that in so many cases, it is startup firms, not established firms, which have acquired these resources. This dynamic seems to have taken place largely because these entrants have struck with models that create exploitable strategic resources. As *Businessweek* has stated, when compared to off-line threats and new entrants it seems that "the online winners today are the winners, period" (Hof, 2002).

Resources leveraged by the online winners rely on a subset of key resources not unlike those exploited by off-line giants, but given the special circumstances of the Internet channel, these resources are exploited in different ways and are not necessarily transferable from one channel to another. Assets include scale, network effects,

Figure 1. Combined strategic positioning & RBV model: From objective to characteristics to assets



data and switching costs, brand, and distribution channels. This is not an exhaustive asset list, however some subset combination of these assets is typically present in firms that have proven to be sustainably dominant in the Internet space. Figure 1 shows the development of the proposed model from objective through characteristics and asset identification. The following examples and theory critique demonstrate the application of the model in various contexts.

Netflix: Defeating Two Goliaths

To illustrate the above model's ability to identify the factors associated with the strategic success of Internet business models, consider the example of Netflix. The Los Gatos, California firm pioneered a DVD subscription service where users pay a flat fee to have DVDs delivered to their home via postal mail. Customers hold DVDs as long as they want with no penalty. Plan fees determine how many DVDs a customer can have at a given time, with the most popular plan offering 3 DVDs at a time for $17.99. Customers choose movies online through a Web browser. If a movie is not available, the customer's next available selection is shipped.

In 2004, many analysts were predicting the death of Netflix (Friesen, 2005). Both Blockbuster and WalMart had entered the market for online DVD subscription services. With over 9,000 outlets and rental cards held by 43 million U.S. households, Blockbuster was by far the nation's leading video rental chain. Wal-Mart at the time was #1 on the Fortune 500 list. Both of these late entrants had large existing customer bases, well-known brands, massive scale, and were attempting to synergize online and off-line channels. Blockbuster, for example, offered coupons to its online subscribers, good for two free in-store rentals a month. Wal-Mart heavily promoted the service with in-store displays. Both services undercut Netflix prices with their initial subscription plans. Increased competition forced Netflix to advertise more at a time when online ad rates were increasing. The outlook for the pioneer was not good.

Fast forward to the end of 2005 and it seems that David has trounced both Goliaths. Netflix profits were up seven fold. During the same period, Blockbuster had posted a loss of $1.2 billion and Wal-Mart withdrew entirely from the subscription DVD market (McGregor, 2005). Subscribers at Netflix topped 5 million, while the firm's year-end customer churn of 4% was at an all time low. Rather than being crippled by competition, Netflix ended the year in its best shape ever.

How could this happen? Netflix possessed key resources for competitive advantage, scale, data, brand, and proprietary technology, which others were not able to match. And even though rivals possessed these resources off-line, none of these advantages significantly translated into the market for online DVD subscription.

In terms of infrastructure scale, by year-end 2005 Netflix had 37 distribution centers capable of reaching over 90% of the country with one day mail turnaround. The model becomes profitable when this warehouse scale is combined with customer scale. With five times the customer base of its next rival, Netflix sends out an estimated 1 million DVDs each day. This huge customer base allows the firm to offer a deeper movie selection than any new entrant. Indeed, Netflix is a poster child for the *long tail* phenomenon where firms offering a large selection find profitable markets for less popular items (Anderson, 2006). Warehouses can afford to stock 42 million DVDs encompassing 55,000 titles categorized in 250 genres. By one estimate, 35,000 unique titles are processed in a given day, vs. a maximum title catalog of 3,000 at most video stores (*The Economist*, 2005).

Managing this selection requires sophisticated tools for collaborative filtering. Netflix's proprietary, home grown ratings system, Cinematch, contains over 1 million lines of code and is considered best-in-class. Users are encouraged to rate content they have seen, and these data are used to make additional recommendations. The average subscriber has rated more than 200 movies. Netflix claims that a million new ratings are added to the system each day, and that the system contains well over half a billion ratings in total. The power of the database to move back catalog content has allowed the firm to partner with studios. The studios provide DVDs to Netflix at a reduced cost, while the firm shares a percentage of its subscription take with the studios based on titles shipped. Studios gain costless marketing of content that has already been produced. One analysis suggests Netflix makes 90-95% of its recommendations from the back catalog rather than new releases (Goldstein & Goldstein, 2006). The revenue sharing alliance with studios also raises an example of channel conflict. In 2001, the only film studio not participating in revenue sharing with Netflix was Paramount. At the time, Paramount parent Viacom also owned Blockbuster. Executives at Viacom, fearing support for a subsidiary's rival, refused to engage in revenue sharing. As retaliation, Netflix refused to recommend Paramount films in Cinematch. In 2001 a Paramount film, the Mel Gibson comedy *What Women Want*, was the #4 most popular rental in the United States, but on Netflix it did not even crack the top 100 (O'Brien, 2002).

The efficiency of the Netflix system and its processes improve over time with applied organizational learning. Earlier in the firm's history, Netflix had 115,000 customers and 100 support reps. But by year end 2005, the firm needed just 43 reps to service a customer base that had grown by a factor of 50. Netflix currently holds over 100 patents broadly covering multiple aspects of the firm's operations, and it has sued to protect the firm from copycat competitors. The continued excellence of the Netflix customer experience has reinforced the firm's brand strength. In 2005, market research firm Foresee ranked Netflix #1 in customer satisfaction among all Internet retailers (McGregor, 2005).

Netflix should be celebrated as a conventional wisdom defying example of how Internet startups with novel models can create resources so powerful, they can defeat category-leading firms that dominate adjacent channels. However, the business is not without grave vulnerabilities. The model works as long as there is no better alternative to long tail content distribution than the firm's dominant DVD-through-mail system. It is highly likely that new competition from video-on-demand services, as well as online rental and purchase opportunities such as Apple iTunes and Amazon Unbox, will present customers with a value proposition that exceeds the Netflix switching cost. While Netflix has announced plans for a video-on-demand business, the firm's CEO has stated that the new service will be underwhelming due to a lack of content from studios. The threat that studio partners may bypass Netflix in the next round of technical shock is significant and concerning.

ING Direct: Same Resources but Different Strength?

While the resources in the model can be powerful advantages, it is important to analyze the strength of any apparent resources within an industry's context. As an example of this, consider the online banking market in the United States. The market share leader in this space is ING Direct, a division of Dutch financial giant ING. The division is highly profitable, due largely to its scalable and highly efficient operating model. The firm deliberately seeks self-service customers for products that have very little marginal cost per transaction. ING Direct only offers paperless checking accounts (all bill pay handled online – ING will mail a check to those that can't accept e-payments), and did not offer any checking until summer 2006. Customers who use labor-intensive phone service too frequently risk being *fired* from the firm (Esfahani, 2004). Each month, ING sheds roughly 3-4% of its unprofitable customers this way. All this leads to a radically high degree of efficiency. The firm holds roughly $42 million in assets per employee, compared to an industry average of just $5 million (Engen, 2005).

On the surface it would seem that ING Direct has at least three of the strategic resources that NetFlix benefits from. As the market share leader, ING should enjoy both a brand and a scale advantage. And the cost to open an account and migrate any automatic payment systems is a switching cost working to keep existing customers with ING. However the existence of an asset alone is not enough to determine if a business can leverage it for sustainable advantage. One must also consider the asset's strength relative to the industry in which it operates. ING Direct's orange bouncing ball logo is well recognized among the firm's target demographic. However the quality of ING's customer base is questionable. Customers are attracted to ING Direct because of low rates, and these price sensitive customers are potentially the industry's most disloyal. Scale plays a key role in asset efficiency, and a true scale advantage suggests that the largest firm should yield the best rates. However, a summer 2006 examination of the highest savings account rates at BankRate.com demonstrates that ING Direct often does not even rank in the top 20. Some banks with higher rates, like MetLife Bank, have strong brands in related financial services markets, but many of the firms that rank higher than ING are relatively unknown firms such as Emigrant Bank of New York, or the Transportation Alliance Bank of Ogden, Utah. While these firms do not advertise direct banking as extensively as ING Direct, the lack of advertising helps these firms keep costs low. In banking, smaller market, privately held firms can run quite lean. Because of this, large size (scale) doesn't necessarily equal the best efficiency, and it certainly does not guarantee the best rates. Because customers seek low rates, this segment is more likely to comparison shop based on rate (a price proxy) than customers in many other industries, suggesting limited brand strength despite high brand recognition. Finally, although switching costs exist, ING is an electronic bank, so migrating accounts is not difficult.

Do these weaknesses mean ING is doomed? No. But it does suggest that ING Direct does not possess resources with the strength to control the market to the extent that Netflix does. The lack of strong strategic resources implies competition based more on operational effectiveness than strategic positioning. While Netflix's strong assets helped the firm achieve a seven-fold increase in profitability in its most competitive year, when ING faced a particularly competitive second quarter in 2006, profits slowed to 3%, vs. a 30 % jump in the fourth quarter of 2006.

Timing, Yahoo, and Google

The role and influence of timing is particularly contentious among strategists who study Internet firms. The case of Yahoo provides interesting examples on the role of timing. From a technical perspective, the Yahoo experience is an easy one to imitate. There are no substantive elements of the user interface that have intellectual property protection. Because of this, during its early rivalry many found the firm's service difficult to distinguish from rivals Excite, Lycos, and Infoseek/Go. Innovation was proven to be insignificant in determining the firm's dominance. The one factor empirically demonstrated to be related to Yahoo's market share was brand (Gallaugher & Downing, 2000). In an admittedly crowded market (firm founders have stated that the first two letters of the firm's name stand for "Yet Another"), Yahoo was first to successfully execute a national branding campaign. Through advertising and most notably PR, Yahoo grabbed media attention ahead of its rivals. An early distribution alliance with Netscape also helped the firm increase its exposure. As such, even in a crowded market, Yahoo was first to create and leverage strategic assets used to trounce its competition. Today Yahoo jockeys with Microsoft, a firm with software platforms and a browser as a distribution asset, for the largest reach in Internet traffic, and Yahoo ranks among the most profitable of U.S. media companies.

While timing played a role in Yahoo's ascendance, it also plays a critical role in its position with respect to its current and greatest challenge: Google. Yahoo was a public company for two years before Google was even founded. Beginning in 2000, Yahoo began paying Google for search, listing results through the subdomain google.yahoo.com. The tactic immediately doubled Google's visitors and helped reinforce Google as a search leader. By the time Yahoo elected not to renew its contract with Google, Google had already exceeded Yahoo in search traffic (Hansell, 2002). Yahoo's failure to see Google as a threat is particularly interesting because the firm continued to innovate with new features when compared to established portal rivals, yet had neglected to improve search. Google's value proposition to users was simple: more accurate search (via the PageRank algorithm), a stripped down user interface containing less than 20 words, and no graphics beyond the firm's logo. Both of these approaches could be duplicated, yet rivals ignored them. During Yahoo's period of search innovation dormancy, Google was able to leverage its technical lead to create brand, grow market share, and thus generate scale. Google's size-based scale advantages today result from both its user and advertiser base, the largest in search advertising, and the size of the infrastructure needed to support its operations (the firm is estimated to use between 500,000 and 1 million servers to power its service). While both Yahoo and Google were started by Stanford doctoral students, the chances of a rival creating a comparable firm today are greatly diminished due to the capital requirements needed to support a competitor. Again, we see Google was not the first entrant, but it was the first to craft defensible assets in its space. And the firm's use of unmatched technology over time directly led to the creation of these assets.

Broken Thought and Breakthrough Models

After examining the model of positioning leveraged through strategic resources we can reflect on some of the most popular writing on the strategic use of the Internet and see that much of the advice offered was wrong or broadly overstated. This broken thought is profoundly dangerous to managers seeking to understand the true nature of competitive advantage and how firms can construct strategies for success. Several examples of this failure are analyzed.

Myth: Moving Early is Unimportant

Michael Porter refers to the "myth of the first mover" in his widely cited piece, "Strategy and the Internet" (2001). Another *Harvard Business Review* article, Nick Carr's "IT Doesn't Matter" offers the advice "follow, don't lead" in a bold call-out (2003). However, much of the evidence suggests this is at best an overly broad platitude and potentially terrible advice for the strategist. It took Barnes and Nobel 17 months to respond to Amazon.com's online effort, but by early 2006, Amazon has three times the profit and seven times the market cap of its late moving rival's online *and off-line* businesses. Wal-Mart, Federated, and many other established retailers have entered markets alongside Amazon, but none has approached the online size of the asset-creating first mover. Schwab launched Web trading in May of 1996, Fidelity in January of 1997. Prior to this, Schwab and Fidelity were closely ranked peers as the top two discount brokers, but by 2000 Schwab had captured 27.5% of the online trading market. Fidelity ranked fifth in trading volume with a share of just 9.3%. In online auctions, Yahoo and Amazon, each an established Internet brand with millions of users, could not break eBay's 80% domestic market share. Yahoo even offered its service commission free the first year, but to no avail. In payment systems, PayPal launched ahead of eBay's home grown service, Billpoint. PayPal's biggest market was in supporting transactions over eBay, but eBay recognized the startup had strategic assets that were simply too strong and eventually acquired PayPal for $1.3 billion. All of these early movers were able to leverage their time lead to create strategic resources, and in every market, the late mover has had to spend more to gain significantly less market share with lower margins.

Myth: Switching Costs Have Limited Impact Online

More broken thinking exists around switching costs. Porter suggests "switching costs are likely to be lower, not higher, on the Internet", and predicts that services like PayPal will allow consumers to migrate from one vendor to anther, avoiding the cost of re-entering order information. In fact, switching costs and attendant data assets have proven to be vitally important. The case of Netflix demonstrated that even when well known rivals enter a market with a cheaper product, consumers were unlikely to switch. Netflix's share and customer base grew well ahead of rivals while customer churn fell. Wells Fargo has stated that firms that use online bill pay, a switching cost source due to time spent entering payee information and learning the interface, are 70% less likely to leave than customers who do not bank online. Part of the reason Yahoo was not able to migrate its user base from eBay to Yahoo Auctions was due to established eBay users' reluctance to give up their seller and buyer ratings and start anew—again, a switching cost. Even a firm like Google, where switching costs apparently are non-existent, has seen its usage rise. While it may be easy in theory for users to move from one service to the other, in practice, despite heavy innovation from rivals, users have not been presented with enough reason to make a switch. These businesses are not special exceptions; they are winners because the dynamics of their markets and models lead to powerful winner-take-most advantages.

Myth: The Benefits of Network Effects are Overstated

Porter has referred to Network Effects as a self-limiting mechanism, suggesting that it is difficult for a single firm to capture their benefits, and that network benefits reach a point of diminishing returns. Porter also argues that "creating a network effect requires a large investment that may offset future benefits". In fact, many firms that have leveraged network effects have done so with a minimum of investment. Firms that establish an early market share lead in markets where network effects are present often find that their consumers become advocates for the service, fueling increased demand with limited advertising. Second generation Internet businesses that have leveraged network effects to achieve half-billion plus valuations with no advertising include MySpace, Facebook, and Skype. While network effects are only significant in industries where exchange is critical (Gallaugher & Wang, 2002), in industries where these factors are at work, a winner-take-all dynamic ensues. EBay's delay in entering the Japanese market led it to withdraw in defeat, ceding a market in excess of $2 billion to Yahoo because of a delay of only 5 months. Network effects, combined with switching costs, are a chief strategic asset at work in establishing the dominance of PayPal, Apple's iPod/iTunes products, Sony's Playstation 2, and major stock exchanges, among other services. Each of these businesses has a value exceeding $1 billion.

Myth: Internet Brands are Weak

Porter suggests a lack of direct contact makes Internet brands more difficult to build than traditional businesses. He cites the high cost of advertising, product discounts, and incentives as part of the difficulty. But as stated previously, early movers have established extremely powerful online brands. In fact, one may argue that truly global brands have never been built faster and at a lower cost than those created by successful Internet firms. Not only is Google's brand strength held despite low switching costs and heavy competition, the firm spends 22 times less than MSN and 7 times less than rival on maintaining its brand advantage (Elgin, 2005). Google executives claim to have spent nothing on advertising through 2003 and continue to spend very little (Hansell, 2002). Amazon, eBay, Skype, Netflix, MySpace have all established themselves as virtually synonymous with their services, creating brands so strong that even rivals with established brands in other channels or markets must overspend to establish a place in the consumer psyche. And in fact consumer behavior demonstrates that there is very little room in the space of consumer mindshare for a second, third, and certainly not forth tier player. Brands lower consumer search costs to find products, they proxy quality, and inspire trust. A failure to establish a strong asset is a recipe for online disaster, and a firm that can secure this asset has a daunting strength for rivals to attempt to match.

Myth: The Online Advertising Business is a Weak Revenue Generator

Early stage Internet investing was excessive, due in part to wild enthusiasm mixed with a lack of understanding regarding the power and necessity of acquiring strategic assets outlined above. However, the anomaly of the dot-com collapse caused many (including Porter) to overstate the case regarding the limitations of ad-centric business models. Porter stated, "Advertisers can be expected to continue to exercise their bargaining power to push down rates significantly, aided and abetted by new brokers of Internet advertising". In fact, once the dust settled from the dot-com collapse, online advertising among mainstream advertisers took off, rates rose, and inventory became scarce (Bonamici & Vogelstein, 2005). Consumer media time continues to accelerate online at the expense of other forms of media. Ford, GM, and Proctor and Gamble are among the firms shifting millions online due largely to the measurable success of their early efforts. And by summer 2006, online advertising had turned Google into the world's largest media company by market cap, earning the firm three quarters of a billion dollars in quarterly profits. At that run rate, the firm's 2006 profits will be greater than Disney's 2005 earnings and nearly as much as Viacom's. Online advertising faces several challenges, including the scourge of click fraud, but the impact and success of the medium has been entirely the opposite of the widespread postbubble punditry.

Myth: Commoditized Technologies Assist Laggards

Nick Carr states that Moore's Law "guarantees that the longer you wait to make your IT purchase, the more you'll get for your money" (Carr, 2003). This is risky and simplistic advice. IT is more than just processor speed. While hardware may be commoditized, suggestions of the value of software commoditization ignore the danger of promoting generic processes or copyable technology in areas where tech can create or strengthen competitive assets. For example, Amazon initially purchased customer profiling and experience customization software from NetPerceptions, yet later decided rolling its own collaborative filtering system would give it an advantage. Apparently users surveyed in the University of Michigan's American Customer Satisfaction Index agree. In 2002, the firm was rated the top service business in any service industry, online or off, ever examined by the study. Netflix dropped Oracle's inventory management system when it realized superiority in delivery was critical to maintaining margin advantages over rivals. And Dell scraped an ERP implementation when it, too, felt that generic processes would be employed over strategic ones (Davenport, 1999). Commodity thinking about technology without regard to the process and resource creating strategic impact of this technology is flawed and potentially damaging.

Myth: The Internet's Low Entry Barriers Mean Firms are More Vulnerable than Off-line Counterparts

In 9 months, iWon.com was able to launch a service that on first blush appeared indistinguishable from Yahoo. But in hindsight it seems the firm had little impact on its larger rival's actions or competitive position. From Yahoo's perspective it was as if iWon never existed. Porter warns that the Internet significantly lowers entry barriers, but as the points above make clear, late entrants have regularly tried and failed at copy the models of existing, strategically positioned firms. Market entry does not equal firm sustainability, and the ability to put up a Web site does not mean a firm will have the resources needed to sustain itself in the market. While low entry barriers can create problems in industries where leaders are unable to craft strategic assets that avoid price-based competition, most firms considered Internet leaders today are not threatened by the low entry barriers because they possess difficult to acquire strategic assets.

CONCLUSION

Firms will make mistakes and markets will evolve. Amazon's highly profitable media retail businesses may be under threat as the firm spends to expand in other categories and confronts established and resource rich firms in digital media. Technology may dismantle the advantages of the Netflix delivery network. MySpace and Facebook may be subject to faddish and changing tastes. Google's assets may be undercut if Microsoft successfully embeds search into Vista. And financial pressures as firms transfer from high growth to mature businesses may cause competitors to engage in costly battles to invade one another's space. By early 2006, Microsoft had $40 billion in cash, Google had $10 billion, Yahoo $4 billion, eBay $2 billion, and Amazon added more new hires in 2005 than any of these firms (Smith & Mangalindan, 2006). The outcomes of any future confrontations are unknown, but the sustainability of any eventual winners will be due to their ability to craft, exploit, and defend strategic resources.

Through cases and examples, this article has demonstrated that Porter's strategic positioning theory can be particularly valuable when combined with resource-based theory. While Porter's frameworks are of great value, practitioners and theorists alike should regard the Internet-related platitudes, suggestions, and examples offered by many writers, including those by Porter and Carr, with skepticism. Strategy requires deep, reflective thinking about the differences across each industry. Technology matters greatly. It plays a key factor in creating valuable resources such as network effects, switching costs, and data assets. It also enables businesses that can leverage an operational lead to establish resources that can include brand and scale. The role of timing remains critical. Moving blindly into an industry with an unsuccessful model is a recipe for failure. It is acknowledged that technology must be sufficiently mature such that customers are prepared to accept a novel product or service (Suarez & Lanzolla, 2005). But comparing failed firms to late moving successes misses a key point: the failed businesses failed many times not because of their early timing but because of their imperfect model or flawed execution. While firms can choose to wait to learn from a rival's failure, if the incumbent is successful, then time leadership may be used to craft powerful resources that are difficult for hesitant rivals to overcome. Betting on rival failure is not a strategy – it is gambling. Strategic thinking about assets, and crafting tactical excellence to create these strategic resources, is a far more appropriate recommendation. It is hoped that the presented framework proves a useful tool in understanding as well as plotting successful businesses.

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Chapter 1.9

Decision Support Systems

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INTRODUCTION

Over the four decades of its history, decision support systems (DSSs) have moved from a radical movement that changed the way information systems were perceived in business, to a mainstream commercial information technology movement that all organizations engage. This interactive, flexible, and adaptable computer-based information system derives from two main areas of research: the theoretical studies of organizational decision making done at the Carnegie Institute in the 1950's and early 1960's as well as the technical work on interactive computer systems which was mainly performed by the Massachusetts Institute of Technology (Keen & Morton, 1978).

DSSs began due to the importance of formalizing a record of ideas, people, systems, and technologies implicated in this sector of applied information technology. But the history of this system is not precise due to the many individuals involved in different stages of DSSs and various industries while claiming to be pioneers of the system (Arnott & Pervan, 2005; Power, 2003). DSSs have become very sophisticated and stylish since these pioneers began their research. Many new systems have expanded the frontiers established by these pioneers yet the core and basis of the system remains the same. Today, DSSs are used in the finance, accounting, marketing, medical, as well as several other fields.

BACKGROUND

The basic ingredients of a DSS can be stated as follows: the data management system, the model management system, the knowledge engine, the user interface, and the users (Donciulescu, Filip, & Filip, 2002). The database is a collection of current or historical data from a number of application groups. Databases can range in size from storing it in a PC that contains corporate data that has been downloaded, to a massive data warehouse that is continuously updated by major organizational transaction processing systems (TPSs). When referring to the model management system, it's primarily a stand-alone system that uses some type of model to perform "what if" and other kinds of analysis. This model must be easy to use, and therefore the design of such model is based on a strong theory or model combined with a good user interface.

A major component of a DSS is the knowledge engine. To develop an expert system requires input from one or more experts, this is where the knowledge engineers go to work, who can translate the knowledge as described by the expert into a set of rules. A knowledge engineer acts like a system analyst but has special expertise in eliciting information and expertise from other professionals (Lauden & Lauden, 2005).

The user interface is the part of the information system through which the end user interacts with the system—type of hardware and the series of on-screen commands and responses required for a user to work with the system. An information system will be considered a failure if its design is not compatible with the structure, culture, and goals of the organization. Research must be conducted to design a close organizational fit, to create comfort and reliability between the system and user. In a DSS, the user is as much a part of the system as the hardware and software. The user can also take many roles such as decision maker, intermediary, maintainer, operator, and feeder. A DSS may be the best one in its industry but it still requires a user to make the final decision.

Power (2003) introduced a conceptual level of DSSs, which contains five different categories. These categories include model-driven DSS, communication-driven DSS, data-driven DSS, document-driven DSS, and knowledge-driven DSS. Defining DSS is not always an easy task due to the many definitions available. Much of this problem is attributed to the different ways a DSS can be classified. At the user level, a DSS can be classified as passive, active, or cooperative.

Essentially, DSS is a computer-based system that provides help in the decision-making process. However, this is a broad way of defining the subject. A better way of describing DSS is to say it is a flexible and interactive computer-based system that is developed for solving non-structured management problems. Basically, the system uses information inputted from the decision maker (data and parameters) to produce an output from the model that ultimately assists the decision maker in analyzing a situation. In the following sections, we first discuss design and analysis methods/techniques/issues related to DSSs. Then, the three possible ways to enhance DSSs will be explored.

DESIGN AND ANALYSIS METHODS/TECHNIQUES/ISSUES RELATED TO DSSS

Design Methods

Today, DSSs hold a primary position in an organization's decision making by providing timely and relevant information to decision makers. It has become a key to the success or survival of many organizations. However, there is a high tally of failure in information systems development projects, even though they are a focal point of industrial concern (Goepp, Kiefer, & Geiskopf, 2006). Designing methods have become an important component that assures a successful information system design. This issue is in relevance to the design of a DSS.

There have been many different strategies employed for the design of a DSS. Current research on DSS design has witnessed the rapid expanding of object-oriented (OO), knowledge management (KM), structured modeling (SM), and design science (DS) approaches.

Object-Oriented Approach

The characteristic of OO approach is to use object-oriented software engineering with unified modeling language (UML) in the design and implementation of a DSS. OO approach involves basically three major steps (Tian, Ma, Liang, Kwok, & Liu, 2005). The user's requirements are first captured by using a set of use case diagrams. These diagrams indicate all the functionalities of the system from the user's point of view. Then classes and their relationships are identified and described in class diagrams. Finally, sequence diagrams or collaboration diagrams are developed, which describe the interaction between objects (instances of classes). Tian et al. (2005) designed a DSS with the OO approach for an organization, which was implemented successfully.

Knowledge Management Approach

In some environment (non-preprogrammed applications), end users, especially the less experienced end users, need to have certain knowledge guiding them how to use the system. The KM design approach supports end users by embedding declarative and/or procedural knowledge in software agents. This approach provides better assistance to inexperienced users of spatial DSS, which requires a design approach that will prioritize knowledge support of the end users' decision-making activities (West & Hess, 2002).

Structured Modeling Approach

SM approach "uses a hierarchically organized, partitioned, and attributed acyclic graph to represent models" (Srinivasan & Sundaram, 2000, p. 598). It consists of three levels: elemental structure, generic structure, and modular structure. The elemental structure intends to capture the details of a specific model instance. The generic structure targets at capturing the natural familial groupings of elements. The modular structure seeks to organize generic structure hierarchically according to commonality or semantic relatedness. The leveled structures allow the complexity of a model to be managed and ranked according to its hierarchies. The graph feature allows modelers and decision makers to understand the model better. A key advantage of SM is the ease with which structured models can be visualized (Srinivansan & Sundaram, 2000).

Design Science Approach

The functionality of a DSS evolves over a series of development cycles where both the end users and the systems analyst are active contributors to the shape, nature, and logic of the system (Arnott, 2004). Yet system developers have little guidance about how to proceed with evolutionary DSS development. DSS developers are facing the fact that insufficient knowledge exists for design purpose, and designers must rely on intuition, experience, and trial-and-error methods. Design science approach, on the other hand, can facilitate developers to create and evaluate information technology artifacts that are intended to solve identified organizational problems (Hevner, March, Park, & Ram, 2004). Vaishnavi and Kuechler (as in Arnott, 2006) proposed a design science methodology with the major process steps of awareness of problem, suggestion, development, evaluation, and conclusion. Arnott (2006) proposed a five steps approach, which was adapted from Vaishnavi and Kuechler, for designing evolutionary DSS: problem recognition, suggestion, artifact development, evaluation, and reflection. A research project by Arnott indicates that design science approach can tackle problems of both theoretical and practical importance.

Design Techniques

As we are advancing in information technologies, business decision makers can now have access to a vast amount of information. On one hand, they may gain necessary and important information for making informed decisions, but, on the other hand, they may also become overloaded by the information irrelevant to what they need. Thus, there is a pressing need for decision-aiding tools that would effectively process, filter, and deliver the right information to the decision makers. Proper combination of DSSs and agent technologies could prove to be a very powerful tool for rendering decision support (Vahidov & Fazlollahi, 2003/2004).

A software agent performs interactive tasks between the user and the system. The user instructs the system what he/she intends to accomplish. The software agent carries out the task. By analogy, a software agent mimics the role of an intelligent, dedicated, and competent personal assistant in completing the user's tasks (Bui & Lee, 1999). In the DSS environment, software agents have been more formally described as autonomous software implementations of a task or goal that work independently, on behalf of the user or another agent (Hess, Rees, & Rakes, 2000). As the traditional, direct manipulation interface of our computing environment is much limited (Maes, 1994), software agents would seem to be a suitable and most needed solution for providing procedural assistance to end users (West & Hess, 2002). "These 'robots of cyberspace' can be effectively utilized in automating many information processing tasks" (Vahidov & Fazlollahi, 2003/2004).

In some DSS environment, such as spatial DSS (Sikder & Gangopadhyay, 2002; West & Hess, 2002), Internet-based DSS (Bui & Lee, 1999), and Web DSS (Vahidov & Fazlollahi, 2003/2004), a multi-agent system should be designed and implemented in the DSS to facilitate the decision makers since decision making involves a complex set of tasks that requires integration of supporting agents (Bui & Lee, 1999), and these agents should have behaviors to work in teams (Norman & Long, 1994). Vahidov and Fazlollahi (2003/2004) developed architecture of multi-agent DSS for e-commerce (MADEC), in which the intelligence team (agents), design team (agents), and choice team (agents) were composed. The multi-agent system was implemented in a prototype of MADEC, which received higher user satisfaction.

THREE POSSIBLE WAYS TO ENHANCE DSSS

Creating Knowledge Warehouses (KW)

Nemati, Steiger, Iyer, and Herschel (2002) proposed that a new generation of knowledge-enabled systems provides the infrastructure required to capture, enhance, store, organize, leverage, analyze, and disseminate not only data and information but also knowledge. Expanding data warehouses to encompass the knowledge needed in the decision-making process is the creation of knowledge warehouses (KW). An important component of KW is a very complex process known as knowledge management. Knowledge management allows for knowledge to be converted from tacit to explicit through such processes as filtering, storing, retrieving, and so forth, thus allowing it to be utilized by decision makers.

The goal of KW is to give the decision maker an intelligent analysis standpoint that enhances all aspects of the knowledge management process. The main drawbacks of KW are the amount of time and money that need to be invested as well as some of the same problems that are found in successfully implementing DSSs. Among these factors are the users' involvement and participation, values and ethics, organization and political issues within the company, and other external issues. The development and implementation of KW still has much work to be done, however, DSSs seem to be headed toward knowledge enhancement in the future, and KW looks to have a promising outlook in the upcoming years as a result.

Focusing on Decision Support

While knowledge management systems seem like a logical way to advance the shortcomings of DSSs, another view also exists. By removing the word "system" from DSSs and focusing on decision support, decision making might cause some interesting, new directions for research and practice. Decision support (DS) is the use of any plausible computerized or non-computerized means for improving sense making and/or decision making in a particular repetitive or non-repetitive business situation in a particular organization (Alter, 2004).

DS embodies a broader perspective that seems logical in environments where the user does not necessarily need the technical aspects of DSSs. This is based on the belief that most work systems of any significance include some form of computerized support for sense making and decision making (Alter, 2004). The difference between DSSs and DS is not too drastic but DS is a sensible option for many companies due to the increase in technology since the creation of DSSs; DSSs may not fit the needs of a business as it had in the past.

Integrating DSSs and KMSs

In line with Bolloju, Khalifa, and Turban (2002), integrating decision support and knowledge management may correct some of the deficiencies of DSSs. The decision-making process itself results in improved understanding of the problem and the process, and generates new knowledge. In other words, the decision-making and knowledge creation processes are interdependent. By integrating the two processes, the potential benefits that can be reaped make the concept seem more worthwhile.

Integrating DSSs and KMSs seems to be the best choice out of the three possible ways to enhance DSS. The reasoning behind this selection is that integrating the two seems to provide a way for including both options without sacrificing one for the other. More importantly, while KW appears to have a very bright future, KW currently requires a great amount of time and money. The combination of both areas allows for a better overall utilization in the present. In time, KW may not be as time consuming and costly as it is now. However, to achieve a better balance of usefulness and efficiency, the integration of DSSs and KMSs appears to be the smartest choice.

FUTURE TRENDS

The future of DSSs, Angus (2003) argued and supported by SAS, Inc. (2004), is in the field of *business analytics* (BAs). BAs differ from that of the recently and previously more common business intelligence (BI). With the fast pace of business and life today it would only make sense for a shift to BA because it does focus on the many possibilities and the future outcomes for production and service.

BAs focus on the future of operations. Opposed to that of BI where it focuses on the past and what can be done to change the past if things were done wrong or repeat if things were done right. However, BAs let managers center on what future trends are developing, which allows them not to accumulate a surplus of inventory of outdated products. It also enables managers to change their prices before the market does, or introduce their new product before anyone else gets the chance to. This is known as first-to-market (Gnatovich, 2006). BAs give the companies that use it a tremendous advantage over their competitors in the marketplace.

CONCLUSION

Since their creation in the early 1960's, DSSs have evolved over the past four decades and continues to do so today. Although DSSs have grown substantially since its inception, improvements still need to be made. New technology has emerged and will continue to do so and, consequently, DSSs need to keep pace with it. Also, knowledge needs to play a bigger role in the form of decision making.

Shim, Warkentin, Courtney, Power, Sharda, & Carlson (2002) emphasized that DSSs researchers and developers should: (1) identify areas where tools are needed to transform uncertain and incomplete data, along with qualitative insights, into useful knowledge; (2) be more prescriptive about effective decision making by using intelligent systems and methods; (3) exploit advancing software tools to improve the productivity of working and decision-making time; and (4) assist and guide DSS practitioners in improving their core knowledge of effective decision support.

The prior statement sums up the courses of action that need to be taken. The successful integration of DSSs and KMSs could revolutionize DSSs and propel it to even greater heights in the future. In closing, DSSs have a storied history which spans the course of four decades; however, the greatest mark may be made in the not so distant future as DSSs continue to evolve.

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KEY TERMS

Business Analytics (BA): A technological system that collects and evaluates all relevant data then scrutinizes it and puts it into different simulations to find out which one is the most appropriate.

Business Intelligence (BI): A system of technologies for collecting, reviewing, and hoarding data to assist in the decision-making process.

Decision Support Systems (DSSs): An interactive, flexible, and adaptable computer-based information system, especially developed for supporting the solution of a non-structured management problem for improved decision making. It utilizes data, provides an easy-to-use interface, and allows for the decision maker's own insights

Interface (or User Interface): A component designed to allow the user to access internal componenst of a system, also known as the dialogue component of a DSS.

Knowledge Management: The distribution, access, and retrieval of unstructured information about human experiences between interdependent individuals or among members of a workgroup.

Sensitivity Analysis: Running a decision model several times with different inputs so a modeler can analyze the alternative results.

Software Agent: A program that performs a specific task on behalf of a user, independently or with little guidance (Bui & Lee, 1999).

Structured Modeling: A generic design strategy for representing complex objects that are encountered in modeling applications (Srinivasan & Sundaram, 2000).

Transaction Processing System (TPS): Computerized systems that perform and record the daily routine transactions necessary to conduct the business; they serve the organization's operational level.

Use Case: A collection of possible sequences of interactions between the system under discussion and its users relating to a particular goal (Tian et al., 2005).

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Chapter 1.10

Decision Support Systems and Decision-Making Processes

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INTRODUCTION

Decision support systems (DSS) deal with semi-structured problems. Such problems arise when managers in organisations are faced with decisions where some but not all aspects of a task or procedure are known. To solve these problems and use the results for decision-making requires judgement of the manager using the system. Typically such systems include models, data manipulation tools, and the ability to handle uncertainty and risk. These systems involve information and decision technology (Forgionne, 2003). Many organisations are turning to DSS to improve decision-making (Turban, McLean, & Wetherbe, 2004). This is a result of the conventional information systems (IS) not being sufficient to support an organisation's critical response activities—especially those requiring fast and/or complex decision-making. In general, DSS are a broad category of IS (Power, 2003).

A DSS is defined as "an interactive, flexible, and adaptable computer-based information system, specially developed for supporting the solution of a non-structured management problem for improved decision-making. It utilises data, it provides easy user interface, and it allows for the decision maker's own insights" (Turban, 1995). There is a growing trend to provide managers with IS that can assist them in their most important task—making decisions. All levels of management can benefit from the use of DSS capabilities. The highest level of support is usually for middle and upper management (Sprague & Watson, 1996). The question of how a DSS supports decision-making processes will be described in this article. This article is organised as follows: The background to decision-making is introduced. The main focus (of this article) describes the development of the DSS field. Some future trends for the DSS field are then suggested. Thereafter a conclusion is given.

BACKGROUND TO DECISION-MAKING

H. A. Simon is considered a pioneer in the development of human decision-making models (Ahituv & Neumann, 1990). His individual work (Simon, 1960) and his joint research with A. Newell (Newell & Simon, 1972) established the foundation for human decision-making models. His basic model depicts human decision-making as a three-stage process. These stages are:

- **Intelligence:** The identification of a problem (or opportunity) that requires a decision and the collection of information relevant to the decision
- **Design:** Creating, developing, and analysing alternative courses of action
- **Choice:** Selecting a course of action from those available.

The decision-making process is generally considered to consist of a set of phases or steps which are carried out in the course of making a decision (Sprague & Watson, 1996). Decision-making can be categorised as:

- Independent
- Sequential interdependent
- Pooled interdependent (Keen & Scott Morton, 1978).

Independent decision-making involves one decision-maker using a DSS to reach a decision without the need or assistance from other managers. This form of DSS use is found occasionally. Sprague & Watson (1996) contend that it is the exception because of the common need for collaboration with other managers. Sequential interdependent decisions involve decision-making at a decision point and are followed by a subsequent decision at another point. In this case the decision at one point serves as input to the decision at another point. A practical example is corporate planning and budgeting where a department formulates a plan which then serves as input to the development of the budget. Sprague & Watson (1996) indicate that DSS are frequently used in support of sequential dependent decision-making but not as frequently as pooled interdependent decision-making.

Pooled interdependent decision-making is a joint, collaborative decision-making process whereby all managers work together on the task. A group of product marketing managers getting together to develop a marketing plan is an example of this type of decision. Specialised hardware, software, and processes have been developed to support pooled interdependent decision-making but for the purposes of this study, these are not explored.

PROBLEMS AND DECISION-MAKING PROCESSES

Ackoff (1981) cites three kinds of things that can be done about problems—they can be *resolved, solved*, or *dissolved*:

- **Resolving:** This is to select a course of action that yields an outcome that is good enough that satisfices (satisfies and suffices).
- **Solving:** This is to select a course of action that is believed to yield the best possible outcome that optimises. It aspires to complete objectivity and this approach is used mostly by technologically oriented managers whose organisational objective tends to be thrival than mere survival.
- **Dissolving:** This to change the nature and/or the environment of the entity in which it is embedded so as to remove the problem.

Sauter (1997) indicates that a DSS will not solve all the problems of any given organisation. The author adds, “however, it does *solve* some problems” (italics added by author).

In a structured problem, the procedures for obtaining the best (or worst) solution are known. Whether the problem involves finding an optimal inventory level or deciding on the appropriate marketing campaign, the objectives are clearly defined. Common business objectives are profit maximisation or cost minimisation. Whilst a manager can use the support of clerical, data processing, or management science models, management support systems such as DSS and expert system (ES) can be useful at times. One DSS vendor suggests that facts now supplement intuition as analysts, managers, and executives use Oracle DSS® to make more informed and efficient decisions (Oracle Corporation, 1997).

In an unstructured problem, human intuition is often the basis for decision-making. Typical unstructured problems include the planning of a new service to be offered or choosing a set of research and development projects for the next year. The semi-structured problems fall between the structured and the unstructured which involves a combination of both standard solution procedures and individual judgment. Keen & Scott Morton (1978) give the following examples of semi-structured problems: (USA) trading bonds, setting marketing budgets for consumer products and performing capital acquisition analysis. Here a DSS can improve the quality of the information on which the decision is based (and consequently the quality of the decision) by providing not only a single solution but a range of alternatives. These capabilities allow managers to better understand the nature of the problems so that they can make better decisions.

Before defining the specific management support technology of DSS, it will be useful to present a classical framework for decision support. This framework will assist in discussing the relationship among the technologies and the evolution of computerised systems. The framework, see Figure 1, was proposed by Gorry & Scott Morton (1971) who combined the work of Simon (1960) and Anthony (1965).

The details of this framework are: The left-hand side of the table is based on Simon's notion that

Figure 1. Decision support framework (Source: adapted from Turban, McLean, & Wetherbe, 1999)

	Type of Control			
Type of Decision	**Operational Control**	**Managerial Control**	**Strategic Planning**	**Support Needed**
Structured	① Accounts receivable, order entry	② Budget analysis, short-term forecasting, personnel reports, make-or-buy analysis	③ Financial management (investment), warehouse location, distribution systems	Management information system, operations research models, transaction processing
Semi-structured	④ Production scheduling, inventory control	⑤ Credit evaluation, budget preparation, plant layout, project scheduling, reward systems design	⑥ Building of new plant, mergers and acquisitions, new product planning, quality assurance planning	DSS
Unstructured	⑦ Selecting a cover for a magazine, buying software, approving loans	⑧ Negotiating, recruiting an executive, buying hardware	⑨ R&D planning, new technology development, social responsibility planning	DSS, ES, neural networks
Support needed	Management information system, management science	Management science, DSS, ES, EIS	EIS, ES, neural networks	

decision-making processes fall along a continuum that ranges from highly structured (sometimes referred to as programmed) to highly unstructured (non programmed) decisions. Structured processes refer to routine and repetitive problems for which standard solutions already exist. Unstructured processes are "fuzzy" for which no cut-and-dried solutions exist. Decisions where some (but not all) of the phases are structured are referred to as semi-structured, by Gorry and Scott Morton (1971).

The second half of this framework (upper half of Figure 1) is based on Anthony's (1965) taxonomy which defines three broad categories that encompass all managerial activities:

- **Strategic planning:** The long-range goals and the policies for resource allocation.
- **Management control:** The acquisition and efficient utilisation of resources in the accomplishment of organisational goals.
- **Operational control:** The efficient and effective execution of specific tasks.

Anthony and Simon's taxonomies are combined in a nine-cell decision support framework in Figure 1. The right-hand column and the bottom row indicate the technologies needed to support the various decisions. For example, Gorry and Scott Morton (1971) suggest that for semi-structured and unstructured decisions, conventional management science approaches are insufficient. They proposed the use of a supportive information system, which they labelled a decision support system (DSS). ES, which were only introduced several years later, are most suitable for tasks requiring expertise.

The more structured and operational control-oriented tasks (cells 1, 2, and 4) are performed by low-level managers. The tasks in cells 6, 8, and 9 are the responsibility of top executives. This means that DSS, executive information systems (EIS), neural computing, and ES are more often applicable for top executives and professionals tackling specialised, complex problems.

The true test of a DSS is its ability to support the design phase of decision-making as the real core of any DSS is the model base which has been built to analyse a problem or decision. In the design phase, the decision-maker develops a specific and precise model that can be used to systematically examine the discovered problem or opportunity (Forgionne, 2003). The primary value to a decision-maker of a DSS is the ability of the decision-maker and the DSS to explore the models interactively as a means of identifying and evaluating alternative courses of action. This is of tremendous value to the decision-maker and represents the DSS's capability to support the design phase (Sprague & Watson, 1996). For the DSS choice phase, the most prevalent support is through "what if" analysis and goal seeking.

In terms of support from DSS, the choice phase of decision-making is the most variable. Traditionally, as DSS were not designed to make a decision but rather to show the impact of a defined scenario, choice has been supported only occasionally by a DSS. A practical example is where a DSS uses models which identify a best choice (e.g., linear programming) but generally they are not the rule.

DEVELOPMENT OF THE DSS FIELD

According to Sprague and Watson (1996), DSS evolved as a "field" of study and practice during the 1980s. This section discusses the principles of a theory for SS. During the early development of DSS, several principles evolved. Eventually, these principles became a widely accepted "structural theory" or framework—see Sprague and Carlson (1982). The four most important of these principles are now summarised.

The DDM Paradigm

The technology for DSS must consist of three sets of capabilities in the areas of dialog, data, and modeling and what Sprague and Carlson call the DDM paradigm. The researchers make the point that a good DSS should have balance among the three capabilities. It should be easy to use to allow non-technical decision-makers to interact fully with the system. It should have access to a wide variety of data and it should provide analysis and modeling in a variety of ways. Sprague and Watson (1996) contend that many early systems adopted the name DSS when they were strong in only one area and weak in the other. Figure 2 shows the relationship between these components in more detail and it should be noted that the models in the model base are linked with the data in the database. Models can draw coefficients, parameters, and variables from the database and enter results of the model's computation in the database. These results can then be used by other models later in the decision-making process.

Figure 2 also shows the three components of the dialog function wherein the database management system (DBMS) and the model base management system (MBMS) contain the necessary functions to manage the database and model base respectively. The dialog generation and management system (DGMS) manages the interface between the user and the rest of the system.

Even though the DDM paradigm eventually evolved into the dominant architecture for DSS, for the purposes of this article, none of the technical aspects is explored any further.

Levels of Technology

Three levels of technology are useful in developing DSS and this concept illustrates the usefulness of configuring DSS tools into a DSS generator which can be used to develop a variety of specific DSS quickly and easily to aid decision-makers; see Figure 3. The system which actually accomplishes the work is known as the specific DSS, shown as the circles at the top of the diagram. It is the software/hardware that allows a specific decision-maker to deal with a set of related problems. The second level of technology is known as the DSS generator. This is a package of related hardware and software which provides a set of capabilities to quickly and easily build a specific DSS. The third level of technology is DSS tools which facilitate the development of either a DSS generator or a specific DSS.

DSS tools can be used to develop a specific DSS application strictly as indicated on the left-hand side of the diagram. This is the same

Figure 2. Components of DSS (Source: adapted from Sprague & Watson, 1996)

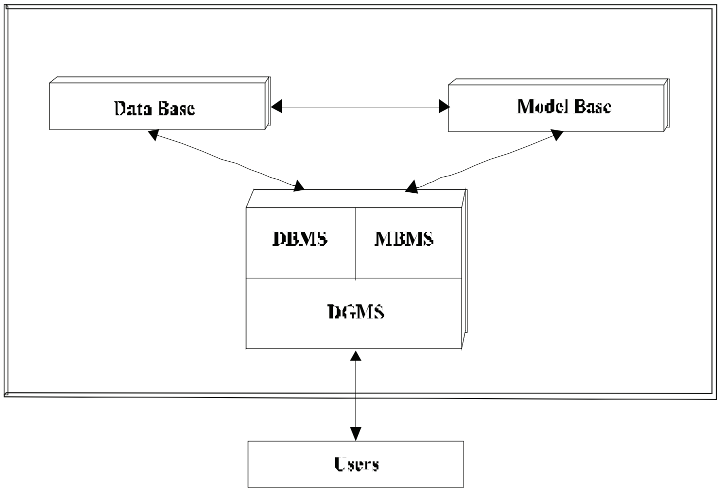
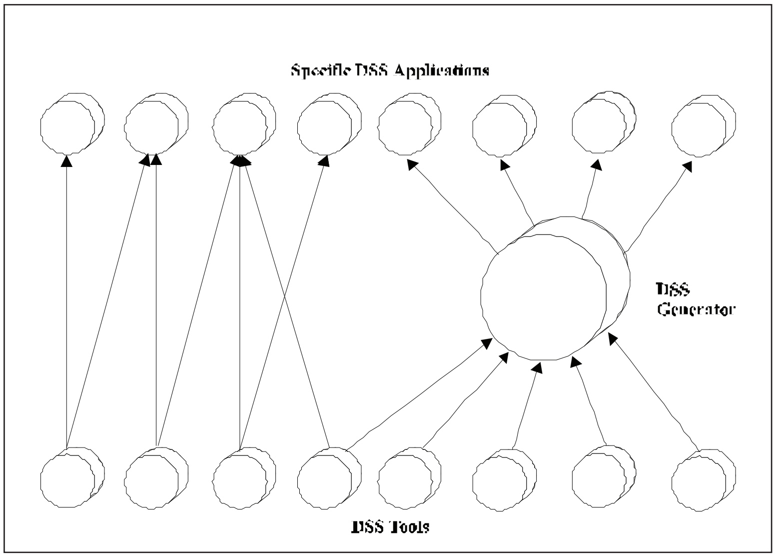


Figure 3. Three levels of DSS technology (Source: adapted from Sprague & Watson, 1996)



approach used to develop most traditional applications with tools such as general purpose languages, subroutine packages, and data access software. The difficulty of the approach for developing DSS is the constant change and flexibility which characterises them. The development and use of DSS generators create a "platform" or staging area from which specific DSS can be constantly developed and modified with the co-operation of the user and with minimal time and effort.

Iterative Design

The nature of DSS requires a different design and development technique from traditional batch and online systems. Instead of the traditional development process, DSS require a form of iterative development which allows them to evolve and change as the problem or decision situation changes. They need to be built with short, rapid feedback from users thereby ensuring that development is proceeding correctly. In essence, they must be developed to permit change quickly and easily.

Organisational Environment

The effective development of DSS requires an organisational strategy to build an environment within which such systems can originate and evolve. The environment includes a group of people with interacting roles, a set of software and hardware technology, a set of data sources, and a set of analysis models.

DSS: PAST AND PRESENT

Van Schaik (1988) refers to the early 1970s as the era of the DSS concept because in this period the concept of DSS was introduced. DSS was a new philosophy of how computers could be used to support managerial decision-making. This philosophy embodied unique and exciting ideas for the design and implementation of such systems. There has been confusion and controversy over the interpretation of the notion decision support system and the origin of this notion is clear:

- Decision emphasises the primary focus on decision-making in a problem situation rather than the subordinate activities of simple information retrieval, processing, or reporting.

- Support clarifies the computer's role in aiding rather than replacing the decision-maker.
- System highlights the integrated nature of the overall approach, suggesting the wider context of machine, user and decision environment.

Sprague and Watson (1996) note that initially there were different conceptualisations about DSS. Some organisations and scholars began to develop and research DSS which became characterised as interactive computer based systems which help decision-makers utilise data and models to solve unstructured problems. According to Sprague and Watson (1974), the unique contribution of DSS resulted from these key words. They contend that the definition proved restrictive enough that few actual systems completely satisfied it. They believe that some authors have recently extended the definition of DSS to include any system that makes some contribution to decision-making; in this way the term can be applied to all but transaction processing. However, a serious definitional problem arises in that the words have certain "intuitive validity;" any system that supports a decision (in any way) is a "Decision Support System." As Sprague and Watson (1996) indicate, the term had such an instant intuitive appeal that it quickly became a "buzz word." Clearly, neither the restrictive nor the broad definition help much as they do not provide guidance for understanding the value, the technical requirements, or the approach for developing a DSS.

A further complicating factor is that people from different backgrounds and contexts view a DSS quite differently: a computer scientist and a manager seldom see things in the same way. Turban (1995) supports this stance as DSS is a content-free expression whereby it means different things to different people. He states that there is no universally accepted definition of DSS and that it is even sometimes used to describe any computerised system. It appears that the basis for defining DSS has been developed from the perceptions of what a DSS does (e.g., support decision-making in unstructured problems) and from ideas about how the DSS's objectives can be accomplished (e.g., the components required and the necessary development processes).

FUTURE TRENDS

New technology continues to affect the dialog, data, and models components. Differences in data, knowledge, and model structures may necessitate the development of new technologies for model retrieval tasks (Forgionne, 2003). Relational database technology and object-oriented databases and data warehousing are influencing how data is stored, updated, and retrieved. Drawing from artificial intelligence advances, there is the potential for representing and using models in new and different ways.

Decision support technology has also broadened to include monitoring, tracking, and communication tools to support the overall process of ill-structured problem solving. DSS implemented on a corporate intranet provides a means to deploy decision support applications in organisations with geographically distributed sites. Clearly these technologies and other emerging Web-based technologies will continue to expand the component parts of a DSS domain. An area of rapid growth is Web-based DSS. Even though Web-based technologies are the leading edge for building DSS, traditional programming languages or fourth generation languages are still used to build DSS (Power, 2003).

CONCLUSION

Moving from the early DSS concept era to almost 35 years later, DSS still comprise a class of IS intended to support the decision-making activities of managers in organisations. The concept has been buffeted by the hyperbole of marketing people and technologies have improved or changed (Power, 2003). While some major conceptual problems may be found with the current terms associated with computerised decision support (and which has been catalysed by marketing hype), the basic underlying concept of supporting decision-makers in their decision-making processes still remains important.

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KEY TERMS

Decision-Making: A three-stage process involving intelligence, design, and choice.

Decision Support System: An interactive, flexible, and adaptable computer-based information system, specially developed for supporting the solution of a non-structured management problem for improved decision-making.

Expert System: An IS which provides the stored knowledge of experts to non experts.

Management Science: An approach that takes the view the managers can follow a fairly systematic process for solving problems.

Pooled Interdependent Decision-Making: A joint, collaborative decision-making process whereby all managers work together on a task.

Semi-Structured Problem: Only some of the intelligence, design, and choice phases are structured and requiring a combination of standard solution procedures and individual judgement.

Structured Problem: The intelligence, design, and choice phases are all structured and the procedures for obtaining the best solution are known.

Unstructured Problem: None of the intelligence, design, and choice phases is structured and human intuition is frequently the basis for decision-making.

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Chapter 1.11

Evaluation of Decision-Making Support Systems

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INTRODUCTION

Decision support systems (DSSs) have been researched extensively over the years with the purpose of aiding the decision maker (DM) in an increasingly complex and rapidly changing environment (Sprague & Watson, 1996; Turban & Aronson, 1998). Newer intelligent systems, enabled by the advent of the Internet combined with artificial-intelligence (AI) techniques, have extended the reach of DSSs to assist with decisions in real time with multiple informaftion flows and dynamic data across geographical boundaries. All of these systems can be grouped under the broad classification of decision-making support systems (DMSS) and aim to improve human decision making. A DMSS in combination with the human DM can produce better decisions by, for example (Holsapple & Whinston, 1996), supplementing the DM's abilities; aiding one or more of Simon's (1997) phases of intelligence, design, and choice in decision making; facilitating problem solving; assisting with unstructured or semistructured problems (Keen & Scott Morton, 1978); providing expert guidance; and managing knowledge. Yet, the specific contribution of a DMSS toward improving decisions remains difficult to quantify.

Many researchers identify a single metric, or a series of single metrics, for evaluation of the DMSS in supporting decision making, if it is evaluated at all (Phillips-Wren, Mora, Forgionne, Garrido, & Gupta, 2006). The authors suggest outcome criteria such as decreased cost, or process criteria such as increased efficiency, to justify the DMSS. Yet no single integrated metric is proposed to determine the value of the DMSS to the decision maker.

The objective of this article is to review literature-based evaluation criteria and to provide a multicriteria evaluation model that determines the precise decision-making contributions of a DMSS. The model is implemented with the analytical hierarchy process (AHP), a formalized multicriteria method.

Building on other core studies (Forgionne, 1999; Forgionne & Kohli, 2000; Keen, 1981; Leidner & Elam, 1993; Money, Tromp, & Wegner, 1988; Phillips-Wren & Forgionne, 2002; Phillips-Wren, Hahn, & Forgionne, 2004; Phillips-Wren, Mora, Forgionne, Garrido, et al., 2006; Phillips-Wren, Mora, Forgionne, & Gupta, 2006; Pieptea & Anderson, 1987), this article focuses on the performance and evaluation of a planned or real DMSS in supporting decision making. Unlike previous DSS studies (Sanders & Courtney, 1985; Leidner, 1996; Wixom & Watson, 2001; Mora, Cervantes, Gelman, Forgionne, Mejia, & Weitzenfeld, 2002) or general information-system studies (DeLone & McLean, 1992, 2003), this study develops a DMSS evaluation model from a design research paradigm, that is, to be built and evaluated (Hevner & March, 2003).

BACKGROUND

Although developers of DMSSs generally report a single criterion for a DMSS, the use of multiple criteria to evaluate a DMSS has been reported in the literature. Chandler (1982) noted that information systems create a relationship between users and the system itself, so that its evaluation should consider both user and system constraints. He developed a multiple-goal programming approach to consider trade-offs between goals and performance. Adelman (1992) proposed a comprehensive evaluation for assessing specifically DSSs and expert systems using subjective, technical, and empirical methods to form a multifaceted approach. User and sponsor perspectives were included in the subjective methods. The analytical methods and correctness of the analysis were assessed in the technical evaluation. Finally, a comparison of performance with and without the system was evaluated in the empirical-methods section. The three approaches were combined to form an overall evaluation of the system. Turban and Aronson (1998) indicate that information systems, including DMSSs, should be evaluated with two major classes of performance measurement: effectiveness and efficiency. According to general systems principles (Checkland, 1999), effectiveness deals with how well the results or outputs contribute to the goals and achievements of the wider system, and efficiency measures how well the system processes inputs and resources to achieve outputs. A third measure, efficacy, deals with how well the system produces the expected outputs. This third measure complements the three general performance or value-based measures for any general system. For example, Maynard, Burstein, and Arnott (2001) proposed evaluating DMSSs by directly including the perspectives of different constituencies or stakeholders in a multicriteria evaluation.

DECISION VALUE OF DMSS

Multicriteria Model

Of the many studies of applied DMSSs published in the last 30 years, assessment usually consisted of characteristics associated with either the process or outcome of decision making using a DMSS (Forgionne, 1999; Phillips-Wren, Mora, Forgionne, Garrido, et al., 2006; Phillips-Wren, Mora, Forgionne, & Gupta, 2006). Process variables assess the improvement in the way that decisions are made and are often measured in qualitative terms. Process variables that have been used to judge a DMSS are increased efficiency, user satisfaction, time savings, more systematic processes, better understanding of the problem, and ability to generalize. Outcome variables assess the improvement in the decision quality when the DM uses the DMSS for a specific decision and are often measured in quantifiable terms. Outcome variables in the literature are, for example, increased profit, decreased cost, accuracy of predicting annual returns, and success in predicting failures.

These two categories of outcome and process are classical descriptions of decision making. Simon (1997) characterized decision making as consisting of the phases of intelligence, design, and choice. The intelligence phase concerns the identification of the problem and data collection, design includes the formulation of the model and search for alternatives, and choice includes the selection of the best alternative. Once the decision is made, the outcome of the decision can be evaluated. Since DMSSs affect both process and outcome, particularly in real-time systems, DMSSs should be evaluated on both criteria.

Previous research (Forgionne, 1999; Phillips-Wren & Forgionne, 2002; Phillips-Wren et al., 2004) has shown that a multicriteria model for the evaluation of DMSSs can be developed based on criteria in the literature. Although other authors have addressed multiple dimensions for information systems success in general (DeLone & McLean, 1992, 2003) and multiple factors for DSS evaluation in particular (Maynard et al., 2001; Sanders & Courtney, 1985), our proposed evaluation model focuses on how well the DMSS supports the specific decision for which it is intended. Our position is that the decision value of a DMSS should be evaluated based on its support for both the process and outcome of decision making. The decision value of the system can be determined quantitatively using a multiple-criteria model such as the AHP with the additional advantage that the precise contributions of the system to the subcomponents in the model can be determined. A stochastic enhancement of the AHP allows the determination of the statistical significance of the contributions (Phillips-Wren et al., 2004).

The AHP (Saaty, 1977) is a multicriteria model that provides a methodology for comparing alternatives by structuring criteria into a hierarchy, providing for pair-wise comparisons of criteria at the lowest level of the hierarchy to be entered by the user, and synthesizing the results into a single numerical value. For example, the decision value of alternative DMSSs can be compared based on criteria and subcriteria. The AHP has been extensively used in decision making for applied problems (Saaty & Vargas, 1994). Once the hierarchy is established, the alternatives are evaluated by pairs with respect to the criteria on the next level. The criteria can be weighted, if desired, according to the priority of each criterion. An eigenvalue solution is utilized to reconcile the initial judgments, and a ranking of the alternatives on the specific criteria is produced using the judgments and the weighting of the criteria.

To evaluate a DMSS using the AHP, a hierarchy of criteria is needed. Although traditional DMSSs have been researched extensively, few, if any, studies have addressed a unifying architecture for the evaluation of DMSSs. A novel and first effort for such an architecture has been recently reported (Phillips-Wren, Mora, Forgionne, Garrido, et al., 2006; Phillips-Wren, Mora, Forgionne, & Gupta, 2006). The following description is a summarized analysis of the proposed evaluation architecture.

Unified Architecture for Evaluation and Design of DMSS

The authors recently reported a conceptualized framework to guide the design and evaluation of intelligent DMSSs for an integrated evaluation approach (Mora, Forgionne, Cervantes, Garrido, Gupta, & Gelman, 2005). It includes both management (i.e., process and outcome) and technical (i.e., services, architectural, and computer mechanisms) views. According to Mora et al. (2005), the primary research premise of intelligent DMSS research can be established as the following.

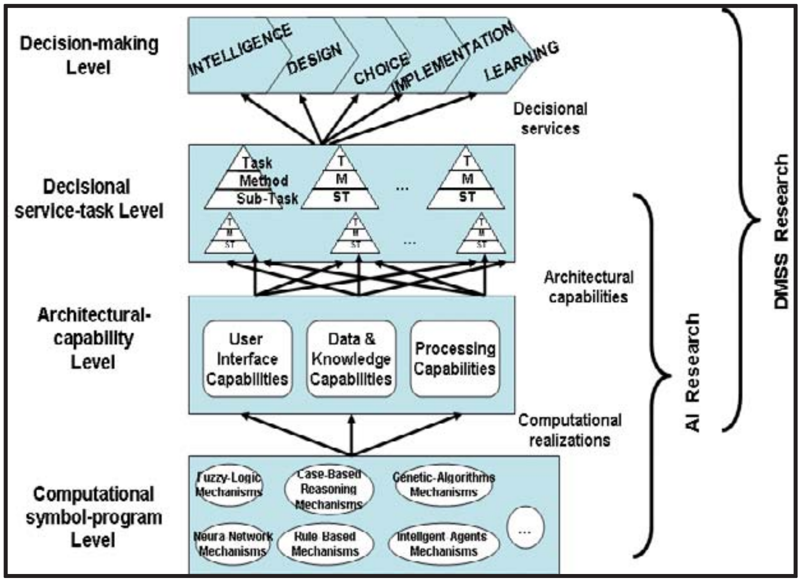
Decision-making phases and steps can be improved by the support of decisional services and tasks, which are provided by architectural capabilities that can or could in the future be computationally implemented by symbol- or program-based mechanisms.

These perspectives (Forgionne, 1999; Phillips-Wren & Forgionne, 2002; Phillips-Wren et al., 2004; Phillips-Wren, Mora, Forgionne, Garrido, et al., 2006; Phillips-Wren, Mora, Forgionne, & Gupta, 2006) propose that any improvement related to the phases and steps of the decision-making process will or should be related to impacts on outcomes to consider a DMSS as satisfactory. Consideration of both premises suggests that any DMSS evaluation must consider metrics associated with outcomes, phases, and steps of the decision-making process as well as with technical issues such as its decisional services, its architectural capabilities, and its internal computational mechanisms. Figure 1 (Mora et al., 2005) depicts the conceptual design and evaluation foundation framework with the four levels as follows:

- **Decision-making level:** To account for intelligence, design, choice, implementation, and learning in the decision-making phases and activities to be executed by a decision maker using a DMSS
- **Decisional service-task level:** To account for the decisional support services of the DMSS, for example, the Newell knowledge levels of task, method, and subtask
- **Architectural capability level:** To account for the user interface capabilities, data and knowledge capabilities, and processing capabilities provided by the components of the architecture of the DMSS
- **Computational symbol-program level:** To account for specific AI computational mechanisms that implement the architectural components of the DMSS such as fuzzy logic, neural networks, case-based reasoning, genetic algorithms, and intelligent agents

In particular, the design and optimization of new mechanisms at the lowest level (i.e., Computational Symbol-Program Level) is an ongoing research area in AI and computer science to provide the design of new or improved algorithms. From the information-systems viewpoint, the

Figure 1. Conceptual framework for design and evaluation of DMSS (Mora et al., 2005)



lowest level contains mechanisms where input-output issues and computational efficiencies are the primary features of interest. In contrast, the next two levels (i.e., the Architectural Capability and Decisional Service-Task Levels) should be addressed jointly with the user in the design and evaluation tasks so that the DMSS designer or evaluator has a comprehensive and integrated view of the decision-making paradigm. The Architectural Capabilities Level has been discussed in previous work (Mora, Forgionne, Gupta, Cervantes, & Gelman, 2003) so it will not be repeated here.

In a study of the Decisional Service-Task Level, Mora et al. (2005) developed a synthesis of the relevant studies of intelligent DMSSs in the DSS and AI literature from 1980 to 2005. Table 1, borrowed from the authors, exhibits the analysis of the Decisional Service-Task Level. Decisional services are classified as services for analysis, synthesis, and hybrid tasks. Although the conceptual description is a high-level view, it also provides for core services that could be developed or implemented by component-based software engineering approaches in the near future as unit building blocks.

In turn, Table 2 reports a general analysis of the main decisional services (i.e., analysis, synthesis, or hybrid services) demanded by each step of the decision-making process.

Example of Utilization of the Unified Architecture for Evaluation of DMSS

Given the architecture for a DMSS presented in Figure 1, the decision value of alternative DMSSs can be determined by evaluating their impact on the process and outcome of decision making. As suggested, the multicriteria model can be implemented with the AHP, and the structure is shown in Figure 2.

An advantage of the structure is that the precise contributions of each DMSS to each element of the architecture as well as to the process and outcome of decision making can be determined.

As an example, suppose that five alternative AI mechanisms are to be evaluated for incorporation into a DMSS: fuzzy logic (FL), neural network

Table 1. Classification of decisional services for DMSSs

Taxonomy of Decisional Services and Tasks		
TASK TYPE	**GENERIC SERVICES (inputs): outputs**	**GENERIC TASKS**
ANALYSIS	CLASSIFY(data): system state	CLASSIFICATION
	MONITOR(system): system variations	CLASSIFICATION
	INTERPRET(data): state assessment	IDENTIFICATION
	PREDICT(system): future system state	IDENTIFICATION
SYNTHESIS	CONFIGURE(parts, constraints, goals): system structure	DESIGN
	SCHEDULE(activities, constraints, goals): states sequence	DESIGN
	FORMULATE(elements, goals, constraints): system structure	COMPLEX DESIGN
	PLAN(activities, resources, constraints, goals): (states sequence, system structure)	COMPLEX DESIGN
HYBRID	EXPLAIN(data, system): system cause-effect links	COMPLEX
	RECOMMEND(system state): system recommendations	COMPLEX
	MODIFY(system, system changes): new system	COMPLEX
	CONTROL(system state, goals):input system actions	COMPLEX
	LEARN(system, knowledge on system): new knowledge	COMPLEX

Table 2. Requirements of decision-making phases and steps compared to analysis, synthesis, and hybrid services

DECISION PHASE	DECISION STEP	ANALYSIS SERVICES				SYNTHESIS SERVICES				HYBRID SERVICES				
		CLASSIFY	MONITOR	INTERPRET	PREDICT	CONFIGURE	SCHEDULE	FORMULATE	PLAN	EXPLAIN	RECOMMEND	MODIFY	CONTROL	LEARN
Intelligence	Problem Detection	√	√									√	√	
	Data Gathering		√										√	
	Problem Formulation			√				√		√	√			
Design	Model Classification	√								√				
	Model Building							√			√	√		
	Model Validation			√						√		√		
Choice	Evaluation	√		√						√				
	Sensitivity Analysis				√					√	√			
	Selection			√						√				
Implementation	Result Presentation					√				√				
	Task Planning						√		√					
	Task Monitoring		√										√	
Learning	Outcome-Process Analysis			√						√				√
	Outcome-Process Synthesis			√						√				√

(NN), case-based reasoning (CBR), genetic algorithm (GA), and intelligent agent (IA). The alternatives are compared in pairs with regard to their contribution to the next level consisting of the user interface (UI), data and knowledge (DK), and processing (P) capabilities. An eigenvalue solution in the AHP reconciles the pair-wise comparisons to yield the input scores shown in Column 1 of Table 3. Each branch in Figure 2 can be weighted to indicate its importance to the next level. Each of our branches is weighted; for example, the outcome is weighted 0.6 compared to the process of 0.4 to indicate that the outcome is more important in our sample problem.

Column 1 shows the amount that each AI alternative contributes to three capabilities on the Architectural Capability Level in the opinion of the user. (Note that the sum of each subcolumn for the values under UI, DK, and P is equal to 1.0.) For instance, in Table 3 we see that the CBR contributes 0.4090 (Column 1) to the UI while GA at 0.3577 is most important to the DK capability (Column 1). The AHP then calculates that NN contributes most significantly to the process (Column 2) and outcome (Column 3). The overall decision value indicates that NN is preferred with the highest score, although NN and CBR are close. A stochastic enhancement of the AHP would permit one to determine if the differences are significant (Phillips-Wren et al., 2004). The analysis provides guidance to the decision maker in the selection of the AI method to be used. In

Figure 2. Multicriteria model implementation to evaluate DMSSs

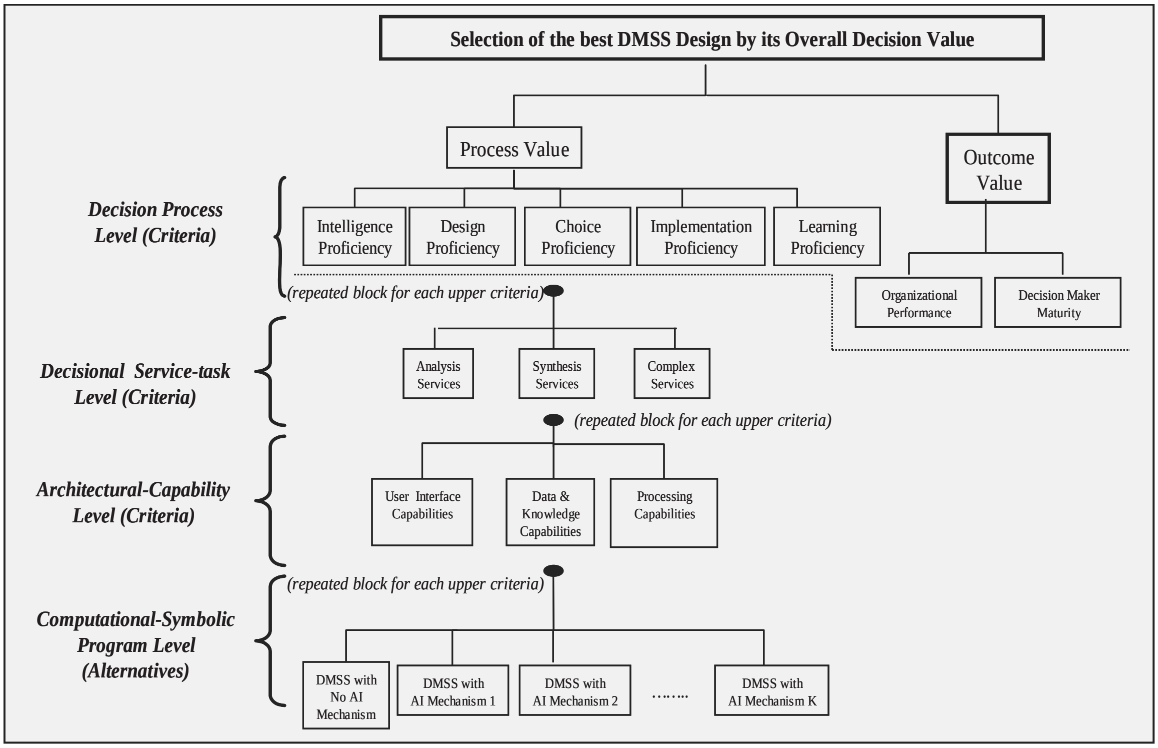


Table 3. Illustration of decision value with user input alternatives

Alter-native	Column 1: Input Scores to UI, DK, and P Criteria	Column 2: Process Value (0.40)	Column 3: Outcome Value (0.60)	Column 4: Overall Decision Value
FL	0.1373, 0.0059, 0.1571	0.0853	0.0854	0.0854
NN	0.1346, 0.2867, 0.3176	0.2496	0.2510	0.2505
CBR	0.4090, 0.1709, 0.1971	0.2488	0.2471	0.2478
GA	0.1844, 0.3577, 0.0760	0.2311	0.2303	0.2306
IA	0.1347, 0.1789, 0.2522	0.1852	0.1862	0.1858

a similar manner, we can trace the contribution of each alternative to each of the subcriteria in Figure 2.

FUTURE TRENDS

Previous AHP-based DMSS evaluations have offered hierarchies that define the nature of support to the outcome and process in decision making. In practice, outcome and process measures can vary across organizations and entities. The organizational and problem context, then, can serve as an additional layer in the AHP hierarchy between the system and the outcome and process levels. This expanded hierarchy would show how outcome and process results are determined by the organizational context and provide guidance for

DMSS design, development, and implementation within the specific context.

There is another hierarchical expansion that can be instructive. In the original formulation, DMSS choices do not disclose the specific architectural elements within the compared systems. It is possible to add a level that would identify the specific decision-making tools delivered by the DMSS. This added hierarchy would link the tools to process and outcome, enabling the researcher or practitioner to identify the specific contributions of the tools to decision value.

Although the additional hierarchical levels can potentially provide useful information, it is not clear if the enhanced clarity would add to decision value. Research, then, is needed to determine if the added information is worth the added cost and complexity of the expanded hierarchy. Put another way, will the extra layers lead to a better (or even different) decision value than the original formulation?

Other unresolved issues involve the weighting and priority schemes used in the AHP methodology. Weights and priorities for the criteria and subcriteria are assigned by the decision maker or researcher and then are used to compute weighted averages from the evaluator's initial pair-wise comparisons. It would be useful to determine how sensitive the calculated decision value would be to alterations in the weights and priorities. Previous DMSS evaluations have not fully addressed this sensitivity analysis issue.

A final potentially fruitful area of further research deals with the data creation process for the AHP analysis. Since the AHP pair-wise comparisons are inherently subjective in nature, there has been a tendency to apply the concept through actual user studies. Such studies have typically involved small samples with dubiously representative participants. Simulation offers a potentially superior data creation approach. Each pair-wise comparison implicitly converts subjective user system alternative ratings to a 0-to-1 scale. Over a population of users, these 0-to-1 values can be expected to follow some probability distribution. It is possible, then, to use randomly generated values from theoretical probability distributions to generate the pair-wise comparisons in the AHP analysis. Analyses with various probability distributions can be used to determine the sensitivity of decision value to alterations in population characteristics

CONCLUSION

The proposed AHP-determined model of decision value provides a mechanism to integrate all previous measures of DMSS value. This formulation is comprehensive, intuitive, and complete. Moreover, the AHP analysis provides a single decision value that is linked to the outcomes and processes that generated the value. As such, the framework can serve as a guide to effective system design, development, and implementation.

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KEY TERMS

Analytic Hierarchy Process (AHP): AHP is a multicriteria model that provides a methodology for comparing alternatives by structuring criteria into a hierarchy, providing for pair-wise comparisons of criteria at the lowest level of the hierarchy to be entered by the user, and synthesizing the results into a single numerical value.

Decision-Making Support System (DMSS): A DMSS is an information system whose purpose is to provide partial or full support for decision-making phases: intelligence, design, choice, implementation, and learning.

Decision Support System (DSS): A DSS is an information system that utilizes database or model-base resources to provide assistance to decision makers through analysis and output.

Decision Value: It is the metric provided by a multicriteria model of the DMSS that quantitatively combines both process and outcome criteria to form a single measure.

Evaluation Criteria: These are qualitative or quantitative metrics on which the DMSS is evaluated.

Multicriteria Method: This is the methodology that integrates two or more criteria to form a single value.

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Chapter 1.12

Interactive, Flexible, and Adaptable Decision Support Systems

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INTRODUCTION

Over the four decades of its history, decision support systems (DSSs) have moved from a radical movement that changed the way information systems were perceived in business, to a mainstream commercial information technology movement that all organizations engage. This interactive, flexible, and adaptable computer-based information system derives from two main areas of research: the theoretical studies of organizational decision making done at the Carnegie Institute in the 1950s and early 1960s as well as the technical work on interactive computer systems which was mainly performed by the Massachusetts Institute of Technology (Keen & Morton, 1978).

DSSs began due to the importance of formalizing a record of ideas, people, systems, and technologies implicated in this sector of applied information technology. But the history of this system is not precise due to the many individuals involved in different stages of DSSs and various industries while claiming to be pioneers of the system (Arnott & Pervan, 2005; Power, 2003). DSSs have become very sophisticated and stylish since these pioneers began their research. Many new systems have expanded the frontiers established by these pioneers yet the core and basis of the system remains the same. Today, DSSs are used in the finance, accounting, marketing, medical, as well as many other fields.

BACKGROUND

The basic ingredients of a DSS can be stated as follows: the data management system, the model management system, the knowledge engine, the user interface, and the users (Donciulescu, Filip, & Filip, 2002). The database is a collection of current or historical data from a number of application groups. A database can range in size from storing it in a PC that contains corporate data that have been downloaded, to a massive data warehouse that is continuously updated by major organizational transaction processing systems (TPSs). When referring to the model management system, it is primarily a stand-alone system that uses some type of model to perform "what if" and other kinds of analysis. This model must be easy to use, and therefore the design of such model is based on a strong theory or model combined with a good user interface.

A major component of a DSS is the knowledge engine. To develop an expert system requires input from one or more experts; this is where the knowledge engineers go to work to see who can translate the knowledge as described by the expert into a set of rules. A knowledge engineer acts like a system analyst but has special expertise in eliciting information and expertise from other professionals (Lauden & Lauden, 2005).

The user interface is the part of the information system through which the end user interacts with the system; it is a type of hardware and the series of on-screen commands and responses required for a user to work with the system. An information system will be considered a failure if its design is not compatible with the structure, culture, and goals of the organization. Research must be conducted to design a close organizational fit, to create comfort and reliability between the system and user. In a DSS, the user is as much a part of the system as the hardware and software. The user can also take many roles such as decision maker, intermediary, maintainer, operator, and feeder. A DSS may be the best one in its industry but it still requires a user to make the final decision.

Power (2003) introduced a conceptual level of DSSs, which contains five different categories. These categories include model-driven DSS, communication-driven DSS, data-driven DSS, document-driven DSS, and knowledge-driven DSS. Defining a DSS is not always an easy task due to the many definitions available. Much of this problem is attributed to the different ways a DSS can be classified. At the user level, a DSS can be classified as passive, active, or cooperative.

Essentially, a DSS is a computer-based system that provides help in the decision-making process. However, this is a broad way of defining the subject. A better way of describing a DSS is to say it is a flexible and interactive computer-based system that is developed for solving nonstructured management problems. Basically, the system uses information inputted from the decision maker (data and parameters) to produce an output from the model that ultimately assists the decision maker in analyzing a situation. In the following sections, we first discuss design and analysis methods/techniques/issues related to DSSs. Then, the three possible ways to enhance DSSs will be explored.

DESIGN AND ANALYSIS METHODS/ TECHNIQUES/ISSUES RELATED TO DSSS

Design Methods

Today, DSSs hold a primary position in an organization's decision making by providing timely and relevant information to decision makers. It has become a key to the success or survival of many organizations. However, there is a high tally of failure in information systems development projects, even though they are a focal point of industrial concern (Goepp, Kiefer, & Geiskopf, 2006). Designing methods have become an important component that assures a successful information system design. This issue is in relevance to the design of a DSS.

There have been many different strategies employed for the design of a DSS. Current research on DDS design has witnessed the rapid expanding of object-oriented (OO), knowledge management (KM), structured modeling (SM), and design science (DS) approaches.

Object-Oriented Approach

The characteristic of an OO approach is to use object-oriented software engineering with unified modeling language (UML) in the design and implementation of a DSS. OO approach involves basically three major steps (Tian, Ma, Liang, Kwok, & Liu, 2005). The user's requirements are first captured by using a set of use case diagrams. These diagrams indicate all the functionalities of the system from the user's point of view. Then classes and their relationships are identified and described in class diagrams. Finally, sequence diagrams or collaboration diagrams are developed, which describe the interaction between objects (instances of classes). Tian et al. (2005) designed a DSS with the OO approach for an organization, which was implemented successfully.

Knowledge Management Approach

In some environment (nonpreprogrammed applications), end users, especially the less experienced end users, need to have certain knowledge guiding them on how to use the system. The KM design approach supports end users by embedding declarative and/or procedural knowledge in software agents. This approach provides better assistance to inexperienced users of spatial DSS, which requires a design approach that will prioritize knowledge support of the end users' decision-making activities (West Jr. & Hess, 2002).

Structured Modeling Approach

The SM approach "uses a hierarchically organized, partitioned, and attributed acyclic graph to represent models" (Srinivasan & Sundaram, 2000, p. 598). It consists of three levels: elemental structure, generic structure, and modular structure. The elemental structure intends to capture the details of a specific model instance. The generic structure targets at capturing the natural familial groupings of elements. The modular structure seeks to organize generic structure hierarchically according to commonality or semantic relatedness. The leveled structures allow the complexity of a model to be managed and ranked according to its hierarchies. The graph feature allows modelers and decision makers to understand the model better. A key advantage of the SM is the ease with which structured models can be visualized (Srinivansan & Sundaram, 2000).

Design Science Approach

The functionality of a DSS evolves over a series of development cycles where both the end users and the systems analyst are active contributors to the shape, nature, and logic of the system (Arnott, 2004). Yet system developers have little guidance about how to proceed with evolutionary DSS development. DSS developers are facing the fact that insufficient knowledge exists for design purpose, and designers must rely on intuition, experience, and trial-and-error methods. Design science approach, on the other hand, can facilitate developers to create and evaluate information technology artifacts that are intended to solve identified organizational problems (Hevner, March, Park, & Ram, 2004). Vaishnavi and Kuechler (as in Arnott, 2006) propose a design science methodology with the major process steps of awareness of problem, suggestion, development, evaluation, and conclusion. Arnott (2006) proposes a five steps approach, which was adapted from Vaishnavi and Kuechler, for designing evolutionary DSS: problem recognition, suggestion, artifact development, evaluation, and reflection. A research project by Arnott indicates that the design science approach can tackle problems of both theoretical and practical importance.

Design Techniques

As we are advancing in information technologies, business decision makers can now have access to a vast amount of information. On one hand they may gain necessary and important information for making informed decisions, but on the other hand they may also become overloaded by the information irrelevant to what they need. Thus, there is a pressing need for decision aiding tools that would effectively process, filter, and deliver the right information to the decision makers. Proper combination of DSSs and agent technologies could prove to be a very powerful tool for rendering decision support (Vahidov & Fazlollahi, 2003/2004).

A software agent performs interactive tasks between the user and the system. The user instructs the system what the user intends to accomplish. The software agent carries out the task. By analogy, a software agent mimics the role of an intelligent, dedicated, and competent personal assistant in completing the user’s tasks (Bui & Lee, 1999). In the DSS environment, software agents have been more formally described as autonomous software implementations of a task or goal that work independently, on behalf of the user or another agent (Hess, Rees, & Rakes, 2000). As the traditional, direct manipulation interface of our computing environment is much limited (Maes, 1994), software agents would seem to be a suitable and most needed solution for providing procedural assistance to end users (West & Hess, 2002). “These ‘robots of cyberspace’ can be effectively utilized in automating many information processing tasks” (Vahidov & Fazlollahi, 2003/2004, pp. 87-88).

In some DSS environments, such as spatial DSS (Sikder & Gangopadhyay, 2002; West & Hess, 2002), Internet-based DSS (Bui & Lee, 1999), and Web DSS (Vahidov & Fazlollahi, 2003/2004), a multiagent system should be designed and implemented in the DSS to facilitate the decision makers since decision making involves a complex set of tasks that requires integration of supporting agents (Bui & Lee, 1999), and these agents should have behaviors to work in teams (Norman & Long, 1994). Vahidov and Fazlollahi (2003/2004) developed architecture of multiagent DSS for e-commerce (MADEC), in which intelligence team (agents), design team (agents), and choice team (agents) were composed. The multiagent system was implemented in a prototype of MADEC, which received higher user satisfaction.

THREE POSSIBLE WAYS TO ENHANCE DSS

Creating Knowledge Warehouses (KW)

Nemati, Steiger, Iyer, and Herschel (2002) propose a new generation of knowledge-enabled systems that provides the infrastructure required to capture, enhance, store, organize, leverage, analyze, and disseminate not only data and information but also knowledge (Nemati et al., 2002). Expanding data warehouses to encompass the knowledge needed in the decision-making process is the creation of knowledge warehouses (KW). An important component of KW is a very complex process known as knowledge management. Knowledge management allows for knowledge to be converted from tacit to explicit through such processes as filtering, storing, retrieving, and so forth, thus allowing it to be utilized by decision makers.

The goal of KW is to give the decision maker an intelligent analysis standpoint that enhances all aspects of the knowledge management process. The main drawbacks of KW are the amount of time and money that need to be invested as well as some of the same problems that are found in successfully implementing DSSs. Among these factors are the users' involvement and participation, values and ethics, organization and political issues within the company, and other external issues. The development and implementation of KW still has much work to be done, however, DSSs seem to be headed toward knowledge enhancement in the future and KW looks to have a promising outlook in the upcoming years as a result.

Focusing on Decision Support

While knowledge management systems seem like a logical way to advance the shortcomings of DSSs, another view also exists. By removing the word "system" from DSSs and focusing on decision support, decision making might cause some interesting, new directions for research and practice. Decision support (DS) is the use of any plausible computerized or noncomputerized means for improving sense making and/or decision making in a particular repetitive or nonrepetitive business situation in a particular organization (Alter, 2004).

DS embodies a broader perspective that seems logical in environments where the user does not necessarily need the technical aspects of DSSs. This is based on the belief that most work systems of any significance include some form of computerized support for sense making and decision making (Alter, 2004). The difference between DSSs and DS is not too drastic but DS is a sensible option for many companies due to the increase in technology since the creation of DSSs; DSSs may not fit the needs of a business as they have in the past.

Integrating DSSs & KMSs

In line with Bolloju, Khalifa, and Turban (2002), integrating decision support and knowledge management may correct some of the deficiencies of DSSs. The decision-making process itself results in improved understanding of the problem and the process, and generates new knowledge. In other words, the decision-making and knowledge creation processes are interdependent. By integrating the two processes, the potential benefits that can be reaped make the concept seem more worthwhile.

Integrating DSSs and KMSs seems to be the best choice out of the three possible ways to enhance DSS. The reasoning behind this selection is that integrating the two seems to provide a way for including both options without sacrificing one for the other. More importantly, while KW appears to have a very bright future, KW currently requires a great amount of time and money. The combination of both areas allows for a better overall utilization in the present. In time, KW may not be as time consuming and costly as it is now. However, to achieve a better balance of usefulness and efficiency, the integration of DSSs and KMSs appears to be the smartest choice.

FUTURE TRENDS

The future of DSSs, Angus (2003) argues and supported by SAS (2004), is in the field of *business analytics* (BAs). BAs differ from that of the recently and previously more common business intelligence (BI). With the fast pace of business and life today it would only make sense for a shift to BA because it does focus on the many possibilities and the future outcomes for production and service.

BAs focus on the future of operations. Opposed to that of BI, where it focuses on the past and what can be done to change the past if things were done wrong or repeat if things were done right. However, BAs let managers center on what future trends are developing, which allows them not to accumulate a surplus of inventory of outdated products. It also enables managers to change their prices before the market does, or introduce their new product before anyone else gets the chance to. This is known as first-to-market (Gnatovich, 2006). BAs give the companies that use it a tremendous advantage over their competitors in the market place.

CONCLUSION

Since their creation in the early 1960s, DSSs have evolved over the past four decades and continues to do so today. Although DSSs have grown substantially since their inception, improvements still need to be made. New technology has emerged and will continue to do so and, consequently, DSSs need to keep pace with it. Also, knowledge needs to play a bigger role in the form of decision making.

Shim, Warkentin, Courtney, Power, Sharda, and Carlson (2002) emphasize that DSSs researchers and developers should (i) identify areas where tools are needed to transform uncertain and incomplete data, along with qualitative insights, into useful knowledge, (ii) be more prescriptive about effective decision making by using intelligent systems and methods, (iii) exploit advancing software tools to improve the productivity of working and decision making time, and (iv) assist and guide DSSs practitioners in improving their core knowledge of effective decision support.

The prior statement sums up the courses of action that need to be taken very well. The successful integration of DSSs and KMSs could revolutionize DSSs and propel them to even greater heights in the future. In closing, DSSs have a storied history that spans the course of four decades; however, the greatest mark may be made in the not-so-distant future as DSSs continue to evolve.

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KEY TERMS

Business Analytics (BA): A technological system that collects and evaluates all relevant data then scrutinizes them and puts them into different simulations to find out which are the most appropriate.

Business Intelligence (BI): A system of technologies for collecting, reviewing, and hoarding data to assist in the decision making process.

Decision Support Systems (DSSs): An interactive, flexible, and adaptable computer-based information system, especially developed for supporting the solution of a nonstructured management problem for improved decision making. It utilizes data, provides an easy-to-use interface, and allows for the decision maker's own insights

Interface (or User Interface): A component designed to allow the user to access internal components of a system, also known as the dialogue component of a DSS.

Knowledge Management: The distribution, access, and retrieval of unstructured information about human experiences between interdependent individuals or among members of a workgroup.

Sensitivity Analysis: Running a decision model several times with different inputs so a modeler can analyze the alternative results.

Software Agent: A program that performs a specific task on behalf of a user, independently or with little guidance (Bui & Lee, 1999, p. 226).

Structured Modeling: A generic design strategy for representing complex objects that are encountered in modeling applications (Srinivasan & Sundaram, 2000, p. 598).

Transaction Processing System (TPS): Computerized systems that perform and record the daily routine transactions necessary to conduct the business; they serve the organization's operational level.

Use Case: A collection of possible sequences of interactions between the system under discussion and its users relating to a particular goal (Tian et al., 2005, p. 406).

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Chapter 1.13

The Evaluation of Decision-Making Support Systems' Functionality

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INTRODUCTION

Contemporary decision-making support systems (DMSSs) are large systems that vary in nature, combining functionality from two or more classically defined support systems, often blurring the lines of their definitions. For example, in practical implementations, it is rare to find a decision support system (DSS) without executive information system (EIS) capabilities or an expert system (ES) without a recommender system capability. *Decision-making support system* has become an umbrella term spanning a broad range of systems and functional support capabilities (Alter, 2004). Various information systems have been proposed to support the decision-making process. Among others, there are DSSs, ESs, and management support systems (MSSs). Studies have been conducted to evaluate the decision effectiveness of each proposed system (Brown, 2005; Jean-Charles & Frédéric, 2003; Kanungo, Sharma, & Jain, 2001; Rajiv & Sarv, 2004). Case studies, field studies, and laboratory experiments have been the evaluation vehicles of choice (Fjermestad & Hiltz, 2001; James, Ramakrishnan, & Kustim, 2002; Kaplan, 2000).

While for the most part each study has examined the decision effectiveness of an individual system, it has done so by examining the system as a whole using outcome- or user-related measures to quantify success and effectiveness (Etezadi-Amoli & Farhoomand, 1996; Holsapple & Sena, 2005; Jain, Ramamurthy, & Sundaram, 2006). When a study has included two or more systems, individual system effects typically have not been isolated. For example, Nemati, Steiger, Lyer, and Herschel (2002) presented an integrated system with both DSS and AI (artificial intelligence) functionality, but they did not explicitly test for the independent effects of the DSS and AI capabilities on the decision-making outcome and process. This article extends the previous work by examining the separate impacts of different DMSSs on decision effectiveness.

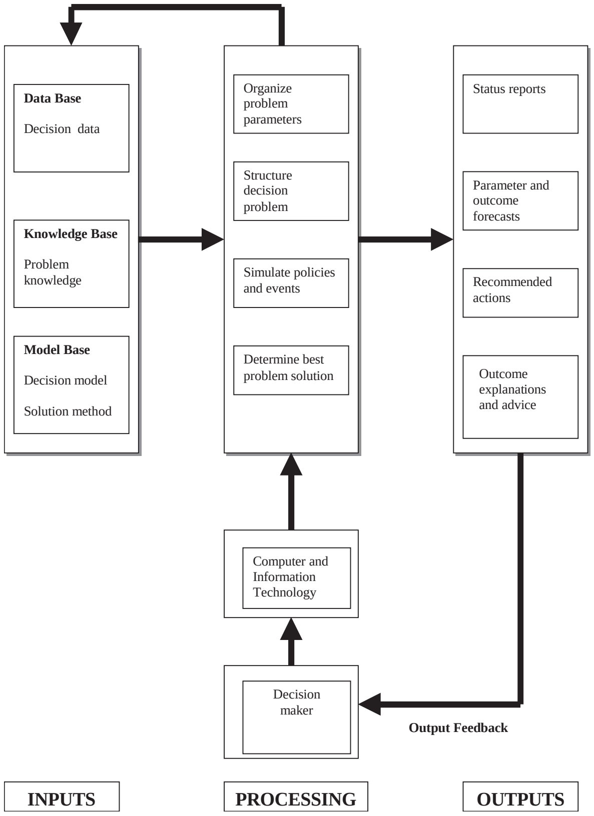
BACKGROUND

DMSSs are information systems that directly support the decision-making process for complex, high-level problems in an interactive manner (Alter, 2004; Mora, Forgionne, & Gupta, 2002). The specific DMSS can be a traditional DSS, EIS, ES, knowledge-based system (KBS), or a system that combines the functionalities of DSS, EIS, KBS/ES.

An architecture that incorporates the functionality of the various proposed systems is shown in Figure 1 (adapted from Forgionne, 2003).

In the typical DSS, the decision maker utilizes computer and information technology to (a) structure the problem by attaching the parameters to a model and (b) use the model to simulate (experiment with) alternatives and events and/or find the best solution to the problem (Borenstein, 1998; Raghunathan, 1999). Results are reported as parameter conditions (status reports), experimental outcome and parameter forecasts, and/or recommended actions. Feedback from user processing guides the decision maker to a problem solution, and created information is stored as an additional input for further processing. A DSS, then, would not include the knowledge base on the input side

Figure 1. General DMSS



or offer explanations on the output side of Figure 1's conceptual architecture.

In a typical EIS, the decision maker utilizes computer and information technology to (a) access dispersed data, (b) organize the data into user-specified broad categories, (c) view the data from interesting perspectives, and (d) highlight important patterns by scanning current trends (Leidner & Elam, 1994; Seely & Targett, 1999). Results are reported as categorical summaries and drill-down details (status reports) and/or suggested problem parameters (parameter forecasts). Feedback from the user processing guides the decision maker to a general problem understanding, and the created parameters are stored as additional inputs for further processing. An EIS, then, would have a limited model base and not include the knowledge base on the input side. Additionally, the system would not offer recommended actions or explanations on the output side of Figure 1's conceptual architecture.

A typical KBS/ES captures and stores as inputs problem-pertinent knowledge, either from experts, cases, or other sources, and the models (inference engine or reasoning mechanisms) needed to draw problem-solution advice from the knowledge (O'Leary, 1998; Preece, 1990; Ullman, 1988; Waterman, 1985). Results are reported as knowledge summaries (status reports), forecasted outcomes, and/or problem advice and explanations for the advice. Feedback from the user processing guides the decision maker to the advice, and the created events and advice pathways are stored as additional inputs for further processing. A KBS/ES, then, would have a limited model base and not include the database on the input side, and similar to an EIS, the system would not offer recommendations on the output side of Figure 1's conceptual architecture.

An MSS integrates the functions of a DSS, EIS, and KBS/ES into a single system (Turban, Aronson, & Liang, 2004). Similar to its component systems, an MSS will have a model base and a database. The database contains data relevant to the decision problem, including the values for the uncontrollable events, decision alternatives, and decision criteria. The knowledge base holds problem knowledge, such as guidance for selecting decision alternatives and uncontrollable inputs, problem relationships, or advice in interpreting possible outcomes. The model base is a repository for the formal models of the decision problem and the methodology for developing results (simulations and solutions) using these formal models. Processing will generate status reports on events and alternatives, simulated outcomes, decision recommendations, and explanations for the recommendations and further processing advice. Feedback provides additional data, knowledge, and models created from the processing.

As such, the MSS will enable the user to perform the operations and computations involved in all four processing tasks and generate all outputs shown in Figure 1.

EVALUATION OF DMSS COMPONENT SYSTEMS THROUGH SIMULATION

Issues, Controversies, and Problems

In theory, the support offered by DSS, EIS, and KBS/ES should improve the process of, and outcomes from, decision making (Forgionne, 1999; Kumar, 1999). Case studies (Lilien, Rangaswamy, Bruggen, & Starke, 2004; Sarter & Schroeder, 2001), field studies (Adelman, Gualtieri, & Riedel, 1994; Kanungo et al., 2001; Sojda, 2004), and experiments (Adleman, 1991; Maynard, Burstein, & Arnott, 2001; Parikh, Fazlollahi, & Verma, 2001; Pratyush & Abhijit, 2004) have all offered evidence that generally supports this theory. Conceptually, the synergistic effects from the integrated functionality of an MSS should further improve decision making when compared to individual DMSSs. There is also some experimental evidence to support this theory (Forgionne

& Kohli, 2000). Yet, there are important gaps in this body of empirical testing. First, it is difficult to acquire and motivate case- and field-study participants, and the acquired participants may not be representative of the population. Second, few, if any, comparative studies measure the separate decision contributions of the individual DMSSs or functional components in the MSS.

These gaps are important for several reasons. Proper isolation of individual or functional contribution can contribute to a proper matching of system types with decision problems. Linking the effects of the isolated contribution to decision-making phases also will facilitate situational system design, development, and implementation. Such linkages can reduce the time and costs involved in the DMSS analysis and design process and provide direct measures of comparative system benefits. This approach combined with population studies will enable researchers and practitioners to generalize results and findings.

Solutions and Recommendations

Simulation can be used to gather pertinent data and conduct the comparative DMSS analyses. Since an extremely large number of trials can be performed in a very short period of time, simulation can generate the population information needed for generalization. While the approach is best suited to problems involving tangible variables, simulation also can incorporate intangible factors through the use of categorical and dummy variables (Coats, 1990; Wildberger, 1990). Once stated categorically, the intangible factors can be linked to the tangible factors through the simulation model equations.

The simulation study utilizes a complex semistructured problem, frequently used in management training and evaluation and typically requiring decision-making support (McLeod, 1986). This problem involves a market in which top management uses price, marketing, research and development, and plant investment to compete for a product's four-quarter total market potential. Demand for the organization's products will be influenced by (a) management actions, (b) competitors' behavior, and (c) the economic environment. The decision objective is to plan a four-quarter strategy that would generate as much total profit as possible.

Strategy making requires (a) setting the product price, marketing budget, research and development expenditures, and plant investment and (b) forecasting the competitors' price, competitors' marketing budget, a seasonal sales index, and an index of general economic conditions. Twelve additional variables, including plant capacity, raw-materials inventory, and administrative expenses, will be calculated from the strategy. Initial values for these twelve variables form the scenario for decision making. These 20 (controllable, uncontrollable, and calculated) variables jointly influence the profitability of the organization.

The problem is sequential in nature. Current decisions are affected by decisions and forecasts in previous and subsequent quarters. In this dynamic environment, poor strategies will have unrecoverable negative consequences over the planning horizon.

A precise and explicit model of the decision problem was programmed in the SAS System for Information Delivery. This software provided a robust programming environment where the decision support system simulation can be created and evaluated (Spector, 2001). Unlike other software approaches, SAS provides a series of linked modules that deliver, in an integrated and comprehensive manner, the wide range of mathematical and statistical tasks needed to perform the simulations.

In a typical DSS, the user would provide the controllable and uncontrollable variable values for the decision model. To incorporate the diversity of inputs from a population of users, each variable was assumed to follow a standard normal distribution with a mean of 0 and a standard deviation of 1. Using the scenario values, the permissible management game ranges, and SAS's random normal function, formulas were developed to ensure that input values would fall within the permissible ranges according to normal probability distributions. Figure 2 presents the corresponding SAS program.

The simulation study includes EIS capabilities within the management game. An EIS focuses on the intelligence (gaining a general problem understanding) phase of decision making. Insights about the decision environment, such as forecasted economic conditions and competitors' potential actions, are an essential form of intelligence. Within the management game, such intelligence can be expressed as guidance for selecting the values of the uncontrollable variables (economic index, seasonal index, competitor's price, and competitor's marketing). Guidance was provided for the selections through the documentation provided with the management game, and the guided values would generate good, although not likely optimal, profits for the organization.

In practice, users may not accept the intelligence guidance. To account for this possibility, guidance acceptance was assumed to follow a standard normal distribution with a mean of 0 and a standard deviation of 1. Simulated values greater than 0 from this distribution represented user acceptance of the guidance, while values of 0 or less constituted rejection of the advice. When users rejected guidance, uncontrollable-variable values were simulated with Figure 2's uncontrollable-inputs section. Figure 3 presents the relevant SAS program.

The simulation study also included KBS/ES capabilities. The focus in a KBS/ES is on the choice (selection of preferred alternatives) phase of decision making. Within the management game, this focus can be expressed as guidance for selecting the values of the controllable variables (price, marketing, research and development, and plant investment). The management-game documentation again provided the guidance for the selections. As with the EIS, guidance acceptance was assumed to follow a standard normal distribution with a mean of 0 and a standard deviation of 1, and simulated values greater than 0 represented user acceptance. When users rejected guidance, controllable-variable values were simulated with Figure 2's controllable-inputs section. Figure 4 presents the relevant SAS program.

By combining the capabilities of DSS, EIS, and KBS/ES, the management game represents an MSS. Consequently, there would be guidance

Figure 2. SAS program for normally distributed DSS inputs

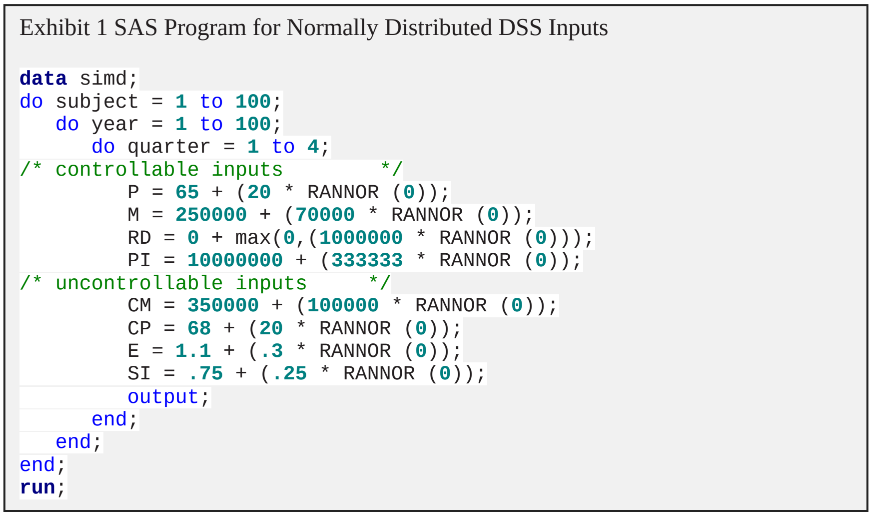
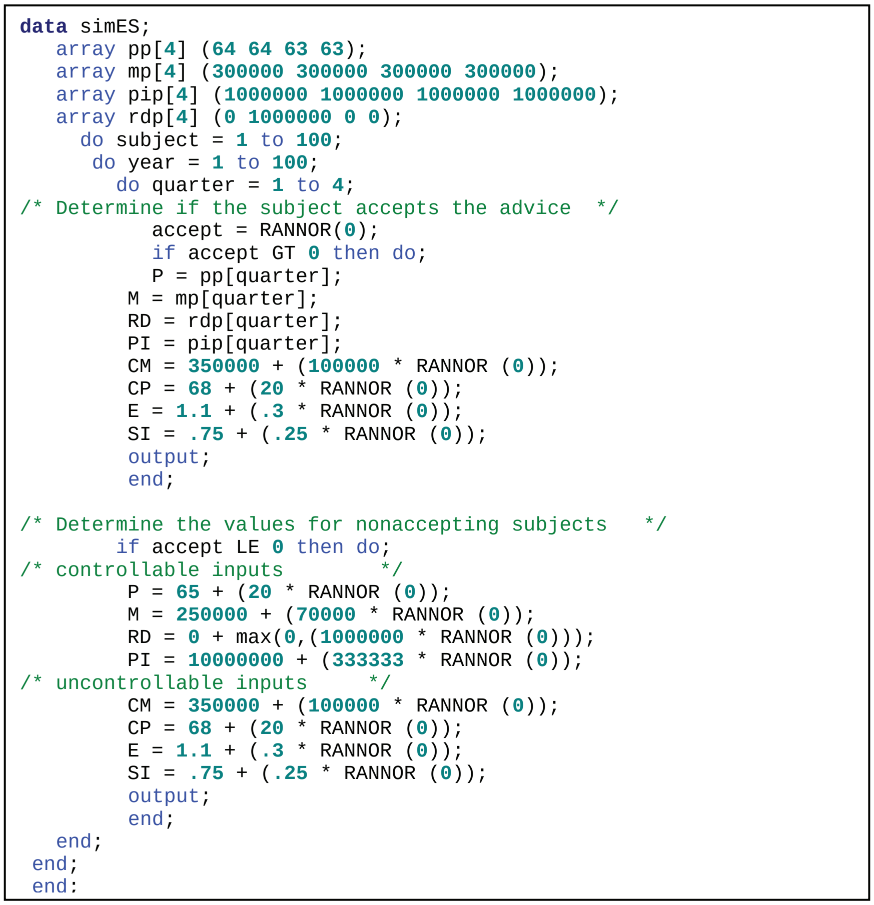


Exhibit 1 SAS Program for Normally Distributed DSS Inputs

```
data simd;
do subject = 1 to 100;
   do year = 1 to 100;
      do quarter = 1 to 4;
/* controllable inputs        */
         P = 65 + (20 * RANNOR (0));
         M = 250000 + (70000 * RANNOR (0));
         RD = 0 + max(0,(1000000 * RANNOR (0)));
         PI = 10000000 + (333333 * RANNOR (0));
/* uncontrollable inputs     */
         CM = 350000 + (100000 * RANNOR (0));
         CP = 68 + (20 * RANNOR (0));
         E = 1.1 + (.3 * RANNOR (0));
         SI = .75 + (.25 * RANNOR (0));
         output;
      end;
   end;
end;
run;
```

Figure 3. SAS program for normally distributed EIS inputs



```
data simES;
   array pp[4] (64 64 63 63);
   array mp[4] (300000 300000 300000 300000);
   array pip[4] (1000000 1000000 1000000 1000000);
   array rdp[4] (0 1000000 0 0);
     do subject = 1 to 100;
      do year = 1 to 100;
        do quarter = 1 to 4;
/* Determine if the subject accepts the advice  */
           accept = RANNOR(0);
           if accept GT 0 then do;
           P = pp[quarter];
         M = mp[quarter];
         RD = rdp[quarter];
         PI = pip[quarter];
         CM = 350000 + (100000 * RANNOR (0));
         CP = 68 + (20 * RANNOR (0));
         E = 1.1 + (.3 * RANNOR (0));
         SI = .75 + (.25 * RANNOR (0));
         output;
         end;

/* Determine the values for nonaccepting subjects   */
        if accept LE 0 then do;
/* controllable inputs        */
         P = 65 + (20 * RANNOR (0));
         M = 250000 + (70000 * RANNOR (0));
         RD = 0 + max(0,(1000000 * RANNOR (0)));
         PI = 10000000 + (333333 * RANNOR (0));
/* uncontrollable inputs     */
         CM = 350000 + (100000 * RANNOR (0));
         CP = 68 + (20 * RANNOR (0));
         E = 1.1 + (.3 * RANNOR (0));
         SI = .75 + (.25 * RANNOR (0));
         output;
         end;
   end;
 end;
 end:
```

for both the controllable- and uncontrollable-variable values. As with the EIS and KBS/ES, (a) guidance acceptance was assumed to follow a standard normal distribution with a mean of 0 and a standard deviation of 1, (b) simulated values greater than 0 represented user acceptance, and (c) when users rejected guidance, variable values were simulated with Figure 2's program.

Figure 5 presents the relevant SAS program. The various simulations were run for 100 users across 100 years, with each year involving four quarters. This methodology generated 40,000 observations for the comparative analysis, including values for the controllable, uncontrollable, and calculated variables, including the organization's net profit after tax. These data were used in an ANOVA (analysis of variance) to test whether there were any significant differences in net profits from DSS, EIS, KBS/ES, and MSS use.

Figure 6 summarizes the ANOVA statistics, and this exhibit also presents means for net profit (the outcome variable in the study).

As Figure 6 demonstrates, there was a significant net-profit difference between the simulated DSS, EIS, KBS/ES, and MSS users. Furthermore, Scheffe's test indicates that EIS, KBS/ES, and MSS users all did better than DSS users. MSS and KBS/ES users also did better than EIS users, but there were no significant differences between the net profits of KBS/ES and MSS users. Although the analyses are not reported here, the same relative results occurred when only accepting-user data were utilized.

Figure 4. SAS program for normally distributed KBS/ES inputs

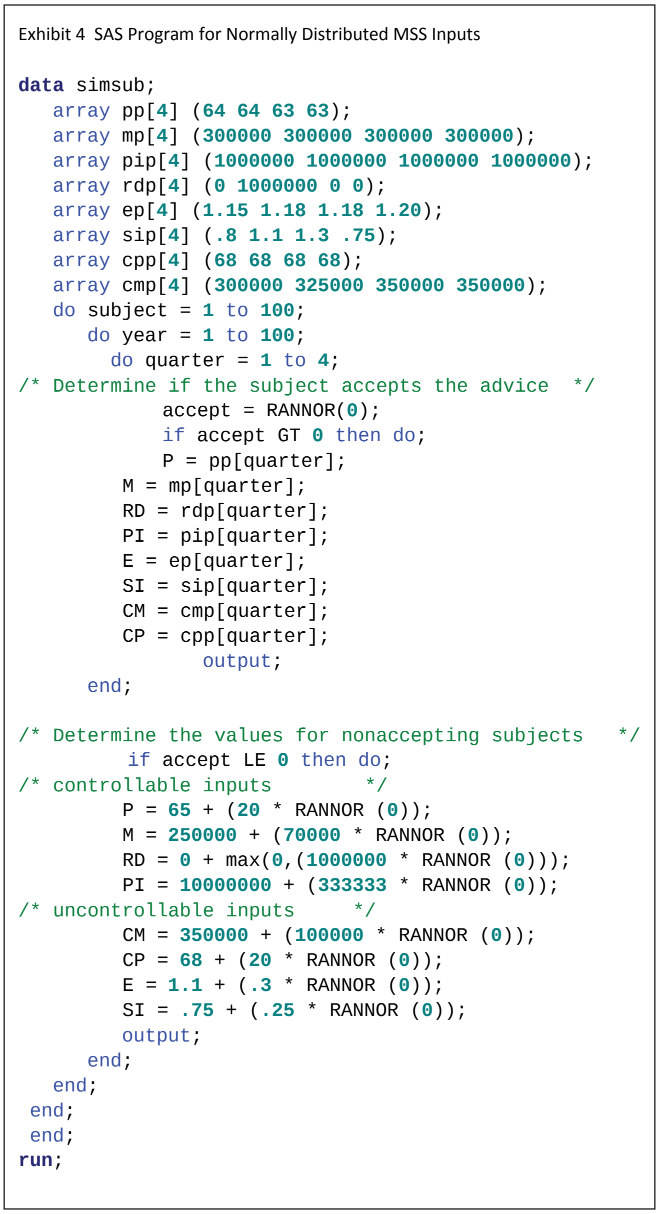


Exhibit 4 SAS Program for Normally Distributed MSS Inputs

```
data simsub;
   array pp[4] (64 64 63 63);
   array mp[4] (300000 300000 300000 300000);
   array pip[4] (1000000 1000000 1000000 1000000);
   array rdp[4] (0 1000000 0 0);
   array ep[4] (1.15 1.18 1.18 1.20);
   array sip[4] (.8 1.1 1.3 .75);
   array cpp[4] (68 68 68 68);
   array cmp[4] (300000 325000 350000 350000);
   do subject = 1 to 100;
      do year = 1 to 100;
        do quarter = 1 to 4;
/* Determine if the subject accepts the advice  */
            accept = RANNOR(0);
            if accept GT 0 then do;
            P = pp[quarter];
         M = mp[quarter];
         RD = rdp[quarter];
         PI = pip[quarter];
         E = ep[quarter];
         SI = sip[quarter];
         CM = cmp[quarter];
         CP = cpp[quarter];
                output;
      end;

/* Determine the values for nonaccepting subjects   */
         if accept LE 0 then do;
/* controllable inputs        */
         P = 65 + (20 * RANNOR (0));
         M = 250000 + (70000 * RANNOR (0));
         RD = 0 + max(0,(1000000 * RANNOR (0)));
         PI = 10000000 + (333333 * RANNOR (0));
/* uncontrollable inputs     */
         CM = 350000 + (100000 * RANNOR (0));
         CP = 68 + (20 * RANNOR (0));
         E = 1.1 + (.3 * RANNOR (0));
         SI = .75 + (.25 * RANNOR (0));
         output;
      end;
   end;
 end;
 end;
run;
```

Since the differences can be traced to the guidance offered by each system, these results suggest that controllable-variable guidance is more important in this decision problem than uncontrollable-input advice. The negative profits across the system types suggest that the advice provided by the management-game documentation was flawed.

FUTURE TRENDS

As this simulation study illustrates, the type of advice can lead to different decision outcomes. This study examined the effects of static advice typically offered through EIS and KBS/ES. Other DMSSs may offer dynamic guidance, changing the advice depending on the evolving circumstances

Figure 5. SAS program for normally distributed MSS inputs

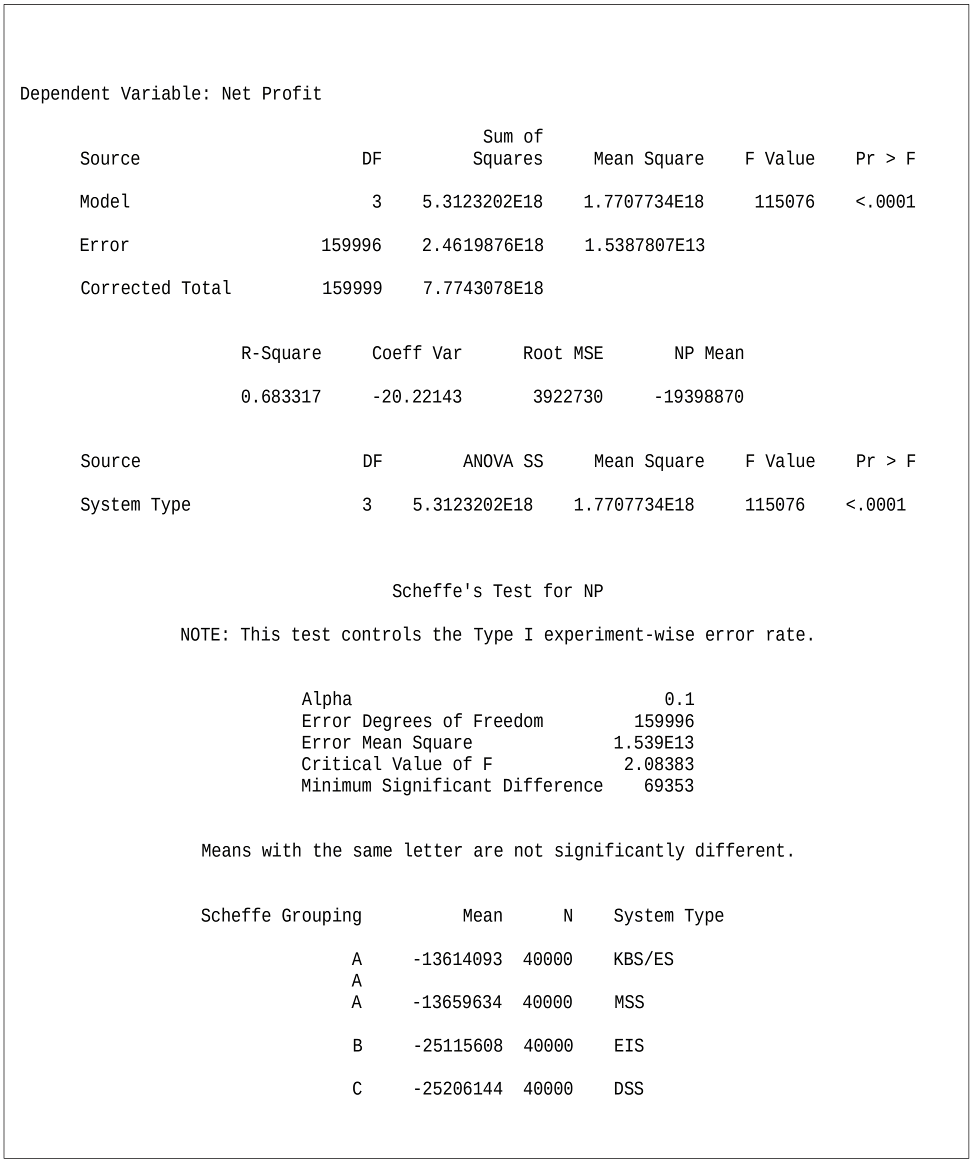
```
data simsub;
   array pp[4] (64 64 63 63);
   array mp[4] (300000 300000 300000 300000);
   array pip[4] (1000000 1000000 1000000 1000000);
   array rdp[4] (0 1000000 0 0);
   array ep[4] (1.15 1.18 1.18 1.20);
   array sip[4] (.8 1.1 1.3 .75);
   array cpp[4] (68 68 68 68);
   array cmp[4] (300000 325000 350000 350000);
   do subject = 1 to 100;
      do year = 1 to 100;
        do quarter = 1 to 4;
/* Determine if the subject accepts the advice  */
           accept = RANNOR(0);
           if accept GT 0 then do;
           P = pp[quarter];
         M = mp[quarter];
         RD = rdp[quarter];
         PI = pip[quarter];
         E = ep[quarter];
         SI = sip[quarter];
         CM = cmp[quarter];
         CP = cpp[quarter];
             output;
      end;

/* Determine the values for nonaccepting subjects   */
        if accept LE 0 then do;
/* controllable inputs        */
         P = 65 + (20 * RANNOR (0));
         M = 250000 + (70000 * RANNOR (0));
         RD = 0 + max(0,(1000000 * RANNOR (0)));
         PI = 10000000 + (333333 * RANNOR (0));
/* uncontrollable inputs     */
         CM = 350000 + (100000 * RANNOR (0));
         CP = 68 + (20 * RANNOR (0));
         E = 1.1 + (.3 * RANNOR (0));
         SI = .75 + (.25 * RANNOR (0));
         output;
      end;
   end;
 end;
 end;
```

in the decision situation. Such dynamic advice can be derived from the decision model's mathematical relationships and rendered in real time through the system. The simulation approach can also be used to alter the mathematical relationships as the decision environment evolves.

Results from any simulation are only as good as the assumptions used in the analyses. This study assumed that the management game was a reasonable representation of many organizations' strategic decision-making problems. Different organizations, however, may utilize different management philosophies, accounting principles, and decision objectives. If so, the decision model should be changed to reflect the organization's practices, philosophies, objectives, and decision environments. In particular, the profit equation may be replaced with an alternative measure or measures of performance, some tangible and others intangible. Variables and relationships may be defined and measured differently. Additional environmental factors may be added to the equations. While such alterations would change the specific form of the simulation model, the general model and experimental methodology would still be applicable.

This study also assumed that acceptance rates and input values would follow normal distributions. A variety of other distributions is possible, including the binomial and Gamma distributions.

Figure 6. ANOVA test for the organization's net profit



```
Dependent Variable: Net Profit

                                           Sum of
      Source                     DF       Squares     Mean Square    F Value    Pr > F

      Model                       3    5.3123202E18    1.7707734E18     115076    <.0001

      Error                  159996    2.4619876E18    1.5387807E13

      Corrected Total        159999    7.7743078E18

                    R-Square     Coeff Var      Root MSE       NP Mean

                    0.683317     -20.22143       3922730     -19398870

      Source                     DF        ANOVA SS     Mean Square    F Value    Pr > F

      System Type                3    5.3123202E18    1.7707734E18     115076    <.0001


                                   Scheffe's Test for NP

                NOTE: This test controls the Type I experiment-wise error rate.

                          Alpha                              0.1
                          Error Degrees of Freedom        159996
                          Error Mean Square             1.539E13
                          Critical Value of F            2.08383
                          Minimum Significant Difference    69353


                  Means with the same letter are not significantly different.


                  Scheffe Grouping          Mean      N    System Type

                                 A     -13614093  40000    KBS/ES
                                 A
                                 A     -13659634  40000    MSS

                                 B     -25115608  40000    EIS

                                 C     -25206144  40000    DSS
```

Further studies, then, should examine the sensitivity of the results to changes in distributions.

Finally, this study examined only four types of DMSSs. There are others, including creativity-enhancing, decision technology, and machine learning systems. In addition, the functionality of the studied systems was operationalized in particular ways. Other operational possibilities exist, such as providing AI-based guidance to model formulations. The other DMSSs with different forms of guidance and assistance warrant further study.

CONCLUSION

The results of this study confirm that EIS, KBS, and MSS all improve decision making when compared to a basic DSS. In addition, these results suggest that guidance for controllable variables is relatively more important than guidance for uncontrollable variables in achieving decision objectives. Since the results are expressed in dollars of net profit, the findings provide an objective measure of determining the relative decision value of the various DMSS functions. Moreover, as large-scale simulation that approaches a census is studied, the evaluation results should be more generalizable in comparison to sample studies that use participants in laboratory, field, or case settings.

The study does not support the concept that higher synergistic value can be achieved through higher levels of functional integration. Instead, it may be sufficient in many circumstances to stop the integration at intelligent decision-making support, adding KBS/ES or other artificially intelligent capabilities to a basic DSS.

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KEY TERMS

Decision Making Process: This is the process of developing a general problem understanding, formulating the problem explicitly, evaluating alternatives systematically, and implementing the choice.

Decision Support System (DSS): A DSS is an information system that interactively supports the user's ability to evaluate decision alternatives and develop a recommended decision.

Executive Information System (EIS): An EIS is an information system that accesses, reports, and helps users interpret problem-pertinent information.

Knowledge-Based or Expert System (KBS or ES): This is an information system that captures and delivers problem-pertinent knowledge and advice for users.

Management Game: It is a model used by a participant to experiment with decision strategy plans in a simulated organization.

Management Support System (MSS): An MSS is an information system that integrates the functional capabilities of a decision support system, executive information system, and knowledge-based or expert system.

Simulation: A simulation is an approach to data creation and analysis that utilizes a model to represent reality.

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Chapter 1.14

Computer-Supported Collaborative Work and Learning:

A Meta-Analytic Examination of Key Moderators in Experimental GSS Research

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ABSTRACT

Evident and growing research interest has been witnessed on the relationship between the use of computer-based systems and effective communication in group-related activities such as collaborative learning and training. The various terms accorded to this research stream include virtual teams, e-collaboration, computer-supported collaborative work, distributed work, electronic meetings, etc. A notable and well-accepted aspect in the information system field is group support systems (GSS), the focus of this article. The numerous GSS studies have reported findings which may not be altogether consistent. An overall picture is much in want which attends to the synthesizing of the findings accumulated over decades. This article presents a meta-analysis study aimed at gaining a general understanding of GSS effects. We investigate six important moderators of group outcomes, namely group size, task type, anonymity, time and proximity,

level of technology, and the existence of facilitation. The results point to important conclusions about the phenomenon of interest; in particular, their implications vis-à-vis computer-supported collaborative learning technologies and use are discussed and highlighted along each dimension of the studied variables.

INTRODUCTION

Group or team-based work and collaborations are becoming an integral part of education and learning environments. With the advance of information communication technologies, there has been a growing potential for utilizing computerized systems to support idea generation, project assignment, instant communication among the IT-age students and educators. The phenomenon has arrested the interest of both educational field and information systems (IS) researchers. In education realm, an emerging area in the instructional technology field called *computer-supported collaborative learning* (CSCL) has focused on the ways to support group learning in different forms of technologies; the technologies include electronic discussion environments, distance learning systems, and intelligent agents (e.g., Koschmann, 1996; Ready, Hostager, Lester, & Bergmann, 2004; Strijbos, Martens, & Jochems, 2003).

In IS literature, *Group Support System*s (GSS) research has accumulated a substantial body of knowledge on the effects of computer-based systems in supporting group work in related to a variety of tasks such as idea generation and decision making. Based on the success of using GSS technology to support groups in nonacademic settings, researchers have begun to explore ways to apply GSS technology in classroom to support and enhance group-based learning (Tyran & Shepherd, 2001). GSS are used in a classroom setting or distance learning groups to support and structure group communication and learning activities (e.g., Alavi, Marakas, & Yoo, 2002; Sawyer, Ferry, & Kydd 2001; Leidner & Jarvenpaa, 1995).

While the past studies centered along using GSS to enhance group work outcomes are numerous, the findings are not altogether consistent. Many researchers have devoted towards efforts in figuring out what GSS can help the group to achieve by reviewing and summarizing the previous studies. Several early meta-analyses exist (e.g., Benbasat & Lim, 1993; McLeod, 1992; Shaw, 1998). Other reviews involve tabular methods which are unavoidably less rigorous (Fjermestad & Hiltz, 1999). Tyran and Shepherd (2001) presented a GSS research framework for analyzing the impact of collaborative technology on group learning, by referring to an earlier framework concerning electronic meeting systems on group processes and outcomes (Pinsonneault & Kraemer, 1990). Nevertheless, as the framework is built based on face-to-face or "same time, same place" research studies (Leidner & Jarvenpaa, 1995), it is somewhat limited in its applicability to group work or learning in other forms such as distributed work or Web-based distance learning. Dennis and Wixom (2002) examined five moderators (task, GSS tools, type of group, group size, and facilitation) and their potential effects on GSS use. It has been noted that for GSS researchers trying to extend the common body of knowledge—and for GSS technology practitioners, such as teaching facilitators, seeking to apply research appropriately—it is necessary for them to "look deeper than the overall effects of GSS use" (p. 236, Dennis & Wixom, 2002). A pertinent question is *under what conditions* collaborative technology use would improve group performance because there are *moderators* that influence the specific effects of GSS (Beauclair, 1989; Dennis & Wixom, 2002;).

Following this idea, instead of focusing on examining the effect of GSS technology alone, the current study attempts to look into *how key moderators individually and jointly influence important group work outcomes* using a meta-analytic technique to help us arrive at conclusions backed by quantitative analysis, as well as provide insights that can be brought into both CSCL and GSS areas. Specifically, our primary interest concerns the use of GSS technology and research in the learning environment. Correspondingly, the article focuses on six important moderators which are pertinent to both organizational and educational contexts; they are group size, task type, anonymity, time and proximity, level of technology, and the existence of facilitation. Hypotheses of the effects they may bring to the group along with the use of GSS, as well as the research model, are articulated. Next, we present a meta-analysis on 33 quantitative experimental studies to gain a synthesized view of the GSS effectiveness. The subsequent sections dwell on the results and discussions relating to each of the outcome variables. We conclude the article by pointing out the relevance to, and implications for, computer-supported collaborative learning research; as well, future research avenues are identified.

THE RESEARCH FRAMEWORK

Learning and GSS Technology

Collaborative learning, as compared to individual learning, is helpful and important for understanding and exploring the process of learning. Embedded within the definition of cooperative learning is an enormous diversity of cooperative approaches. These may be informal as short meetings to simply discuss and share information, or formal approaches where structure is imposed with specific ways of forming teams. Students may be working together on projects or other creative activities involving specific contents.

Growing interests in supporting the needs of collaborative learning, along with concurrent improvements in GSS, have led to the emergence of a research area in the instructional technology field in CSCL; research in CSCL centers on the interaction of computer-supported learning systems and GSS by integrating collaborative learning and Information Technology (IT) (O'Malley, 1995). The rising importance of teamwork and group decision-making has triggered vast research efforts since the 1960's when the GSS concept was first raised by Doug Engelbart (Wagner, Wynne, & Mennecke, 1993). GSS are defined as computer-based systems that support group decision making which is the result of the integration of communication, information processing and computer-based group structuring and support (DeSanctis & Gallupe, 1987; Huber, 1984; Poole & DeSanctis, 1990). The CSCL research domain encompasses benefits derived from GSS applications to support group-oriented methods of instruction, including networked discussion environments and distance learning systems.

Desktop conferencing, videoconferencing, co-authoring features and applications, electronic mail and bulletin boards, meeting support systems, voice applications, workflow systems, and group calendars are key examples of groupware (Grudin, 1991). In addition to a set of common features, different applications provide users with different tools and functions. Many IS researchers have used GSS in the classroom and experiments to enhance the learning experience (Kwok, Ma, & Vogel, 2002), whereas other works in IS and related fields have developed asynchronous learning networks (ALNs) (Coppola, Hiltz, & Rotter, 2002). These systems enable affective learning objectives related to interactive communication and teamwork to be achieved, on top of meeting the traditional cognitive learning objectives.

GSS were originally designed to support discussion and decision making in the commercial/business sector, but in the last few years there has been a surge of interest in their usage to support collaborative learning (Khalifa & Kwok, 1999; Vogel, Davison, & Schroff, 2001). DeSanctis and Gallupe's (1987) two-by-two framework for GSS has been applied to understanding IT usage in learning environments. Although this framework enables us to classify learning settings based on

Table 1. GSS features and their facilitation of group communication

GSS support feature	Feature description	Potential benefit
Anonymity	It supports group members to input information to the group anonymously by means of an electronic communication channel.	It may help to reduce evaluation apprehension by allowing group members to submit their ideas without having to speak up in front of the rest of the group.
Parallel Communication	It supports all group members to communicate at the same time, implemented in a GSS by means of an electronic communication channel.	It may help to reduce domination in a group by one or more members, since parallel communication allows more than one person to express ideas at a time. In larger groups, the feature may also reduce problems associated with limited airtime for group members, since all group members can submit information concurrently without having to wait for other to finish speaking. This feature is able to support more complex communication in groups as compared to that in groups without the aid of GSS (Bandy & Young, 2002).
Process Structure	It supports the process techniques or rules that guide the content, pattern or timing of communication. Besides, it provides structure to a group process by establishing an approach the group may follow in order to perform a group activity. This feature is implemented in a GSS by means of one or more group-oriented software tools that support group activity.	It may help to reduce coordination problems for a group by keeping the group focused on the task or agenda. For example, to focus on electronic discussion, an idea generation activity may be structured by using an electronic discussion system with predefined categories (Bandy & Young, 2002). The process structured by this feature contributes to effective learning (Kwok & Khalifa, 1998).

the dimensions of space and time, it does little to improve our understating of the technologies required to support the learning objectives in different settings. Sharda, Romano, Lucca, Weiser, Scheets, and Chung (2004) propose extending DeSanctis and Gallupe's framework by adding a third dimension, learning objectives achieved (cognitive and affective in classroom form vs. cognitive, affective and psychomotor in lab). Craig and Shepherd (2001) have drawn from the GSS and education literatures to develop a research framework that may be used to analyze the impacts of collaborative technology on learning. This framework is an extension from Pinsonneault and Kraemer's (1990) framework for electronic meeting systems research. Table 1 illustrates how the GSS features can support groups in collaborative learning (Craig & Shepherd, 2001).

Effects of Important Moderators

Fjermestad (1998) attempts to integrate various GSS research models into a comprehensive model. He included four major categories of variables: *contextual* or *independent* variables, *intervening* variables, *group adaptation processes*, and *outcomes* or *dependent variables*. However, the variables included in this framework are overwhelming with some may not be important in practice and difficult for manipulating. Therefore, for the interest of this article, we selected the potential moderators from this framework cautiously.

The basic criteria for choosing the moderators necessitate them to be practically important and to have a clearly defined measurement. We need a theoretical basis for each moderator to suggest that it might have the effects on the group activities. Therefore, we choose to consider six moderators from the four categories defined by Fjermestad (1998): group size, task type, anonymity, time and proximity, level of technology, and the existence of facilitation.

Group performance and satisfaction serve as the two categories of outcome variables, as consistent with previous studies (e.g., Sambamurthy & Poole, 1992; Tan, Raman, & Wei, 1994). We defined these two outcomes according to Benbasat and Lim (1993) and Dennis and Kinney (1998) in the following way: (1) performance includes decision quality, number of ideas and time to reach decision; (2) satisfaction includes process satisfaction and decision satisfaction.

The rationales for studying group performance in collaborative learning are explained in the following. Group collaborative technologies have been found to help to increase teacher-student interaction, and to make learning more student-centered (Hiltz, 1995). Collaborative technologies may potentially eliminate geographical barriers while providing increased convenience, flexibility, currency of materials, knowledge retention, individualized learning, and feedback (Kiser, 1999). In practice, more and more professionals have to collaborate and it is an important goal for any educational institution to improve students' performance in collaborative situations. With the group evaluation approach, one may verify whether the performance of a specific group has increased or assess if group members have developed some generic ability to collaborate which they could possibly reuse in other groups (Dillengourg, 1999). An important potential benefit of CSCL environment is the support of diverse learning styles (Wang, Hinn, & Kanfer, 2001). Hiltz and Turoff (1993) found a strong tendency toward more equal participation, and that more opinions tended to be asked for and offered.

Group Size

Research on the effects of group size in nonGSS-supported group work has a long history. The general consensus is that as group size increases, effectiveness increases because there are more individuals who will contribute to knowledge and skills (Hare, 1981; Thomas & Fink, 1963). However, upon the reach of a certain optimal value, the difference in participation becomes more pronounced so that a few members will dominate the group meeting (Shaw, Hinn, & Kanfer, 1981; Diehl & Stroebe, 1987) and thus the effectiveness and member satisfaction will decrease (Hare, 1981). The optimum size for groups without GSS support is suggested to be no more than six in the perception of managers (James, 1951; Rice, 1973). Empirical research has drawn similar conclusions suggesting the optimum size to be five (Hackman, 1970; Hare, 1981; Shaw, 1981).

In the case of GSS-supported group meetings, the optimum size of the group is unknown. Two studies have found no differences on the effects due to group size (Watson, DeSanctis, & Pool, 1988; Zigurs et al., 1988). Both of the studies used groups of three and four. In addition, GSS have the potential to reduce the barriers to communication that will increase with group size, thus we expect the performance of groups—and larger groups in particular—will be improved (DeSanctis & Gallupe, 1987). Therefore, we believe that the optimum size for GSS groups will be larger than the nonGSS groups.

Previous nonGSS research suggests that performance does not increase as group size becomes larger (Dennis, Valacich, & Nunamaker, 1990). GSS research has found that larger groups benefit more from GSS use than smaller groups (Dennis, 1991; Dennis et al., 1990; Dennis & Valacich, 1991; Gallupe, Dennis, Cooper, Valacich, Nunamaker Jr., & Bastianutti, 1992; Nunamaker et al., 1988; Valacich, Dennis, & Connolly, 1994). Theories suggest that GSS can reduce the following process losses which are common to nonGSS groups: air time, production blocking, evaluation apprehension, free riding, and cognitive inertia (Dennis et al., 1990).

H1a: Large groups will generate more ideas than small groups.
H1b: Large groups will have higher decision quality than small groups.
H1c: Large groups will have a shorter time to reach decision than small groups.

Previous research has found decreased user satisfaction in larger groups in the context of non-GSS-supported group meetings due to the decreased performance, increased evaluation apprehension and the lack of equality of participation (Shaw, 1981; Diehl & Stroebe, 1987). In the GSS-supported meeting environment, we expect increased performance, decreased evaluation apprehension and increased equality of participation. Therefore, the user satisfaction will be higher for larger groups in GSS supported environment.

H1d: Large groups will have higher process satisfaction than small groups.
H1e: Large groups will have higher decision satisfaction than small groups.

Task Type

The reason for studying task type as a moderator is that groups in an organization engage in a wide variety of tasks, thus necessitating investigations of the differential effects of various task types (Hackman, 1968). According to McGrath (1984), tasks can be divided into four quadrants (generating, choosing, negotiating and executing). The first two types are relevant to the GSS context, and commonly studied in GSS experimental studies. Likewise, the current work focuses on idea generation tasks and decision-making tasks, as they are considered most common forms of collaborative learning tasks (Ready et al., 2004).

Idea generation tasks involve participants to work together to generate ideas or plans. The results are best obtained through the active contribution of each participant. The number of ideas and quality of the ideas are most important in such tasks. However, for decision-making tasks, members have to reach consensus to make a decision. The decision has to be superior to other alternatives. Therefore, the quality of the decision is the most important for this type of tasks. As the measures for the results of these two task types are different, we will be unable to compare the performance outcome for the different task types.

Since idea generation tasks are additive tasks which do not need to reach a consensus as in the case for decision-making tasks, the level of conflict will be lower for idea generation tasks. Shaw (1998) compared the GSS groups performing the two tasks and found that the group performing idea generation tasks had higher satisfaction. Therefore, we have the following hypotheses:

H2: Process satisfaction will be higher for idea generation tasks than for decision-making tasks.

Anonymity

One important feature that GSS can provide to group meetings is anonymity compared to nonGSS meetings. Participants can sit in front of each terminal to input text with their identities being unrevealed. The anonymity provided through GSS sessions have been hailed as the primary way through which GSS help groups overcome process losses (the difference between the group's potential and actual performance (Kerr & Bruun, 1981)). Anonymity can facilitate group processes by moderating those who dominate group discussions (decision by minority rule), have a high position in the group (decision by authority method), and rely on nonverbal cues to get their point across. Wilson and Jessup (1995) propose that anonymous GSS groups should allow more ideas to be generated during a meeting, because group members with low-status can contribute ideas more freely and openly. One of the benefits of anonymity is that it may reduce the pressure to conform to the groups thought the process and minimize evaluation apprehension. These process gains are often tempered by an increase in free riding because it is more difficult to determine when someone is free riding (Albanese & VanFleet, 1985). Other benefits such as more objective evaluation and the creation of a low-threat environment are attributed to anonymity and can ultimately result in improved decision quality (Nunamaker, Applegate, & Konsynski, 1993). Anonymity removes the identity of individuals which eliminates minority influence. The anonymous discussion tends to be more open, honest, and free-wheeling (Nunamaker et al., 1993).

H3a: Anonymous groups will generate more ideas than identified groups.
H3b: Anonymous groups will have higher decision quality than identified groups.
H3c: Anonymous groups will take a shorter time to reach decision than identified groups.

Rao and Monk (1999) stated that if participants made a decision anonymously, the need for external justification would not exist and the participants' level of commitment to the group decision would be lower than the commitment of identified participants because the identified participants would require external justification. If the participants are anonymous, they only need to maintain an internal sense of competence. This difference in desire to appear externally competent results in a higher level of commitment when participants are identified. Thus the level of anonymity provided in a problem-solving environment (either GSS or face-to-face) will negatively impact user satisfaction with the group outcome. Anonymity also increases objective evaluation. In this case, contributions are judged based on their merits rather then on the source of the contribution. Criticism is perceived as being directed at the idea, not the contributor (Nunamaker et al., 1993). Therefore, it is hypothesized that increased anonymity should improve user attitudes because of the depersonalization of the comments and ultimately the critiques of the comments.

H3d: Anonymous groups are less satisfied with decision than identified groups.
H3e: Anonymous groups are more satisfied with process than identified groups.

Time and Proximity

Meeting environment can be divided into four categories with the different combination of the two dimensions, time and proximity (DeSanctis & Gallupe, 1987). They are: synchronous and colocated, synchronous and remote, asynchronous and co-located, and asynchronous and remote. We classify the synchronous and colocated meeting environment as face-to-face environment while the other three as Virtual Team environment. CSCL can be grouped in similar fashion, for example "same time, same place" learning (Leidner & Jarvenpaa, 1995), virtual classroom (Hiltz & Turoff, 1993), distance learning (Verdejo, 1993), and telelearning (Alavi, Wheeler, & Valacich, 1995).

Previous experimental studies mainly focus on the synchronous and colocated meetings which are called face-to-face meetings. However, today's global economy requires many organizations to coordinate work across a variety of intra- and inter-organizational boundaries (Armstrong & Cole, 1995; Carmel, 2006; Lipnack & Stamps, 1997). Virtual Teams allow organizations to improve efficiency and productivity, procure expert knowledge from internal and external sources, and transfer "best practice" information nearly instantaneously (Huber, 1990). Therefore, studying the GSS effect in Virtual Team environment attracted our attention.

GSS that supports Virtual Team have their own characteristic which is the store-and-forward capability across time and space. This characteristic allows members to attend to information at any time at which they can turn their attention to group problems; furthermore, it liberates message senders from having to wait for other members to finish (Watt, Walther, & Nowak, 2002), preventing "production blocking" (the tendency to hold back or forget information while waiting for a live speaking turn; see Connolly, Jessup, & Valacich, 1990). "Production blocking" is a very common problem in face-to-face group meetings as parallel input is often lacking in face-to-face meetings. Therefore, we have the following hypothesis:

H4a: Virtual Teams will generate more ideas than face-to-face teams.
H4b: Virtual Teams will have higher decision quality than face-to-face teams.
H4c: Virtual Teams will take a shorter time to reach decision than face-to-face teams.

Existing research suggests that team members' satisfaction may depend on the type of communication technology being used. Researchers suggest that the richness of the communication technology media may reduce many of the problems associated with Virtual Team interaction (Daft & Lengel, 1986; Dennis & Kinney, 1998). Face-to-face communication provides a richer medium for group communication since participants can use gestures, expressions and voice to communicate with each other. Therefore, we expect that the satisfaction level for Virtual Team will be lower.

H4d: Virtual Teams will have higher process satisfaction than face-to-face teams.
H4e: Virtual Teams will have higher decision satisfaction than face-to-face teams.

Level of Technology

DeSanctis and Gallupe (1987) identified three levels of GSS design to characterize the degree of technological sophistication of the system. Previous studies focused on the effects of level-1 GSS and level-2 GSS since level-3 GSS were not mature enough and the tools were rarely available in the market. Therefore, we choose to compare the effects of level-1 GSS and level-2 GSS.

Level-1 GSS attempt to remove common communication barriers through technical features such as anonymous input of ideas and preferences, large screen for simultaneous display of ideas and preferences, electronic message exchanging among members and compilation and display of members' assessments. Level-2 GSS provide decision modeling and group techniques aiming at reducing the uncertainty and "noise" in the group process. The former one supports primarily communication activities (such as entering ideas and simple rating, ranking and voting) while the latter provides support for communication and consensus activities (providing the structured decision techniques). An important enhancement in level-2 GSS is the support for both idea generation and synthesis.

The existing theories indicate the differences in the two systems result in the different of meeting outcomes in the following ways. Level-1 GSS provide support primarily for communication and do not impose strict structure on the meeting which does not hinder the participants' creativity compared to level-2 GSS (Sambamurthy & DeSanctis, 1990). As a result, we propose that level-1 GSS will provides better support for idea generation. However, level-1 GSS often lack the support for reaching group consensus. Level-2 GSS help groups reach agreement on fewer number of members' expectations, generate more valid and important assumptions, and achieve a superior quality of decision in a shorter time (Sambamurthy & DeSanctis, 1990). Level-2 GSS provide structure for groups to manage both communication and consensus activities. Groups using them may perceive that they have compared all ideas and know the differences and similarities between these ideas. As a result they may perceive their decision as a better one than others' (Sambamurthy & DeSanctis, 1990). They are also satisfied in the consensus reaching process since the support for consensus reaching helps them manage conflicts more easily (Sambamurthy & DeSanctis, 1990).

H5a: Groups using level-1 GSS will generate more ideas than those using level-2 GSS.
H5b: Groups using level-2 GSS will have higher decision quality than those using level-1 GSS.
H5c: Groups using level-2 GSS will take a shorter time to reach decision than those using level-1 GSS.
H5d: Groups using level-2 GSS will have higher process satisfaction than those using level-1 GSS.
H5e: Groups using level-2 GSS will have higher decision satisfaction than those using level-1 GSS.

The Existence of Facilitation

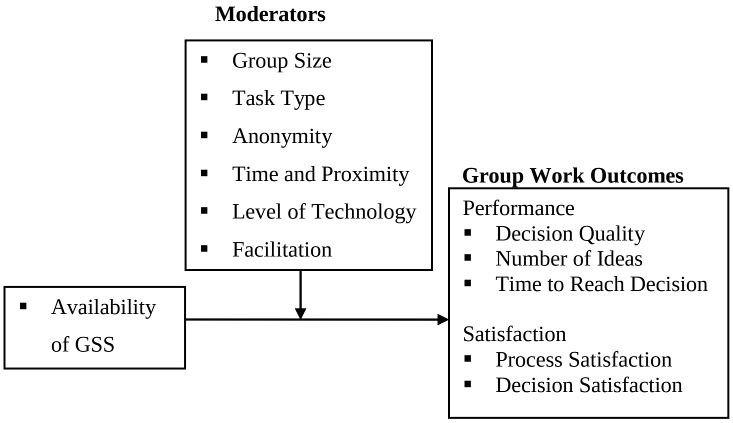
Facilitation is the external assistance on the group meeting while remaining neutral as to the content of discussion. A facilitator brings expertise regarding effective procedures and techniques to the meeting. The facilitator elicits, selects, and modifies structures drawn from expertise, from the available GSS tools, or from the members (Anson, Bostrom, & Wynne, 1995). It is generally believed that facilitation can improve meeting outcomes (Nunamaker et al., 1987). Adaptive Structuration Theory (AST) (DeSanctis & Poole, 1991; Gopal, Bostrom, & Chin, 1992; Poole & DeSanctis, 1987, 1989) highlights an additional, special role of group interaction—a means to appropriate technology-based and nontechnology structures to guide further group interaction. Structures are meant to organize and direct group behavior process. Appropriation is the "fashion in which a group uses, adapts, and produces a structure" (Poole & DeSanctis, 1989). When well-designed and relevant structures are successfully appropriated, the group interaction will be improved, which will in turn contribute to higher performance. Poole and DeSanctis (1989) suggest three dimensions which affect the appropriation of structures: faithfulness, attitudes and level of consensus. A facilitator can help the group successfully appropriate structures by providing guidance to encourage faithfulness, as well as encourage positive attitudes and consensus over the structures' use (Anson et al., 1995). Poole (1991) argues that freely interacting groups often do not effectively apply procedures unless assisted. Therefore, although the leaders and members can provide structures and support, the process may not be as effective as that with the presence of facilitators.

H6a: Groups with facilitators will generate more ideas than those without.
H6b: Decision quality will be higher for groups with facilitators than those without.
H6c: Groups with facilitators will reach decision in a shorter time than those without.

Relationships among group members may require mediation by an external source because of conflicts or power differences (Ackermann, 1996; Pinsonneault & Kramer, 1989). A facilitator can apply his or her expertise and experience of conflict management to mediate the group process effectively. Therefore, we expect the improved process satisfaction of group members. Facilitators are often experienced and well trained. Group members with facilitation support tend to think they have followed the guidance and instruction of a well-trained and experienced while neutral outsider. Therefore, they may imagine they have reached the decision under the guidance of an expert.

H6d: Groups with facilitators are more satisfied with process than those without.
H6e: Groups with facilitators are more satisfied with decisions than those without.

Figure 1. The research framework



The Research Framework

Figure 1 presents our research framework which encompasses hypotheses earlier raised.

THE META-ANALYSIS

Over almost three decades of GSS research, researchers conducted plenty of both quantitative and qualitative studies. Quantitative studies are mainly those experimental studies where the students are the main subjects and the researcher has control on the experimental settings. Researchers collect quantitative data from experts' judgment on the meeting outcomes and through post-session questionnaires.

Meta-analysis is a set of statistical procedures designed to accumulate experimental results across independent studies in the literature that address a related set of research questions. It is to deal with secondary data which are quantitative in nature. Unlike traditional research methods, meta-analysis uses the summary statistics from individual studies as the data points. A key assumption of this analysis is that each study provides a differing estimate of the underlying relationship within the population. By accumulating results across studies, one can gain a more accurate representation of the population relationship than is provided by the individual study estimators. The typical steps for meta-analysis studies include selection of studies and outcome measures, followed by analytic procedure and hypotheses testing. We adopt the meta-analysis approach as developed and detailed by Hunter and Schmidt1 (Hunter & Schmidt, 1990). Essentially, the meta-analysis procedure produces the mean effect size and a standard deviation across all studies. Positive effect sizes indicate that the mean effect of GSS use across all included studies was to increase the outcome measure (e.g., the use of GSS will increase decision quality). The following sections outline our research procedures.

Selecting Studies and Outcome Measures

The first step is to select the appropriate studies that investigate the performance of both a control group and a treatment group. We selected those studies that compare the GSS-supported groups with non-GSS-supported groups on the five outcome variables which are decision quality, number of ideas, time to reach decision, process satisfaction and decision satisfaction with statistical results. We searched various major databases such as ProQuest. Various journals are searched for relevant studies. We have also included the proceedings of Hawaii International Conference on System Sciences. The result includes studies from early 1980's to present. Since some studies have comparison for the selected moderators such as Gallupe et al. (1992) compared the effect of GSS on groups with different sizes—the study alone resulted in five data points. Therefore, we obtained 33 studies (Appendix A) with 62 data points (Appendix B).

In the included studies, the outcome variables are measured as follows: Decision quality was defined by most researchers as the correctness (intellective tasks with correct answers) or "goodness" (decision-making tasks without correct answers); Number of ideas was defined as number of ideas generated for idea generation tasks or number of alternatives generated for decision-making tasks); Time to reach decision was measured the time taken by the group to reach consensus on a particular decision; Process satisfaction and decision satisfaction are measured through the post-experimental surveys or interviews. Some variables have different measurement, thus we have adjusted them to unsure reliability during the analysis.

Analytic Procedure

In short, this procedure computes an average effect size (d) for a given dependent variable across an entire set of studies corrected for sampling error and unreliability. One shall convert the individual study statistic to d for accumulation later. Hunter and Schmidt (1990) presented the conversion equation:

$$d = \frac{X_e - X_c}{S_p}$$

X_e: Experimental group mean
X_c: Control group mean
S_p: Pooled standard deviation
and

$$S_p = \frac{(N_e - 1)S_e^2 + (N_c - 1)S_c^2}{N_e + N_c - 2}$$

The net effect of this transformation is that the differences are now standardized to a common metric across all studies, and this in turn means that effect sizes may be statistically combined and evaluated.

After converting data to a common statistic, reliability information was collected. Since not all the studies for calculating d provide reliability information, we have included all the studies that provide the reliability information of the studied moderators and outcome variables. Then we calculated the mean reliability for each moderator and outcome variable for correcting the unreliability later.

The next step is to eliminate the bias caused by sampling error. Sampling Error refers to the random variation in study results due to sample size. Smaller sample sizes tend to vary more widely from the true relationship within the population than do studies that have large samples. Accordingly weighting the effect size of a study by its sample size will provide a more accurate approximation to the relationship within the population, unaffected by the size of the sample. The sample weighted mean d is:

$$\overline{d} = \frac{\sum [N_i d_i]}{\sum N_i}$$

N_i: Number of subjects in the study
d_i: Effect size for the individual study

The sample weighted variance of d is defined by the following formula:

$$S_d - \frac{\sum [N_i (d_i - \overline{d})^2]}{\sum N_i}$$

While the sample weighted mean correlation is not affected by sampling error, its variance is greatly increased. A two-stage procedure is used to correct the variance of the sample weighted mean correlation. The first stage calculates the sampling error variance:

$$S_d^2 - \frac{K(1-\bar{d}^2)^2}{\sum N_i}$$

K: Number of studies in the analysis

To estimate the biased population variance, the sampling error variance is subtracted from $S_e{}^2$.

$$S_{BP}{}^{2\,=}\,S_d{}^{2}—S_e{}^{2}$$

So far this meta-analysis technique has corrected for one source of error, sampling error. There is another form of error: Measurement Error. Measurement Error or Test reliability is assessed by using the two reliabilities which apply to the study: $\underline{r}_{xx}$ and $\underline{r}_{yy}$. Hunter and Schmidt (1990) presented a method of correcting the sample weighted mean effect size using a distribution of reliability estimates. Any study that assesses the pertinent reliability estimates can be used to construct the reliability distribution. To conduct the reliability corrections, we constructed a distribution of reliability using all available sources. This distribution has the mean of:

$$\bar{r}_{xx} = \frac{\sum\sqrt{r_{xx}}}{K}$$

$\underline{r}_{xx:}$ Reliability for the individual study
K: Number of reliability studies

The variance for this distribution is defined as:

$$S_{xx} = \frac{\sum\sqrt{r_{xx}} - \bar{r}_{xx})^2}{K}$$

The mean reliability and variance for the dependent variable use the same formulas.

Given these statistics, the relationship within the population can be estimated. Correct the sample weighted mean of d for measurement error using the following formula:

$$\bar{d}_P = \frac{\bar{d}}{r_{xx}r_{yy}}$$

$$S_P{}^2 = \frac{S_{BP}{}^2 - \bar{d}_P(r_{xx}S_{yy}2 + r_{yy}S_{xx}{}^2)}{r_{xx}r_{yy}}$$

By now, we have the estimates of the mean and standard deviation for the population, $\bar{d}_P$ and S_P. The mean effect sizes indicate that the mean effect of GSS use across all included studies was to increase the outcome variable.

Hypotheses Testing

To test our hypotheses, we used a three-step approach developed by Hunter and Schmidt (1990). First, the studies are divided into two sets according the different criteria on the moderators. Second, a meta-analysis is performed separately on the studies within each set to produce relevant statistics for each set. Third, t-tests are used to compare the mean effect sizes between the two sets to see if there are significant differences among them.

For H1 (group size), we have split the data set into two partitions: small (five or fewer members) and large (more than five members). We choose the split point of five because it is argued that the optimum group size for nonGSS-supported groups is five (Shaw, 1981). For H2 (task type), we have split the data set into one set which deals with idea generation tasks, and another set which deals with decision making tasks. For H3 (anonymity), we have split the data set into one set that requires members to remain anonymous and another set with members identified. For H4 (time and proximity), we have split the data set into one set in which members communicate face-to-face in real time and one set with members communicating either remotely or asynchronously or both. For H5 (level of technology), we have split the data set into one set with level-1 GSS support and another set with level-2 GSS support. For H6 (the existence of facilitation), we have split the data set into one set with the support from facilitators and another set without facilitators.

RESULTS

The result of the meta-analysis is summarized from Table 2 to Table 6. They are arranged according to different outcome variables. The set of moderators that may have impact on the specific outcome variable is included in the respective Table. The first column "Number of Data Points" indicates the number of studies partitioned to this set. Rxx refers to reliability of the moderator and Ryy refers to reliability of the outcome variable. The column labeled "Uncorrected d" represents the mean effect size *d* after correcting sampling error but before correcting unreliability. The "Corrected d" column represents the mean effect size after correcting both sampling error and unreliability. "Significantly Different?" indicates whether the difference between "Corrected d" for two partitions of each independent variable is significant over dependent measures. "Hypothesis supported?" column indicates whether each hypothesized relationship is supported (Yes) or not (No), or there was not enough data to report (N.A.).

Decision Quality

Table 2 shows the moderator effects on decision quality. The first major column is the number of data points in the meta-analysis for the respective moderators, for example, 29 data points with the description of level of technology with 17 of which are using level-1 GSS. The second column is the reliability of the moderator. Since all the moderators we included in the study have definite and single measurement, the reliabilities should be 1 by definition. The third column is the reliability of the outcome variable which is decision quality. As we have mentioned above, this number is the mean value across all studies not only included

Table 2. Moderator effects on decision quality

	Number of Data Points	Rxx	Ryy	Uncor-rected d	Corrected d	Significantly Different?	Hypothesis supported?
Group Size	28	1	0.926			0.05	Yes
Small	21			0.177	0.191		
Large	7			1.169	1.263		
Anonymity	33	1	0.926				No
Identifed	21			0.328	0.354**		
Anonymous	12			-0.073	-0.079		
Time and Proximity	32	1	0.926				No
Face-to-Face	24			0.002	0.002		
Virtual Team	8			0.604	0.652**		
Level of Technology	29	1	0.926			0.05	Yes
Level-1	17			-0.03	-0.031		
Level-2	12			0.491	0.531*		
Facilitation	33	1	0.926				No
Without	26			0.348	0.377		
With	7			0.702	0.758**		

**p<0.05, **p<0.01*

in the meta-analysis but all the studies that have included the measurement of decision quality as there are different measurement for this outcome variable, such as “goodness” and “correctness” of the decision outcome. The fourth column is the uncorrected effect size and the fifth column is the corrected effect. Since reliability is always below 1, the corrected effect size is larger than the uncorrected one. Positive numbers indicate that moderators have improved the outcome variables (with the time to reach decision as exception since a positive number indicates that the moderator has increased the time to reach a decision which means the GSS-supported meeting is less efficient). The next column reports the *p*-value for a two-tailed *t*-test of the hypotheses which compares the mean effect sizes on different values of the moderator, e.g., comparing the effect size between level-1 GSS and level-2 GSS. The final column shows whether the hypothesis is supported.

Table 2 suggests that anonymous group meetings and level-1 GSS have negative effects on decision quality (-0.079 and -0.031 respectively) comparing between the GSS groups and control groups. But neither of them is significant. In the other situations, the decision quality is improved when GSS are used. However, not all the effect sizes are statistically significant. The decision quality is improved when meeting is supported by GSS in either of the four situations or any combination of them: identity revealed (0.354); Virtual Team setting (0.652); level-2 GSS support (0.531); with the existence of facilitation (0.758).

Overall, comparing GSS groups and control groups, large groups have significantly higher mean effect size on decision quality than small groups. Using level-2 GSS also results in significantly higher decision quality than using level-1 GSS. Facilitated group meetings have higher mean effect size than non-facilitated group meetings and significant. Therefore, H1a, H5a are supported.

Number of Ideas

Table 3 shows the moderator effects on number of ideas. In all the situations when GSS are used (with the exception where Virtual Team setting is used since there are no enough studies to test the effect size), the number of ideas are not significant different compared to control groups. The moderator effect of time and proximity cannot be tested due to the lack of data in the Virtual Team setting. Hence H1b, H3b, H5b, H6b are not supported, and H4b cannot be tested.

Time to Reach Decision

Table 4 shows the moderator effects on the time to reach decision. In all the situations when GSS are used, the mean time needed to reach a specific decision is increased compared to control groups with the increase in time occurred (effect sizes) in the following conditions: small groups supported by GSS (2.357), meetings with identified participants (2.376), Virtual Teams formed to make decisions (2.638), level-1 GSS used (2.221), and group meeting without facilitation (2.376). Therefore, H1c, H3c, H4c, H5c, H6c are not supported.

Process Satisfaction

Table 5 summarizes the moderator effects on satisfaction of meeting process. The resulting effect sizes are mixed. In some situations, the effect size is negative that is, participants are less satisfied with the meeting process in the GSS-supported group meetings than in the non-GSS-supported group meetings. In these situations, when the group size is small or the group is targeting a decision-making task, there is a significant decrease on the process satisfaction (-0.545). In the other situations, the effect size is positive. In these situations, only when the group size is large, there is a significant increase on the process satisfaction (0.32).

Table 3. Moderator effects on number of ideas

	Number of Data Points	Rxx	Ryy	Uncorrected d	Corrected d	Significantly Different	Hypothesis supported?
Group Size	20	1	1				No
Small	14			1.5	1.5*		
Large	6			0.989	0.989***		
Anonymity	20	1	1				No
Identified	13			1.456	1.456***		
Anonymous	7			0.693	0.693*		
Time and Proximity	20	1	1			N.A.	N.A.
Face-to-Face	20			1.18	1.18***		
Virtual Team							
Level of Technology	20	1	1				No
Level-1	14			1.304	1.304***		
Level-2	6			0.969	0.969***		
Facilitation	20	1	1				No
Without	12			1.088	1.088**		
With	8			1.326	1.326***		

**p<0.05, **p<0.01, ***p<0.001*

Table 4. Moderator effects on time to reach decision

	Number of Data Points	Rxx	Ryy	Uncorrected d	Corrected d	Significantly Different	Hypothesis supported?
Group Size	12	12	1				No
Small	8			2.357	2.357**		
Large	4			1.334	1.334		
Anonymity	14	14	1				No
Identified	9			1.51	1.51**		
Anonymous	5			2.978	2.978		
Time and Proximity	14	14	1				No
Face-to-Face	8			1.343	1.343		
Virtual Team	6			2.638	2.638*		
Level of Technology	14	14	1				No
Level-1	9			2.221	2.221*		
Level-2	5			1.385	1.385		
Facilitation	14	14	1				No
Without	10			2.376	2.376**		
With	4			1.074	1.074		

**p<0.05, **p<0.01*

Table 5. Moderator effects on process satisfaction

	Number of Data Points	Rxx	Ryy	Uncor-rected d	Corrected d	Significantly Different	Hypothesis supported?
Group Size	26	1	0.915			0.001	Yes
Small	17			-0.499	-0.545*		
Large	9			0.293	0.32**		
Task Type	26	1	0.915			0.01	Yes
Idea Generation	7			0.356	0.388		
Decision Making	19			-0.415	-0.453**		
Anonymity	25	1	0.915				No
Identified	13			-0.039	-0.043		
Anonymous	12			-0.237	-0.259		
Time and Proximity	25	1	0.915			N.A.	N.A.
Face-to-Face	25			-0.15	-0.163		
Virtual Team							
Level of Technology	26	1	0.915				No
Level-1	18			-0.278	-0.304		
Level-2	8			0.111	0.121		
Facilitation	19	1	0.915				No
Without	16			-0.152	-0.166		
With	3			0.358	0.391		

**p<0.05, **p<0.01*

Large groups are significantly more satisfied with meeting process; Groups dealing with idea-generation tasks have significantly higher process satisfaction than those dealing with decision-making tasks; The moderator effect of time and proximity cannot be tested due to the lack of data in the Virtual Team setting. Therefore, H1d, H2 are supported while H3d, H4d, H5d, H6d are not.

Decision Satisfaction

Table 6 summarizes the moderator effects on decision satisfaction. The resulting effect sizes are mixed. In most situations, the use of GSS decreases the participants' satisfaction on decision outcome (only when level-2 GSS are present, the decision satisfaction is increased but not significantly). However, none of the effect sizes is significant except when level-1 GSS are in place.

The moderator effect of group size cannot be tested due to the lack of data in case that group size is 6 or above; The difference between anonymous group meetings and identified ones is small and not significant; The difference between Virtual Teams and face-to-face teams is also small and not significant; Level-2 GSS can achieve better decision satisfaction than level-1 GSS, but the difference is not significant; The presence of facilitators helps the group to increase the decision satisfaction but neither significantly different. Therefore, H1e cannot be tested; H3e, H4e, H5e and H6e are not supported.

DISCUSSIONS

The main objective of this study was to better understand the moderators that affect group performance when using collaborative technologies. The

Table 6. Moderator effects on decision satisfaction

	Number of Data Points	Rxx	Ryy	Uncorrected d	Corrected d	Significantly Different	Hypothesis supported?
Group Size	21	1	0.925			N.A.	N.A.
Small	21			-0.186	-0.201		
Large							
Anonymity	21	1	0.925				No
Identified	11			-0.161	-0.174		
Anonymous	10			-0.203	-0.22		
Time and Proximity	21	1	0.925				No
Face-to-Face	17			-0.077	-0.083		
Virtual Team	4			-0.084	-0.091		
Level of Technology	21	1	0.925				No
Level-1	14			-0.334	-0.362*		
Level-2	7			0.088	0.095		
Facilitation	18	1	0.925				No
Without	11			-0.192	-0.208		
With	7			0.125	0.136		

$*p<0.05$

interaction between the moderators and factors is also investigated in the article. We investigated six potential moderators on five different outcome variables. We tested 26 hypotheses while only 4 of them (H1a, H1d, H2, H5a) are supported by the results from meta-analysis. H4b and H1e cannot be tested due to the lack of quantitative evidence we can find. The remaining 20 hypotheses are not supported. None of these hypotheses can be tested by tabular review on qualitative part of the research because the past research focuses on certain type of GSS application and environment, for example, those studies mainly studied groups under face-to-face setting. However, they generally proved that GSS do help groups achieve better meeting and group outcomes in the above mentioned five dimensions.

Group Size

Group size plays an important role on decision quality and process satisfaction. In the context of computer supported collaborative learning, group size has been identified as an important factor that requires further investigation with respect to group interaction (Strijbos et al., 2003). Interaction patterns and learning benefits differ among dyads (two members), small groups (three to six members) and large groups (seven or more), especially if participation equality or group-generated products are required (Strijbos et al., 2003; Wilkinson & Fung, 2002). Larger groups can achieve higher decision quality and are more satisfied with the process. However, there was no significant difference between decision qualities of larger GSS groups and non-GSS groups. Neither is there between smaller GSS groups and non-GSS groups. But after the comparison of the mean effect sizes, we were able to show that larger groups did obtain more significant improvement on decision quality than smaller groups. Whereas, smaller groups were significantly less satisfied with the process (*d*=-0.545) while larger groups were significantly more satisfied with the process (*d*=0.32). In previous research on nonGSS groups, larger group size is often related to production blocking and free riding. However, with the presence of GSS and the parallel input feature, large group size (six and above) does not contribute as a hindrance to optimum group outcomes any more (Sawyer et al., 2001). In contrary, larger groups promote more individual contribution to the group and more justification on the decisions.

On the other side, with the presence of GSS, larger groups do not help on groups to generate more ideas. One plausible reason is related to the issue of group composition involved in the experiments. In most studies, the groups were mostly formed by student subjects from similar backgrounds and cultures. They tend to think and behave as shaped by their background, culture and experiences. This similarity prevents them from thinking in completely different view of points, which does not make GSS a significantly better tool for larger groups to generate more ideas than smaller groups. This result has important implications in designing collaborative learning activities for distributed learners in CSCL system designers; GSS may enable a more effective communication in large groups involving learners from different cultural backgrounds.

Task Type and Level of Technology

Task type has a significant influence on process satisfaction. The effect size on process satisfaction was significantly higher for groups dealing with idea generation tasks than for groups dealing with decision making tasks. Specifically, GSS groups dealing with idea generation tasks were more satisfied with the process than non-GSS groups (*d*=0.388). Whereas, GSS groups dealing with decision making tasks were significantly less satisfied with the process than non-GSS groups (*d*=-0.453). That is mainly because the idea generation process is easier to be supported by GSS. In idea generation process, the GSS need only provide an electronic communication media to facilitate parallel inputs. However, for decision-making process, additional technologies that help the group in conflict management and facilitate the group to reach consensus are required. The use of GSS adds in additional challenge and complexity. Therefore, groups are less satisfied with the process.

In this regard, the features and structures supported by GSS should vary according to the task. **The level of technology** does affect significantly on decision quality. Level-1 GSS did not improve the decision quality (*d*=-0.031) while level-2 GSS improved the decision quality significantly (*d*=0.531). This can be explained that level-2 GSS provide additional support on decision making and consensus reaching compared to level-1 GSS. Level-2 GSS can help groups clearly organize, rank and present information and ideas by providing supporting tools. Therefore, the group members can have a clear and well-organized picture of the problems and possible solutions. The decision quality thus can be improved based on this deeper understanding.

The objectives of supporting collaborative learning through GSS are not only to duplicate the feature and effectiveness of face-to-face environment, but also to use the technology to create a more effective learning environment (Alavi et al., 2002; Turoff & Hiltz, 1995). Findings regarding task types and level of GSS support have highlighted the notion of the fit between the learning tasks and GSS support when instructors design the collaborative learning activities. As idea generation and decision making are both common activities in collaborative learning (Ready et al., 2004), level-1 GSS are generally more suitable for idea generation (e.g., brainstorming) and level-2 GSS are more preferable if learners are required to make a decision as a group. The level-2 GSS could improve the efficiency and effectiveness of group decision making either by optimizing the decision marking process or maximizing the quality of the outcome (Kwok, Lee, Huynh, & Pi, 2002).

Anonymity

Anonymity has been considered as one of the important features that help ease the cognitive load and encourage participation so as to improve the efficiency and effectiveness of group meeting (Dennis, Tyran, Vogel, & Nunamker, 1997; Kwok et al., 2002). However, we find in this study that anonymity did not make significant differences on the outcome variables. A plausible reason is that anonymity is hard to maintain in long-term and established groups (Guiller & Durndell, in press). Although it is claimed to be anonymous, other members can still guess the one's identity by looking into the styles of writing and ways of organizing ideas. In an ad-hoc group, anonymity can hardly have significant effects since the group members are new to each other, thus whether to keep the identity unrevealed does not make much sense unless the group has worked collaboratively on some projects before.

The anonymity feature tends to reduce interpersonal communication (Markus, 1994); as a result, in the educational contexts, students may be less responsive to the ideas of their peers during discussion, therefore hampering the extent of affective learning. On the other hand, due to the anonymity feature, the absence of social context cues in discussion is able to eliminate the undesirable influences caused by hierarchy, status and power, thus leading to relatively more equal participation among all learners (Guiller & Durndell, in press). Indeed, the effects of anonymity and how to use this feature properly deserve a closer look in future research.

Time and Proximity

The key role of technology application in supporting CSCL is to enable flexibility, timeliness, and increased frequency of group interaction and communication processes (Alavi et al., 2002). In this study, we found that **time and proximity** did not make any significant differences on decision quality, time to reach decision and decision quality in decision making tasks (the difference on number of ideas and process satisfaction could not be tested due to the lack of data). This indicates the potential of GSS in supporting collaborative learning across different locations and time zones. Furthermore, in most of the primary studies, users have access to communicate verbally either through Video-conferencing or telephone networks. Therefore, verbal communication is believed to remain critical for the group to converge on a decision and it should not be overlooked in collaborative learning activities. This suggests that instructors should try to provide means for learning groups to communicate verbally to achieve better decision-related outcomes such as decision quality, time and satisfaction.

Existence of Facilitation

Finally, the **existence of facilitation** does not have significant effects on the outcome variables. Careful and effective facilitation skills—by taking into consideration facilitator's expertise, prior experience, group member expectations and group task—are important to achieve better outcomes in using GSS in collaborative learning (Khalifa, Davison, & Kwok, 2002). However, intensive training to ensure facilitators equipped with careful and effective facilitation skills may not be attainable in the experimental settings; this possibly explains the absence of effects of facilitation on the outcome variables in the meta-analysis. Nevertheless, the role of facilitation is not to be totally dismissed in the context of CSCL. Along this line, Khalifa et al. (2002) call for more studies to address the effects of facilitation on the process and outcome of e-learning. Accordingly, we suggest that in order to make facilitation a means to effectively improve group outcomes, the facilitators must carefully manage the technologies as well as the meeting process. It is conceivably more effectively for the leadership and facilitator roles to be assumed by the same individual. Facilitators who are using

GSS to support collaborative learning need to be aware of as well as attempt to meet the related new requirements (Clawson, Bostrom, & Anson, 1993). For example, facilitators should select the appropriate technology, promote understanding of the technology, and help reinforce an open, positive, and participative environment in learning groups.

CONCLUSION

The central theme of the article is to assemble the findings from a set of studies to draw overall conclusions about a phenomenon of interest (Hunter & Schmidt, 1990). The current study has utilized the mechanism of meta-analysis to attain a deep understanding on prior studies and to provide direction for future research.

Based on the results of the analysis, we have highlighted the patterns on how key factors play their roles in affecting important outcomes of concern to computer-supported group work. The implications to CSCL technology design and implementation would contribute to advancement of understanding of enhancing collaborative work in educational settings.

Although GSS were originally designed to support discussion and decision making in the commercial organizations, there has been a growing interest in their usage to support collaborative learning (Alavi, 1994; Khalifa et al., 2002; Vogel et al., 2001). Studies have shown that group-based collaborative learning methods have been applied successfully for university as well as primary school students (Johnson & Johnson, 1994; Salomon & Globerson, 1989). It is not surprising for groups of learners to experience the same or similar types of problems faced by groups in non-educational settings (Tyran & Shepherd, 2001). In this light, findings born by this meta-analysis can have important implications for the CSCL context. Flexibility is a key in the design of GSS in order that maximum benefits may be reaped when catering to the needs of different task and group conditions. In past research, level-3 GSS were rarely used since the technology was not sufficiently mature. With the advancements of computer and communication technology, a more powerful and improved GSS can be built which may include artificial intelligence to automate the facilitator's job.

The use of the meta-analytic technique naturally implies inheritance of the limitations of the technique itself (Hunter & Schmidt, 1990). A limitation of the current analysis is the exclusive use of experimental studies. While quantitative studies are required for meta-analysis, generalization to the real-world situation may not be desirably strong. Future research should take into account both quantitative and qualitative findings to enrich the understanding towards a holistic view of computer-support group work.

Further efforts are called for to address the following. First, while technology has enabled Virtual Team to perform the same tasks as face-to-face teams, there exist disproportionately few studies that have examined Virtual Teams in the context of collaborative distance learning. More work is needed in this regard. Next, while the current study has selected six moderators from the model of Fjermestad (1998), there are conceivably a good number of other potential moderators. It is necessary for future research to investigate their effects. Another focus concerns the possible interactions between moderators; these should be examined to arrive at a richer theoretical framework.

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ENDNOTE

[1] For comparison of this method and its alternatives (e.g., Hedges & Olkin's (1985) multiple regression procedures), refer to the work by Hunter and Schmidt (1990, pp. 85-89). Also, technical details pertaining to meta-analysis can be found in their work.

APPENDIX A: STUDIES INCLUDED IN THE META-ANALYSIS

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APPENDIX B: SUMMARY OF LABORATORY STUDIES

Study ID	Technology	Number of subjects	Number of Groups	Group Size	Anonymity	Task Type	Face-to-Face	Facilitator	GSS Tools	Decision Time	Number of Ideas	Decision quality	Process satisfaction	Decision satisfaction
[1]	Co-Op	72	24	4-6	n	Decision Making	y	y	1	3.189		0.102		-0.612
[1]	Co-Op	72	24	4-6	n	Decision Making	y	y	1	0.167		0.927		0.315
[2]	Vaxnotes	55	22	5	y	N.A.	n	n	1	6.407				
[3]	SAMM	243	N.A.	3,4	n	Decision Making	n	n	1					0.475
[4]	Group-Systems	140	28	5	y	Decision Making	y	y	2					-0.17
[4]	Group-Systems	140	28	5	y	Decision Making	y	y	2					0.339
[4]	Group-Systems	140	28	5	y	Decision Making	y	y	2					0.976
[4]	Group-Systems	140	28	5	y	Decision Making	y	y	2					2.042
[5]	Vision-Quest	53	12	4,5	n	Idea Generation	y	y	1		1.357			
[5]	Vision-Quest	53	12	4,5	n	Idea Generation	y	y	1		1.574			
[6]	GSS: Vision-Quest	53	12	4,5	n	Idea Generation	y	y	2		1.357			

Note*: "n" represents "no"; "y" represents "yes"; "N.A." represents "not mentioned"; blank cells mean "no measure on the outcome variable"*

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[6]	GSS: Vision-Quest	53	12	4,5	n	Idea Generation	y	y	2		1.575			
[7]	Group-Systems	140	14	10	y	Decision Making	y	n	2	1.113		0	0.016	
[8]	TCB-Works	150	15	10	y	Decision Making	y	n	2	4.504		-1.856		
[8]	TCB-Works	150	15	10	y	Decision Making	y	n	2	0.191		1.606		
[9]	DE-CAID	54	18	3	y	Decision Making	y	n	2			-0.026	0.489	
[9]	Plexsys	93	20	4,5	y	Decision Making	y	n	2			-0.167	0.449	
[10]	Group-Systems	129	10	2	n	Idea Generation	y	n	1		-0.156	0.134	-0.618	
[10]	Group-Systems	129	10	4	n	Idea Generation	y	n	1		0.88	1.412	0.126	
[10]	Group-Systems	129	10	6	n	Idea Generation	y	n	1		2.218	2.258	0.455	
[10]	Group-Systems	144	24	6	n	Idea Generation	y	n	1		0.794	1.252	0.278	
[10]	Group-Systems	144	24	12	n	Idea Generation	y	n	1		3.364	3.056	1.082	
[11]	DE-CAID	42	12	3	n	Decision Making	y	y	1		3.126	1.687	-0.502	

Note*: “n” represents “no”; “y” represents “yes”; “N.A.” represents “not mentioned”; blank cells mean “no measure on the outcome variable”*

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[11]	DE-CAID	42	12	3	n	Decision Making	y	y	1	0.585	1.205	0.585	1.306	
[12]	GSS: DE-CAID	27	9	3	n	Decision Making	n	n	1	1.667		-0.095		-0.554
[12]	GSS: DE-CAID	27	9	3	n	Decision Making	y	n	1	0.625		0.157		-0.528
[13]	Meeting-Ware	80	32	5	n	Idea Generation	y	y	2		0.726	0.633		
[14]	SAMM	80	16	5	n	Decision Making	y	n	2				-1.908	-0.862
[14]	SAMM	80	16	5	n	Decision Making	y	n	2				-0.798	0.486
[15]	SAMM	240	48	5	N.A.	Decision Making	n	N.A.	1					
[16]	GSS: SAMM	144	16	9	n	Decision Making	y	y	2	-0.372	0.849	0.986	0.332	-0.267
[17]	NICK	21	3	7	n	Idea Generation	y	n	2					
[17]	NICK	21	3	7	n	Idea Generation	y	n	1					
[18]	Vision-Quest	40	10	4	y	Decision Making	n	N.A.	1				-0.83	-0.81
[19]	CMC unknown	70	35	2	n	Decision Making	n	n	1	3.007		-0.484		
[19]	CMC unknown	70	35	2	n	Decision Making	n	n	1	1.097		-1.026		

Note: *"n" represents "no"; "y" represents "yes"; "N.A." represents "not mentioned"; blank cells mean "no measure on the outcome variable"*

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[20]	CAH	216	72	3	n	Decision Making	y	n	2			0.737		
[21]	Group-Systems	124	31	4	n	Decision Making	y	n	1				-0.692	-0.35
[21]	Group-Systems	124	31	4	n	Decision Making	y	n	1				-0.48	-0.19
[22]	CMC: Unknown	256	0	4	y	Decision Making	y	N.A.	1				-0.893	-0.885
[22]	CMC: Unknown	256	0	4	y	Decision Making	y	N.A.	1			0.471		
[22]	CMC: Unknown	256	0	4	y	Decision Making	y	N.A.	1				-0.793	-0.387
[22]	CMC: Unknown	256	31	4	y	Decision Making	y	N.A.	1			-0.292		
[23]	CaptureLab	78	34	4,5	n	Decision Making	y	n	1				0.44	
[24]	Group-Systems	230	22	10-12	y	Idea Generation	y	N.A.	2		0.788		0.46	
[24]	Group-Systems	239	20	10-12	y	Idea Generation	y	N.A.	2		1.055		0.46	
[25]	CMC: Web-EIES	130	27	4-7	n	Both	n	y	2			0.564		

Note*: “n” represents “no”; “y” represents “yes”; “N.A.” represents “not mentioned”; blank cells mean “no measure on the outcome variable”*

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APPENDIX B: CONTINUED

[26]	CMC: EIES2	0	21	5-7	n	Both	n	n	2			0.744		
[26]	CMC: EIES2	0	20	5-7	n	Both	n	n	2			0.371		
[27]	Group-Systems	171	22	8	N.A.	Decision Making	y	N.A.	1				-0.254	
[27]	Group-Systems	136	18	8	y	Decision Making	y	N.A.	1				-0.327	
[28]	CMC: E-mail	60	20	3	y	Type 5,6	n	n	1	1.456				
[29]	GSS: EDS	44	10	4,5	n	Decision Making	n	n	2			0.532		
[30]	GSS: EDS	44	10	4,5	n	Decision Making	n	n	2	1.691		1.046		
[31]	GSS, SAGE	96	23	4	n	Decision Making	n	y	0					
[31]	GSS, SAGE	96	23	4	n	Decision Making	n	y	0					
[32]	CMC: Option-Link	70	14	5	y	Decision Making	y	n	1		0.639	0.723	-0.502	-0.62
[32]	CMC: Option-Link	70	14	5	y	Decision Making	y	n	1		-0.135	-0.264	-0.606	-0.065
[32]	CMC: Option-Link	70	14	5	y	Decision Making	y	n	1		1.005	-0.48	-0.45	-0.166
[32]	CMC: Option-Link	70	14	5	y	Decision Making	y	n	1		-0.135	-0.264		

Note*: “n” represents “no”; “y” represents “yes”; “N.A.” represents “not mentioned”; blank cells mean “no measure on the outcome variable”*

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[32]	CMC: Option-Link	70	14	5	y	Decision Making	y	n	1		1.423	0.515		
[33]	CMC: Meetin-gWeb	72	24	3	n	Decision Making	n	n	1					-1.393

Note: *"n" represents "no"; "y" represents "yes"; "N.A." represents "not mentioned"; blank cells mean "no measure on the outcome variable"*

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Chapter 1.15

Supply Chain Information Systems and Decision Support

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INTRODUCTION

Supply chains have become have become increasingly important as organisations have moved from competing on a stand-alone basis to recognizing that their success depends upon their trading partners. This includes their upstream suppliers and downstream customers. A supply chain involves a number of tiers of suppliers and customers that extends from the initial source of raw materials through to the final consumer of the finished product.

Supply chain management involves the coordination of a number of functional areas in multiple organisations. Large amounts of information can be captured describing the activities in these organisations. It is possible to use this information in order to assist in decision making at strategic, tactical, and operational levels of the supply chain. The large volume of information available and the interdependencies between the activities within these multiple organisations means that it is necessary to employ computerized decision support systems to optimize supply chain activities.

BACKGROUND

Christopher (2005, p. 4) defines logistics as

> *the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organisation and its marketing channels in such a way that current and future profitability are maximised through the cost-effective fulfillment of orders.*

While logistics focuses on the movement of materials, Christopher (2005) describes supply chain management as being broader and defines supply chain management as "the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole" (p. 5).

Porter's value chain model describes an organisation as a set of primary and support activities. The excess of the value added by the primary activities over the costs incurred by all the activities of the organisation provide the organisation's margin (Porter, 1985). The excess of value delivered to the customer over costs incurred throughout the supply chain represents the margin available to be shared among the supply chain participants. There has been a move away from traditional, transaction-oriented logistics practices which served to maximise the profitability of the individual firm. The relationship between supply chain participants has changed from being adversarial in nature to being cooperative. Organisations seek to increase the profitability of the supply chain as a whole and to share the available margin. Relationships between organisations have changed from a zero-sum game to a win-win situation.

Since the early 1990s, the process view of organisations has been mooted as a preferred alternative to the traditional functional structure. A process is a set of related activities which take place in a number of different functional units. A process-oriented organisation seeks to optimise the overall process in order to meet the needs of the end-customer of that process. This contrasts with the functional view which seeks to optimise individual functional units and which leads to suboptimal overall performance and which tends to ignore the needs of the customer.

The supply chain concept extends the process view to include multiple organisations. Processes which extend across organisational boundaries seek to satisfy the needs of the end-customer in an optimal manner. The profitability of each organisation in the supply chain depends on the success of the supply chain as a whole in serving the needs of the customer. Ultimately it is from the end-customer that funds are made available throughout the entire supply chain.

The execution of these interorganisational processes generates large amounts of data which can be shared among supply chain members. This information can be used to aid decision making to support the complex task of managing the supply chain. The major areas which require decision support are production planning, transportation, and inventory control.

SUPPLY CHAIN INFORMATION SYSTEMS AND DECISION SUPPORT

The process view of organisations as espoused by Hammer (1990) and Davenport and Short (1990) identified the interdependent nature of activities within organisations and promoted the alignment of these activities to focus on the customer. The move away from functional silos, which treated each functional unit as independent, required a sharing of information between these functional areas. The move to process-oriented organisations was hampered by the limited power of available information technologies at that time. Many organisations had computer applications which existed as islands of automation within these functional silos. These applications were not designed to share information and in many cases the applications and their data were incompatible. There emerged a business requirement for applications which were more process-oriented and which could serve to integrate multiple functional areas within the organisation. This period also saw the development of more powerful information and communication technologies. Local area networks, client-server computing, database servers, application servers, and Internet technologies were adopted by many organisations and facilitated the deployment of interfunctional information systems. Linked applications helped move away from islands of automation to provide a seamless flow of information.

Supply chains can be seen as a set of linked value chains. For example, the outbound logistics activity of one value chain links with the inbound logistics activity of its downstream partners. Cooperation can also exist in activities such as marketing and research and development. In order to meet the needs of the end-customer, the principles of integration that have been applied to internal company activities should be extended to activities that span the supply chain. The development of integrated activities requires a strategic approach. Organisations that have taken a process view of their internal activities have moved from having strategies which have an intracompany intraoperation scope which seeks to minimise local costs to having strategies with an intracompany interfunctional scope. Extending the strategy to include supply chain partners leads to an intercompany interfunctional scope (Chopra & Meindl, 2004, pp. 44-49).

Organisational structure and processes should be designed in order to support the chosen strategy. Harmon (2003) advocates the development of a process architecture to meet the goals set out in the organisation's strategy. Information technology (IT) planning should be informed by, and support, the process architecture. An intercompany interfunctional strategy requires processes that cross organisational boundaries and interorganisational information systems to support these processes. These processes should be designed to meet the needs of the end-customer and the information systems used should assist in the operation and management of these processes.

A number of generic supply chain processes have been proposed. The Supply Chain Council has proposed the Supply Chain Operations Reference (SCOR) model. This model includes five top level processes which are plan, source, make, deliver, and return. These are decomposed into a number of level 2 and level 3 subprocesses (Harmon, 2003). Lambert and Cooper (2000) propose a number of supply chain processes. These are customer relationship management, customer service management, demand management, order fulfillment, manufacturing flow management, procurement, product development and commercialization, and returns. These processes rely on the flow of information across the supply chain.

STRUCTURE OF THE SUPPLY CHAIN

The structure of the supply chain depends upon the nature of the product and the nature of demand for the product. Fisher (1997) stated that functional products require efficient supply chains whereas innovative products require responsive supply chains. Efficient supply chains are associated with the concept of leanness, which developed from the Toyota Production System and which emphasizes cost reduction. Responsive supply chains are associated with the concept of agility which developed from flexible manufacturing systems. Christopher (2000) associates lean supply systems with products that have low variety/variability and high volume demand conditions. He associates agile supply systems with products that have high variety/variability and low volume demand.

Webster (2002) states that the appropriate supply chain structure exists on a continuum from lean to agile. Lean supply chains, which can be regarded as rigid supply pipelines, use a fixed streamlined approach with dedicated links and long-term trusting relationships. Lean supply chains emphasise the meeting of customer requirements in an efficient manner. Agile supply chains have a more fluid and flexible structure and can be regarded as virtual organisations which form to meet market demand and disperse once the need has been met. Agile supply chains are loosely based and use short-term flexible contracts. Agile supply chains emphasise the meeting of customer requirements in an effective manner (Webster, 2002).

SUPPLIER SELECTION

It is important that an organisation selects suppliers that can match the needs of the chosen supply chain structure. Zeng (2000) describes supplier selection as a strategic decision. A supplier selection process seeks to identify and choose appropriate suppliers. The selection decision should involve participation from a number of functional areas within the organisation including quality assurance, research and design, manufacturing, purchasing, and accounting. The selection criteria should include material specification review, equipment capability, quality assurance, financial capability, cost structure, supplier value analysis effort, and production scheduling (Zeng, 2000). Boer, Labro, and Morlacchi (2001) provide a review of supplier selection methods. Weber and Ellram (1993) describe a decision systems approach to supplier selection. Kahraman, Cebeci, and Ulukan (2003) describe a decision support system that uses fuzzy analytic hierarchy process (AHP) to select suppliers based on supplier, product performance, service performance, and cost criteria.

Organisations may choose to use multiple sourcing where a number of suppliers are chosen for a given product or family of products. This allows flexibility, helps reduce risks, and increases competition between suppliers. Multiple sourcing may be more appropriate for short-term contracts (Zeng, 2000). The use of multiple sourcing can help reduce the bargaining power of suppliers and may be more appropriate for agile networks.

In single sourcing, one supplier is selected to meet the needs of the organisation for a given product or family of products. Single sourcing leads to improved communication and closer cooperation between the organisation and its suppliers. Transaction costs may be reduced and the trading partners can enjoy a stable long-term relationship (Zeng, 2000). Single sourcing arrangements may be more appropriate for lean supply chain structures.

Given the increasing globalization of markets, many organisations are considering global sourcing. Global sourcing enables an organisation to rationalize its supply base on a worldwide basis. Monczka and Trent (1991, in Zeng, 2003, p. 367) define global sourcing as “the integration and coordination of procurement requirements across worldwide business units, looking at common items, processes, technologies and suppliers.” A number of factors take on an increasing importance in the sourcing decision when using global sourcing. These factors include customs procedures, transport and communications infrastructure, and transport lead times for various modes of transport.

There has been a movement away from simple outsourcing arrangements to contract manufacturing. This enables the creation of virtual organisations based on the dynamic creation of links to suppliers. The Li & Fung trading company of Hong Kong is an example of a company which operates an agile supply system based on contract manufacturing and linking suppliers and buyers on a global basis. This agile system allows Li & Fung to match the rapidly changing demands of its customers with the production capabilities of thousands of suppliers (Chan & Chung, 2002).

Appelqvist, Lehtonen, and Kokkonen (2004) describe a framework for supply chain decision making in which different approaches to decision making are appropriate depending on whether a new or existing supply chain, and whether a new or existing product is involved. These situations vary in terms of availability of data, constraints and decision variables, and time horizons. Different approaches to modeling are appropriate in these cases.

The performance of suppliers must be monitored in order to facilitate decisions which impact on the optimal functioning of the supply chain.

Lambert and Cooper (2000) describe a number of types of supply chain process links. Managed process links are links that the company regards as important to integrate and manage. These include links to first-tier suppliers and customers and other important links further along the supply chain. Monitored process links are not as important to the company but are considered as important to be integrated between the other participants. Not-managed process links are not actively managed and are not considered important enough to monitor. Zeng (2003) describes a generalised five-stage process which can be used for supplier selection and management decisions. The stages in this process are investigation and tendering, evaluation, supplier selection and development, implementation, and performance measurement and continuous improvement.

The decisions taken regarding choice of lean or agile supply chain, and single or multiple sourcing leads to a network structure that can be described by a number of variables. Horizontal structure determines the number of links from initial supplier to end-customer. Vertical structure determines the number of participants at each stage of the supply chain. Horizontal position describes how close the organisation is to the end-customer or initial source of supply. Organisations must decide which processes they will implement across the supply chain (Lambert & Cooper, 2000).

For each process implemented, a set of performance measures should be selected. These measures should focus on the steps necessary to satisfy the needs of the end-customer. Data should be captured for these measures and this data should be monitored. This information should be made available, as appropriate, across the supply chain. This data can be used as feedback to facilitate decision making in order to control the processes (Harmon, 2003).

An information flow facility allows transactional and management data to be distributed across the supply chain on a real-time basis (Lambert & Cooper, 2000). This facilitates integration of process activities in various supply chain participants. It also supports real-time decision making to respond to the needs of the end-customer and to respond to changing conditions. The information flow facility can influence the efficiency and effectiveness of the supply chain.

The management of supply chain processes can help overcome supply chain uncertainties. Uncertainties exist in terms of the volume and nature of demand and the availability of supply. Demand uncertainty exists in terms of required volumes, response times, variety, service levels, and price. Supply uncertainty exists because of breakdowns, predictability of yields, quality, supply capacity, supply flexibility, and maturity of production process (Chopra & Meindl, 2004 pp. 31-34). Organisations must make informed decisions in light of supply chain uncertainties.

Demand uncertainty is the greatest source of demand variability. In addition, variability in demand tends to become amplified along the supply chain thus causing difficulties in the planning and execution of operations. This tendency for increasing variability has been labeled the bullwhip effect (Lee, Padmanabhan, & Whang, 1997). In many cases the level of variability further up the supply chain is greater than the actual underlying customer demand. A major cause of the bullwhip effect is that planning decisions are based upon forecasts, which, by their very nature, are inaccurate. As forecasts further up the supply chain are based on forecasts downstream in the supply chain the level of error is compounded. Other causes of uncertainty arise from issues such as forward buying to take advantage of favourable trade terms such as discounts and overordering to overcome rationing of scarce products. The timely availability of actual underlying marketplace demand data can help overcome the difficulty whereby many participants in the supply chain cannot respond appropriately to the marketplace (Handfield & Nichols, 2002; Lee et al., 1997; Mason-Jones & Towill, 1997).

INFORMATION AND INVENTORY

Inventory exists at the interface between organisations in the supply chain. This can take the form of raw materials, components, and subassemblies. Inventory is held by suppliers in order to meet possible future demand from downstream. Inventory is held by buyers in order to offset any delays in supply. The outbound logistics function and inbound logistics function of organisations are therefore involved in handling levels of inventory that exceed the immediate demands. In many cases, the level of excess inventory can be measured as many months of actual demand. Decision making, based on shared information regarding actual market demand and available capacity, can help reduce the amount of inventory held at various stages, and in different forms, along the supply chain. This has been a driver for various initiatives such as Just-in-Time (JIT), vendor managed inventory (VMI), collaborative planning forecasting and replenishment (CPFR), and efficient customer response (ECR) (Handfield & Nichols, 2002; Lee et al., 1997).

The integration of logistics capabilities of supply chain participants requires information visibility. This enables the balancing of demand with available capacity. Capacity exists in a number of forms including production, inventory, and transport. Given the interdependence of these functions, both within and across organisations, decision making requires an integrated view be taken.

It is often at the interface between functional units or organisations that difficulties arise in business processes. It is at these interfaces that particular attention needs to be paid in process design efforts (Harmon, 2003). The existence of excess inventories is an example of such difficulty. The availability of up-to-date demand and supply information can help reduce the level of excess inventory held. Information can therefore act as a substitute for inventory.

Webster (2002) proposes information and inventory as two supply chain management variables. Technology and relationships are the two variables proposed. Technology is described as an enabler of integration. The form taken by these management variables should be appropriate to the supply chain structure which exists on a continuum from agile to lean. The structure depends on the product type and demand profile. The performance of the supply chain depends on these management variables and can be measured in terms of effectiveness and efficiency (Webster, 2002).

INFORMATION SYSTEMS FOR SUPPLY CHAIN MANAGEMENT

Information systems for use in supply chain management have evolved over a number of decades. They progressed from stand-alone islands of automation supporting narrow functions within business units to become highly integrated systems spanning organisational boundaries. Manufacturing planning and control systems have their origin in the double-entry bookkeeping system developed by Luca Pacioli in 1494 (McCarthy, David, & Sommer, 1996), and in the manual stock reordering systems operated by foremen in the industrial plants in the 1800s. Initial computer applications were automated reorder point systems. Functionality was extended to include forward looking demand based planning and production reporting tool thus giving computerized materials requirements planning (MRP) systems. The addition of capacity requirements planning led to the development of manufacturing resource planning (MRP-II) systems. Further expansion to include functional areas such as marketing, finance, and human resources led to the development of enterprise resource planning (ERP) systems (Rondeau & Litteral, 2001).

The development of systems such as electronic data interchange (EDI) for sharing information across organisational boundaries means that information systems now link functional units in a number of organisations. A well known example is that of Wal-Mart and Procter and Gamble. Wal-Mart shares point-of-sale data with Procter and Gamble, who use this data to manage the replenishment of stock in Wal-Mart stores. Wal-Mart benefits by having well stocked stores while Procter and Gamble benefits by being able to respond to actual market demand thereby improving decision making for production and distribution (Mason-Jones & Towill, 1997).

Organisational complexity demands integrating mechanisms (Lawrence & Lorsch, 1967). These large-scale integrated information systems act as integrating mechanisms for complex systems such as supply chains. The evolution of these systems is recognition of the interdependent nature of the activities involved. ERP systems provide horizontal integration across functional units. At an operational level, execution systems assist in the planning and control of daily activities. Manufacturing execution systems (MES) facilitate the planning and control of the production function. Warehouse management systems (WMS) assist in the planning and operation of activities involved in inventory control. Transportation management systems (TMS) assist in planning and operation of activities involved in the physical movement of goods along the supply chain. Vertical integration links these execution systems with enterprise systems.

ANALYTIC SYSTEMS

An information flow facility can help integrate information systems across organisational boundaries and enable integrated supply chain processes. Integration can also be achieved between analytical and transactional systems (Helo & Szekely, 2005). Analytical IT systems can be used to model and optimise the supply chain at a number of levels. Modeling systems can be used for strategic analysis and long-term tactical analysis. Modeling can also be employed for short-term tactical analysis for production planning optimization and logistics optimization. Operational analysis can assist in decision making for optimization of production and distribution scheduling. Operational analysis systems can have integrated links with transactional IT systems (Helo & Szekely, 2005; Shapiro, 2002). A wide variety of analytical techniques can be used for advanced planning and scheduling. These include linear programming, heuristic programming, genetic programming, and constraint based programming. The use of analytical techniques combined with transactional data from across the supply chain can provide for improved accuracy, reliability, and control. The large volumes of data involved suggests that data warehousing, data mining, statistical analysis, and online analytic processing (OLAP) techniques can be employed to facilitate decision support.

FUTURE TRENDS

As information technology becomes embedded in physical systems, the availability of information to assist in supply chain management increases. Examples include the use of geographical positioning systems (GPS) to track movement of vehicles, radio frequency identification (RFID) tags to trace movement of containers and packages, and the use of laptop computers on forklift trucks. Data obtained with these systems can be captured in execution systems such as WMS and TMS systems. This data in turn can be integrated with enterprise level systems. Information can therefore enable coordination of activities across the supply chain and can enable the supply chain to operate on a sense-and-respond basis (Kumar, Karunamoorthy, Roth, & Mirnalinee, 2005; Power, 2005).

To date, many supply chain information systems have operated on the basis of passing data in standardized structured formats such as EDI messages. In the future, it is likely that supply chain systems will use technologies such as the extensible markup language (XML), component based systems, service oriented architectures (SOA), and Web services. Instead of simply the passing of data, there is likely to be a greater lever of integration between applications. Enterprise application integration (EAI) will allow applications to be developed which call on the processing capabilities of other applications some of which may exist in other organisations in the supply chain.

Folinas, Manthou, Sigala, and Vlachopoulou (2004) describe the changing nature of information and decision making processes as supply chains evolve. Decision support applications to support supply chain management have been designed to operate at different levels of the organisational hierarchy. A system to assist with the selection of suppliers and the dynamic configuration of supply networks has been described by Helo, Xiao, and Jianxin (2006). Verwijmeren, van der Vlist, and van Donselaar (1996) described a design for a system to assist in the management of inventory at multiple stages along the supply chain. Swanepoel (2004) describes an integrated decision support system that supports decision making at both operator and managerial level in a manufacturing setting.

CONCLUSION

The availability of more powerful technologies to process, store, and transmit information will facilitate the development of supply chain applications. The large amounts of transaction data and process monitoring data generated by these applications, coupled with the complexity of the supply chain and of the marketplace and the need to react swiftly to the changing needs of customers, necessitates the use of powerful decision support applications. Further research is needed to investigate how decision support technologies can be applied in this area.

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KEY TERMS

Information Flow Facility: An information flow facility is the combination of information technologies which facilitates the bidirectional flow of information between participant organisations in a supply chain.

Manufacturing Execution System: A manufacturing execution systems allows for recording, reporting, online enquiry, planning, and scheduling of production floor activities.

Process Architecture: A process architecture is a hierarchical description of the large scale processes, subprocesses, and activities that occur within an organisation.

Supply Chain: A supply chain is a network of organisation involved in producing and delivering a finished product to the end-customer. Supply chains exist for goods and services. From the viewpoint of a focal organisation, a supply chain involves a number of tiers of suppliers and of buyers. A supply chain involves the flow of products, funds, and information.

Supply Chain Management: Supply chain management is the set of activities carried out at strategic, tactical, and operational levels to manage the interorganisational processes involved in providing products that meet the needs of end-customers.

Transportation Management Systems: A transportation management system (TMS) is used for the short term planning of movement of material in a manner which optimises the use of resources. A TMS facilitates the scheduling of both intercompany and intracompany movement of materials, processes the associated transactions and assists in the preparation of associated documentation.

Warehouse Management System: A warehouse management system is used to control the movement and storage of materials with one or more warehouses in a manner which seeks to optimise the use of space, labour, and equipment.

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Chapter 1.16

Strategic Decision Making in Global Supply Networks

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INTRODUCTION

Globalization has inexorably affected the economies of many nations in both the developed and developing world. As a consequence, national boundaries are becoming less important to the large, multinational corporations who now operate on a global scale.

Corporate global networks range from short term outsourcing contracts to long term investments in developing countries that offer low cost operations and/or the promise of future market expansion. Today the Internet and high-speed data networks enable knowledge tasks to be completed practically anywhere in the world, allowing companies in the developed world to achieve cost savings or simply stay competitive enough to survive by shifting work offshore (Saunders, 2003; Schultz, 2004). As a result, an increasing shift of work to low-cost countries will continue for the foreseeable future.

Global supply networks decisions such as supplier selection and distribution assignments are strategic decisions that involve medium to long term commitment. These decisions in turn affect the organization's future business structure, competitiveness and market value. In the literature there are numerous studies dealing with global supply network decisions in the context of mathematical modeling, risk assessment and conceptual strategic evaluations. The literature can be divided into two categories with respect to the application of tools that are used to analyze and model the corporate decision making processes. One stream of literature extensively utilizes operations research techniques to model the supply networks and assess the profitability of production (or service) operations on the basis of quantitative variables. The other stream of literature concentrates on intangible determinants and evaluates the drivers and consequences of global operations by examining the business conditions, risk factors, opportunities and many other qualitative as well as quantitative variables. In the next sections, a conceptual framework will be developed to examine the structure, determinants, and outcomes of global operations. A broad review of the literature will be presented, and novel modeling approaches will be summarized while discussing the complexity of global supply network decisions and the necessity for integrated methodologies.

GLOBAL SUPPLY NETWORKS AND OUTSOURCING

The ever-increasing pace of information and communication technology allowed corporations to distribute their operations all over the world. Today the global supply network refers to a complex set of business relationships that consist of not only the distinct elements of the supply chain (i.e., supplier, distributor, and retailer) but also the operational divisions within a company, including accounting operations, human resources and customer service among others. The intense competition among many industries imposes pressure on corporations to elevate productivity and reduce costs by transferring activities to more efficient vendors that can add a competitive edge with their specialization. Offshore outsourcing (or simply “outsourcing”) especially is a growing trend leading to further transnational distribution of corporate activities. Research indicates that, when well designed and well managed, outsourcing reduces operating costs, enhances competitive strategy, and enlarges shareholder value (Bryce & Useem, 1998).

There are many reasons for companies to distribute their operations either in the form of outsourcing to different parties or by investments in different regions of the world. The primary objective is to reduce the costs of services and products by utilizing the low labor-rates in developing countries such as China and India. The initiative towards improving the focus of core competences such as R&D and market research also plays an important role. According to Ferrell (2003), and more than 800 executives in the United States and Europe think that cost savings are still a key outsourcing benefit, but the additional business controls generated by outsourcing are driving the trend to external providers.

The determinants of global supply network decisions can be divided into two interrelated classes in terms of the elements of competitiveness: cost competitiveness and organizational competitiveness.

Cost Competitiveness

Cost is usually the initial major determinant in global supply network decisions. The selection of supplier location, logistic structure, distribution network and many other components of decisions are based on the objective of minimizing the total cost. For a global supply network, the total cost accounts for the aggregation of product/service costs along with the costs of relocation, documentation and communication. Although in many cases, supply networks are designed based on calculations of projected variable and fixed costs, the actual practice of operations involves the hidden costs that are frequently overlooked. The cost of selecting a vendor, contracting costs, transfer costs and many other costs associated with organizational change and management are incurred over the lifetime of global operations. Vining and Globerman (1999) describe the cost of outsourcing as a function of three variables: Production costs, bargaining costs and opportunism costs, with the latter two being costs of governance. Bargaining costs include the costs arising from negotiating contract details, costs of negotiation changes to the contract in the post contract stage, the cost of monitoring whether performance is being adhered to by the other party, and the cost of disputes. Opportunism is defined as any behavior by a party to a transaction that endeavors to change the agreed terms of a transaction in its favor.

Therefore, the cost of a global supply chain should be perceived as the sum of foreseeable financial values as well as the possible fees and expenditures that can emerge as a result of segmentation of business processes. To facilitate an increase in cost competitiveness, the strategic decisions on global supply networks should be based on a projection of complete cost values.

Organizational Competitiveness

Competitive advantage is the ability of a firm to outperform rivals on the primary performance goal: profitability (Grant, 2004). By this definition, an organization inevitably elevates its profitability, and therefore gains competitive advantage if the costs of products/services are lowered in comparison to the other existing players in the market. In addition to the cost advantage, in order to maintain competitiveness in the long run, an organization needs to differentiate itself relatively to its rivals. For many organizations, research and development activities are of the utmost importance in maintaining the core competence. Even in mature markets where there is little room for innovation, it is important to create new marketing ideas and achieve quality improvement to preserve market share. Organizations are able to focus on these core functions by transferring custom business processes, such as accounting and information systems, to specialized vendors around the world. On the other hand, other factors of competitiveness such as responsiveness, customer service, and flexibility may be adversely affected by the decentralization of operations and authority. The risk of intellectual property theft due to the multiplicity of vendors and the irregularity of protection laws is another area that underscores the importance of indefinable elements of supply chain decisions.

DECISION MODELS

Researchers and practitioners have investigated the performance, design and analysis of global supply networks and provided numerous decision models based on a diversity of methodologies. While incorporating the entire dynamics of the problem into one method is difficult, the majority of the work presented in the literature delineates promising schemes for superior strategic decisions in global supply networks.

Mathematical Formulation Based Approaches

The mathematical formulation based literature on decision models in global supply networks mostly includes tools from decision sciences, operations research and economics. These models typically include financial parameters and solve global supply network problems to provide solutions to production quantities, production locations, distribution routes, etc. The following gives examples from various disciplines that model the global supply network decisions utilizing different techniques.

Arnzten et al. (1995) represent a global supply chain model (GSCM) that minimizes a weighted combination of total cost and activity days where the total cost includes production costs, inventory costs, taxes, facility fixed charges, production line fixed costs, transportation costs, fixed costs associated with a particular method of manufacturing, and duty avoidance. The MIP model is solved for a digital equipment corporation that is in a decision making process to determine plant charters and allocation of production loads. The model is then utilized to analyze the supply chain for new products as well as the supply bases for existing commodities. The decision model is applicable to multi-stage, multi-product manufacturing environment.

Huchzermeier and Cohen (1996) develop a stochastic dynamic programming formulation for the valuation of global manufacturing options. These options are delineated by distinct time periods that are defined by the available sources of supply, plant capacities, product allocations to market regions, and open supply linkages within the global supply chain. There is a cost associated with switching between options over the time horizon of the strategic decision. The model maximizes the global after-tax profits and incorporates option valuation and exchange rates.

Nagurney et al. (2003) develop a framework for the modeling, analysis, and computation of solutions to global supply networks. The authors build extensive mathematical models that include dynamics of price and behaviors of supply chain partners. The model maximizes the total profit by deciding on the amount of product shipments based on the costs as well as the equilibrium prices of products in different currencies at the demand markets in different countries. It allows for the analysis and solution of the equilibrium product flows and prices by considering the behavior of multiple parties (customers, retailers, etc.) at the supply network. The authors apply discrete-time algorithm to compute solutions to several numerical examples.

Grossman and Helpman (2005) study the determinants of outsourcing and model outsourcing activities as the equilibrium of production and trade between parties. The authors present an economic model of location selection with respect to market conditions, supplies and demands. The authors first study how the labor supplies, country sizes and technological investments affect the pattern of outsourcing and location equilibrium. Then they investigate the role of the contracting environment by incorporating the legal setting of countries. Based on macroeconomic and product cost data, authors draw conclusions on how an organization should proceed in choosing specific locations to transfer activities.

Kouvelis and Munson (2004) develop a mixed integer programming (MIP) model to represent the cost of global facility networks that incorporates government subsidies, tariffs and taxations. The MIP model maximizes the net present value of profit subject to demand and capacity constraints. The model incorporates the time value of money by including the interest rates on loans and discount rate of after tax cash flows at each country. Based on the MIP formulation, the authors provided a structural equation modeling approach.

Goetschalckx et al. (2002) present two global logistics system models. The first one is a non-convex optimization problem that focuses on the transfer prices in a global supply chain with an objective of maximizing the after tax profit of an international corporation. The second one focuses on the production and distribution allocation of a single country system when customers have seasonal demands.

Steenhuis and De Burijn (2004) follow a different approach and compare manufacturing location alternatives in a global supply network by using productivity measures as a basis for analyzing the international location/industry combination options. Gross domestic product (GDP) values and dependencies of industries are used to calculate the productivity levels in each country (or region) and a decision process that can be utilized by both corporations and governments is suggested.

Qualitative Reasoning Based Approaches

Decisions in global supply networks incorporate multidimensional variables that cannot always be expressed in terms of monetary values. In the literature, there are also studies that concentrate primarily on the qualitative determinants of global operations such as risks, knowledge bases and market opportunities. Researchers in both academia and industry have generated various studies that emphasize the value of intangible attributes in global supply network decision making.

MacCormack et al. (1994) examine the impact of qualitative factors on the performance and efficiency of global supply networks. They call attention to the importance of incorporating parameters such as exchange rates, tax systems, government regulations and technological capabilities. The authors present an overview of the macroeconomic and business level trends while summarizing the technological advances in production systems and related trends in management philosophies. After highlighting the insufficiency of cost based decision models, the authors propose a new framework for assisting in site location decisions and a model of the future global manufacturing firm.

The global management consulting firm A.T. Kearney (2004) has developed a scheme for offshore decisions based on the offshore location attractiveness indices of countries. Their report also highlights the issues that corporations must balance in their strategic offshore decisions. Countries are evaluated based on corporate surveys, current offshore IT and business process outsourcing activities, people skill levels and availabilities, business environment, infrastructure, culture adaptability, security of intellectual property, and financial structure.

The Global Outsourcing Report 2005 (Minevich & Richter, 2005) assesses countries in terms of two indices: the global outsourcing index (GOI) and the future outsourcing rank (FOR). According to this report, India and China are the two distinct low-cost labor countries that emerge as leaders for organizations considering outsourcing. China is mostly known for low cost manufacturing labor, whereas India has the advantage of an English speaking population and thus attracts a large amount of business process outsourcing (BPO) contracts. Alternatively, Taiwan and Korea are known as the centers of the semi-conductor industry. Besides these big players, countries such as Indonesia, Philippines and Malaysia also can also effectively compete for the outsourcing business.

Multi-attribute modeling approaches are also exploited in order to integrate intangible decision variables into supply network decisions. Udo (2000) employs the analytic hierarchy process (AHP) technique to analyze information system outsourcing decisions. The vendor of choice is selected based on the five criteria: strategic importance, stakeholder's interest, vendor's issues, cost of operations and industry environment. The vendor alternatives are assessed by pairwise comparisons and the decision is made based on the overall synthesized ranking values associated with each vendor. In another application, Badri (1999) combines AHP with goal programming for a global facility location allocation problem. The author first defines seven quantitative goals, including minimizing the total cost and maximizing the environmental quality. Then, AHP is used to determine weight factors for each goal, and goal programming is used to solve the aggregate model.

A majority of work done on evaluating the non-cost related determinants of global supply network decisions relies on empirical studies. Many consulting firms have separate departments that specialize in decisions related to transfer of operations overseas and relocation of corporate divisions. Their reviews mostly include extensive evaluations of risks, benefits, hidden costs, and stakeholder incentives.

Integrated Models and Future Trends

The major objective in global supply network decisions is to maximize profit (or minimize cost). For instance, initial cost differentials of approximately 40% are often cited as a major factor in relocating business processes offshore (Hickey, 2005). However, these decisions engage dimensions other than financial variables. Moreover the decision making process involves many stakeholders who often have conflicting interests, and it is difficult to satisfy all of these interests.

Global supply network decisions are, in large part, based on organizational strategies. A small shift from the optimal decision can have disastrous effects on organizational competitiveness. Therefore, these decision processes should ideally occur within a structured and constrained discipline rather than with a model from a single perspective considering a single element of measurement such as cost. Multidimensionality necessitates the integration of different stakeholder views while taking into account all of the qualitative and quantitative variables.

Mathematical modeling is a reliable technique to solve complex decision problems that involve variables of numerical values such as cost, size and quantity. It is a common technique used to solve global supply network problems. On the other hand, the intangible elements cannot be exactly expressed as functions of numerical variables. In literature, the intangible values are either quantified by using techniques such as multi-attribute utility functions or are heuristically interpreted by empirical studies. Although these approaches are valuable in their wide scope for incorporating many factors, they are not sufficient to generate effective multidimensional decisions. The list below presents some of the research initiatives for integrating intangible and tangible variables for a variety of problems. Many of these research initiatives are not directly geared towards global supply networks but can be utilized as a direction towards composite models.

Cook et al. (1997) present the application of the Cook and Kress (CK) model for evaluating alternatives in multiple criteria decision modeling. This approach has the strength of applicability even when some alternatives do not share the same criteria. The authors propose lemmas for the relation of proportions, and the paper concludes with a performance evaluation.

Yang (2001) proposes two methods for transforming qualitative and quantitative attributes (rule based and utility based). The author presents an evidential reasoning (ER) based approach that integrates qualitative and quantitative data. This approach is also applicable for problems with partial information. Certain monetary equivalent (CME) is used to estimate utilities of quantitative variables, whereas a Probability Assignment approach is used to estimate utilities of qualitative variables.

Yeh et al. (2001) formulate dredger dispatching (a complex decision making process) as a fuzzy multi-criteria analysis model. The authors present an empirical study based on a fuzzy multi-attribute algorithm. They are able to integrate quantitative and qualitative factors and make conclusions accordingly. A similar study is performed by Prodanovic and Simonovic (2003). The authors combine a multi-criteria technique (fuzzy compromise programming) with group decision making by means of multiple criteria and multiple participants. Both quantitative and qualitative criteria are modeled via fuzzy sets.

The strategic problem of designing the optimal global supply networks is also a research area at the University of Pittsburgh, where the authors develop novel integrated methods to assist corporate decision makers in global supply networks. The integration of continuous and discrete decision spaces under qualitative and quantitative criteria is established by utilizing mathematical modeling (i.e., mixed integer programming) and qualitative data analyses (i.e., analytic network process), and integrating them under the multi-objective optimization (MOP) techniques. The multi-criteria feature is structured by MOP where the continuous decision spaces can be treated with a mathematical programming approach. Quantification methods enable the input of multiple experts and provide a theoretical basis for the preference reasoning.

As in the case for most of the decision problems in real life, global supply network decisions consist of several objectives, such as maximization of opportunities and minimization of costs. For an integrated global supply network decision model, intangible and tangible variables are formulated within different objectives and constraints. The optimization of mathematical objectives with quantitative variables can be achieved by means of operations research (OR) tools. Moreover, if the intangible variables are quantified by a qualitative data analysis, the objective functions associated with these intangible variables can also be combined with the quantitative objectives in a multi-objective optimization problem.

In multi-objective optimization problems an optimum solution that optimizes all of the conflicting objectives does not exist. Formulation of a multi-objective optimization problem (Sawaragi, 1985) is given as:

Minimize $f(x) = (f_1(x), f_2(x), ..., f_p(x)$ over $x \in X$
where f_i is an objective function

Instead of a single optimum value, there is a set of best solutions in multi-objective problems. When one or more objective functions are conflicting, the concept of "optimality" does not apply directly in the multi-objective setting. A useful replacement is the notion of *Pareto optimality.*

Definition 1. *A point* $x^* \in X$ *is said to be Pareto optimal solution to the problem if there is no* $x \in X$ *such that* $f(x) < f(x^*)$.

Once the multi-objective problem is formed by combining the quantitative objectives with quantified intangible variables, the Pareto optimal space is generated. The Pareto optimal space represents the set of alternatives which are most favorable for the global supply network decision in consideration. Consequently, the preferences of the decision makers are determined by using utility theory and the final structure of the global supply network is established by selecting the Pareto solution that maximizes the total utility.

CONCLUSION

In today's environment of ever-increasing globalization, a major challenge for organizations is to implement an efficient strategy that can provide a cost advantageous global supply network. Over the years, scientists have established quantitative and qualitative models to support decisions that range from long-term to short-term and from those that are broad in scope to micro-decisions. Uncertainty and diversity of multiple objectives are the greatest challenges for these decision models. Quantitative methods deliver solutions by means of simulation, probabilistic models, and mathematical models, whereas qualitative decision methods imitate the functions of the human brain by transforming intangibles to numbers in order to compare and assess their magnitude. Most of these methods are supported by a strong theoretical framework and their relevance is accepted by researchers and scientists, yet many do not fulfill the specific needs for decision making in complex global environments.

A common and reliable approach in supply network decisions is to structure the decisions from a cost/benefit perspective and formulate mathematical models by numerical equations that reflect the utilities and monetary values of the related decision variables. However a major challenge here is the lack of intangible variables that cannot be expressed in terms of equations. On the other hand, other decision analysis techniques may lack the rationality and sensitivity of mathematical modeling approaches. An ideal decision model should combine the strengths of mathematical and qualitative models. Research clearly shows that integrated decision making models specific to global supply networks is a necessity simulated by the complexity and multidimensionality of the problem.

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KEY TERMS

Decision Analysis: Formulation of models and interpretation of systems to generate the optimum set of choices that will lead to the best consequences.

Global Supply Network: Transnational network of retailers, distributors, transporters, suppliers, and manufacturers that participate in the process of production and/or service. The term "global supply chain" is used interchangeably.

Multi-Criteria Decision Making (MCDM): Methods that are designed to solve decision problems incorporating multiple-criteria whose solutions often result in conflicting objective values.

Multi-Objective Optimization: Optimization of mathematical models that share the same decision variables but differ in their objectives and constraints.

Outsourcing: Transferring an operation or operations to an outside vendor. Offshore outsourcing (offshoring) refers to the transfer of operations to a vendor overseas.

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Chapter 1.17

Leveraging Supply Chain Management in the Digital Economy

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INTRODUCTION

A supply chain is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers. In other words, supply chain encompasses all of the activities associated with moving goods from raw-materials stage through to the end user.

The information systems needed to monitor all of these activities are a critical part of the mix. Successful supply chain management (SCM), then, coordinates and integrates all of these activities into a seamless process. It embraces and links all of the partners in the chain. In addition to the key functional areas within the organization, these partners include vendors, carriers, third-party logistics companies, and information systems providers.

THE BUSINESS CASE FOR SUPPLY CHAIN MANAGEMENT

Improving supply chain management has become the major objective of the corporate world, because it represents an opportunity to resolve monumental problems that face corporations and create a mismatch between supply and demand throughout their supply chains.

For example, let us go back a few years to 1992, when a study of a major department store facing serious market-share troubles showed that 46% of the buyers who entered its stores that year did not buy anything! More than half of the empty-handed said it was not because they did not want something—they did, but the store did not have the product. The department store ended up with dissatisfied buyers and lost sales, plus a surplus of goods in stock that people did not buy, leading to mark downs. This is not a unique story. The number of markdowns among retailers have skyrocketed in the last decade, to the point where people refuse to buy unless goods are on sale and they totally distrust words like "suggested retail price".

This epidemic arises from a total mismatch of supply and demand. Customer and retailer and manufacturer alike are victims of "wrong product, wrong time, wrong place, and probably wrong price." It is a staggeringly costly problem. The retailer must support unwanted goods. The manufacturer must often deal with returns and a complex system of credits.

With constant markdowns, many retailers have faltered and ultimately gone out of business. The manufacturers have not been paid and there they sit with resources allocated to the wrong arenas. The mismatch between supply and demand ultimately arises from the inability of vendors and manufacturers, as their markets change, to make the right decisions about who they want to be. For instance, do the department stores want to be discounters, competing on the basis of commodity products? That is, all department stores would carry the same basic designer/manufacturing lines in clothing. Or do they want to differentiate themselves through such means as exclusive designers, private labels, and customer service?

Let us consider another example. Hewlett-Packard was historically known for high quality, high functionality products in computing and measurement that few, if any, could deliver. As these products became commoditized, customers expected HP to lower its prices, while maintaining a high level of functionality. In HP's case the transition has been from high quality and functionality at a premium price, to differentiation through a competitive combination of price, functionality, and delivery performance. The customer today is looking for a tradeoff: "Can you customize it for my requirements and can you deliver it reliably? And, oh, by the way, keep the price down" (http://www.internetsolutions.enterprise.hp.com/supplychain/library/articles/30000_feet.html).

The real challenge for companies, then, is to make the right decision about where they want to position themselves in cost, functionality, and delivery performance with respect to both their customers' requirements and their competitors' strategies and gambits (see Figure 1). Companies can achieve this with better supply chain management.

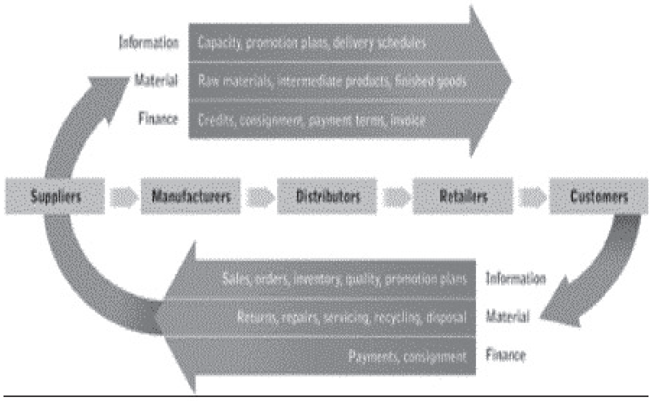
Supply chain management involves the flows of material, information, and finance in a network consisting of customers, suppliers, manufacturers, and distributors. (Figure 2 gives an overview.) Material flows include both physical product flows from suppliers to customers through the chain and reverse flows via product returns, servicing, recycling, and disposal. Information flows involve order transmission and delivery status. Financial flows include credit terms, payment schedules, and consignment and title ownership arrangements.

These flows cut across multiple functions and areas both within a company and across companies (and sometimes industries). Coordination and integration of these flows within and across companies are critical to effective supply chain management. However managing these flows effectively is a daunting task, particularly for global corporations. A global corporation's supply chain now usually consists of multiple enterprises lo-

Figure 1. Products and services differentiate on price, functionality, and delivery performance

(Source: http://www.internetsolutions.enterprise.hp.com/supplychain/library/articles/30000_feet.html. 2000)

Figure 2. The supply chain flows (Source:www.manufacturing.net/scl/scmr/scm0016/integration_1.html)



cated around the world. Furthermore, each of these enterprises is involved in a wide variety of supply chain activities—order fulfillment, international procurement, acquisition of new information technology, and customer service. There are complex relationships such as multiple suppliers serving multiple customers, or a supplier who may be a customer or even a competitor in different parts of the chain. This complexity is why some people refer to supply chains as "supply networks" or "supply webs" (http://www.manufacturing.net/scl/scmr/scm0016/integration_1.html).

Executives of the various companies are increasingly recognizing the tremendous payoff of truly integrated supply chains. They read about Wal-Mart's leveraging of the chain to achieve a dominant position in the retail marketplace. They hear of companies like Dell Computer reconfiguring the supply chain to respond almost immediately to customized orders. They are intrigued by the bold measures taken by M&M Mars to virtually eliminate standing inventory from the pipeline.

The supply chain payoff can come in many forms. It might reduce transaction costs by eliminating unnecessary steps in moving product to market. It could enhance customer service through closer coordination among vendors upstream and carriers, distributors, and customers downstream. Or may be it increases market share within better customer service or lower costs.

KEY CHARACTERISTICS AND PRINCIPLES OF SUPPLY CHAIN MANAGEMENT

The best supply chain management programs display certain common characteristics. For one, they focus intensely on actual customer demand. Instead of forcing into the market product that may or may not sell quickly (and thereby inviting high warehousing and inventory-carrying costs), they react to actual customer demand. And by doing so, the supply-chain leaders are able to minimize the flow of raw materials, finished product, and packaging materials at every point in the pipeline.

Andersen Consulting has encapsulated these qualities in what it terms the "Seven Principles" of supply chain management. When consistently and comprehensively followed, the consulting firm says, these principles lead to a host of competitive advantages—among them, enhanced revenues, tighter cost control, and more effective asset utilization. The seven principles are (http://www.ascet.com/ascet/wp/wpQuinn.html):

1. Segment customers based on service needs. Companies traditionally have grouped customers by industry, product, or trade channel and then provided the same level of service to everyone within a segment. Effective supply chain management, instead, groups custom-

ers by distinct service needs—regardless of industry—and then tailors services to those particular segments.

2. Customize the logistics network. Companies need to design their logistics network based on the service requirements and profitability of the customer segments identified. The conventional approach of creating a "monolithic" logistics network runs counter to successful supply chain management.
3. Listen to signals of market demand and plan accordingly. Sales and operations planning must span the entire chain to detect early warning signals of changing demand in ordering patterns, customer promotions, and so forth. This demand-intensive approach leads to more consistent forecasts and optimal resource allocation.
4. Differentiate product closer to the customer. Companies today no longer can afford to stockpile inventory to compensate for possible forecasting errors. Instead, they need to postpone product differentiation in the manufacturing process closer to actual consumer demand.
5. Strategically manage the sources of supply. By working closely with their key suppliers to reduce the overall costs of owning materials and services, supply chain leaders enhance margins both for themselves and their suppliers.
6. Develop a supply chain-wide technology strategy. Information technology must support multiple levels of decision making across the supply chain. The IT system also should afford a clear view of the flow of products, services, and information.
7. Adopt channel-spanning performance measures. Excellent supply chain measurement systems do more than just monitor internal functions. They adopt measures that apply to every link in the supply chain, incorporating both service and financial metrics.

To respond more accurately to actual customer demand and keep inventory to a minimum, leading companies have adopted a number of speed-to-market management techniques. The names by now have become part of the supply chain vernacular...Just in Time (JIT) manufacturing and distribution; efficient consumer response (ECR); vendor managed inventory (VMI); collaborative planning, forecasting, and replenishment (CPFR); cross docking; and more. These are the tools that help build a comprehensive supply chain structure.

The critical questions are: How do companies get to be supply chain leaders? What are the challenges involved in the process of implementation?

An essential first step is to integrate the key internal organizational functions that are involved in moving product to market. But, advancing from a highly segmented structure to a cross-functional team orientation can be a formidable challenge; people are inherently resistant to change. But, as the industry leaders have demonstrated, making that essential transition pays handsome dividends in terms of cost reduction, operational efficiency, and customer satisfaction.

Once the internal integration is underway companies can set their sights on the next challenge--executing the supply chain strategy and building the bridges to the external partners. This is not an easy task, even for the best-run organizations. It takes a dedicated effort and committed people who know the meaning of persistence.

A STRATEGIC SUPPLY CHAIN AGENDA: INTENT AND IMPLEMENTATION

The consulting firm of A.T. Kearney has developed an instructive framework for setting—and then implementing—a strategic supply chain agenda. The consultants recommend that a supply chain assessment team be created to spearhead the effort. Under the team's guidance, the agenda-setting process would proceed along four steps. (http://www.ascet.com/ascet/wp/wpQuinn.html)

1. **Assess the organization's supply-chain competitiveness.** The evaluation begins by comparing business objectives to existing capabilities and performance. This exercise typically reveals where the existing supply chain can achieve immediate competitive advantage (the "low-hanging" fruit) and where inefficiencies may be leaving the company vulnerable to the competition.
2. **Create a vision of the desired supply chain.** Through a series of "visioneering" sessions that include key customers and suppliers, the team considers how such trends as globalization, channel shifts, and new technology will affect the desired supply chain configuration. It addresses questions such as, what supply chain factors and performance levels drive customer buying decisions? What would make one supply chain a winner over others?
3. **Define those actions required to close the gap between tomorrow's vision and today's reality.** The team identifies possible re-engineering, restructuring, or other actions that could help narrow any gaps. At this stage, the team also works closely with management to assess the organization's readiness to pursue needed changes.
4. **Prioritize the action items identified and then commit the appropriate resources.** The end result of this task should be a unified commitment to a supply chain strategy and a clear agenda to achieve that strategy.

Subsequent actions to implement the supply-chain agenda typically fall into these broad categories:

- Designing the long-term supply chain structure to position the company in the right roles in the right supply chains with the right customers and suppliers.
- Re-engineering supply chain processes to streamline product, information, and funds flow internally and externally.
- Reinforcing the supply chain's functional foundation by improving quality and productivity within operational areas such as warehousing, transportation, and fleet management.

Ultimately, successful execution of this strategy will depend upon how effectively companies can integrate their operations with supply chain partners both upstream and downstream. As consultant James T. Morehouse of A.T. Kearney has pointed out in his writings and speeches, in tomorrow's market arena it will be supply chain vs. supply chain as opposed to company against company.

ANALYSIS OF PAYOFF OF SUCCESSFUL SUPPLY CHAIN MANAGEMENT

Given the extensive time, effort, and commitment of resources involved, is design and execution of a comprehensive supply-chain strategy really worth it all? An evaluation of the bottom-line numbers is the best way to respond to this question. According to A.T. Kearney's research, supply chain inefficiencies can waste up to 25% of a company's operating costs. With profit margins of only 3 to 4%, then, even a 5% reduction in supply-chain waste can double a company's profitability.

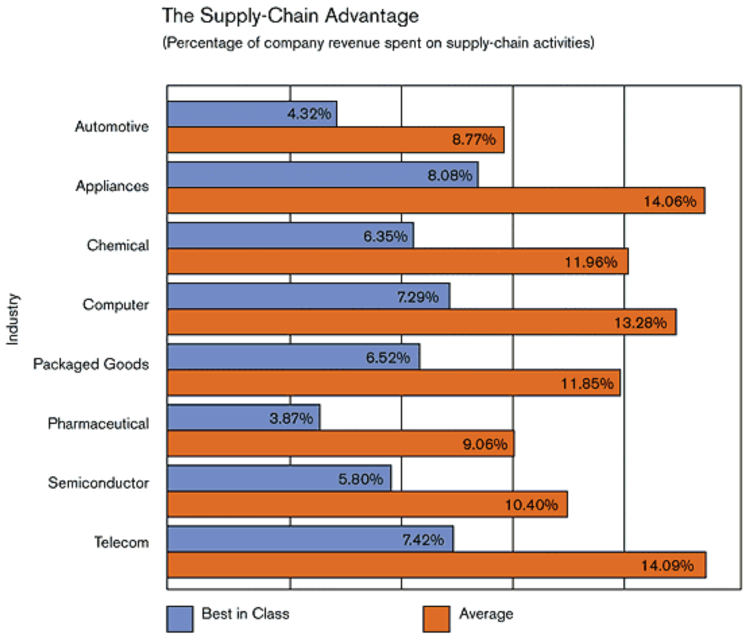
Through its comprehensive Integrated Supply Chain Benchmarking Study, Pittiglio Rabin Todd & McGrath (PRTM) found that best practice supply chain management companies enjoyed a 45% total supply chain cost advantage over their median competitors. Specifically, their supply chain costs as a percentage of revenues were anywhere from 3 to 7% less than the median, depending on the industry (see Figure 3).

Based on his experience with companies participating in MIT's Integrated Supply Chain Management Program, Prof. Metz has identified certain commonly reported bottom-line benefits. These center on cost reductions in such areas as inventory management, transportation and warehousing, and packaging; improved service through techniques like time-based delivery and make-to-order; and enhanced revenues, which result from higher product availability and greater product customization.

There are other payoffs as well. For example, the supply chain technique of optimizing the distribution network—that is, determining the best location for each facility, setting the proper system configuration, and selecting the right carriers—can bring immediate cost advantages of 20 to 30%. That's the number determined by IBM's Wholesale Distribution Industry Segment, based on consulting engagements in a wide range of industries. "This typically breaks down into transportation savings of 15 to 25 percent and improvements in inventory-carrying costs of 10 to 15 percent," says Mark Wheeler, national solutions manager for the IBM consulting unit. (www.ascet.com/ascet/wp/ wpQuinn.html)

Another supply chain technique with proven payback potential is cross-docking—the practice of receiving and processing goods for reshipment in the shortest time possible and with minimum handling. According to Maurice A. Trebuchon, a partner with PricewaterhouseCoopers, cross docking can produce savings of 25% or more over conventional warehousing. In a presentation made at the annual Council of Logistics Management meeting, Trebuchon cited one manufacturer that used cross docking to realize a net savings of $0.84 per ton of freight processed. The savings resulted from the elimination of putaway, picking, and storage costs.

Figure 3. The supply chain advantage



(Source:http://www.ascet.com/ascet/wp/wpQuinn.html)

CONCLUSION

In today's business world, one thing becomes strikingly clear: Supply-chain management is not just the wave of the future. For professionals working in this field, the issue is not so much whether to become expert in the art and science of supply-chain management, but rather how fast. This means becoming intimately familiar with the corporate mission and figuring out how supply chain processes can help achieve that mission. It means becoming an evangelist of the supply chain word—preaching both within the organization and externally to customers, suppliers, carriers, and third party logistics providers.

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KEYWORDS

Collaborative Planning, Forecasting and Replenishment (CPFR): Aims at the enhancement of supply chain integration by supporting and assisting joint practices. It seeks for cooperative management of inventory through joint visibility and replenishment of products throughout the supply chain. Information shared between suppliers and retailers aids in planning and satisfying customer demands through a supportive system of shared information.

Efficient Consumer Response (ECR): The joint trading and industry working towards a more efficient and productive answer to consumer demand and the removal of unnecessary costs from the supply chain. It's characterized by the emergence of collaborative management in the supply chain.

Supply Chain: A network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers.

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Chapter 1.18

A Relative Comparison of Leading Supply Chain Management Software Packages

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ABSTRACT

Supply Chain Management (SCM) has proven to be an effective tool that aids companies in the development of competitive advantages. SCM Systems are relied on to manage warehouses, transportation, trade logistics and various other issues concerning the coordinated movement of products and services from suppliers to customers. Although in today's fast paced business environment, numerous supply chain solution tools are readily available to companies, choosing the right SCM software is not an easy task. The complexity of SCM systems creates a multifaceted issue when selecting the right software, particularly in light of the speed at which technology evolves. In this paper, we use the approach of Analytic Hierarchy Process (AHP) to determine which SCM software best meets the needs of a company. The AHP approach outlined in this paper can be easily transferred to the comparison of other SCM software packages.

INTRODUCTION

A supply chain represents the veins of a business; it is a network of facilities and distribution options that perform the functions of material procurement, the transformation of materials into intermediate and finished products, and finally the distribution of finished products to customers. Supply chains are not specific to any one industry; they are inherent in both manufacturing and service based organizations. Supply chains do however vary in complexity from industry to industry and even firm to firm. The process of managing supply chains is a multi-billion dollar software industry; the worldwide market for SCM software topped an estimated $6 billion in 2006 and is expected to reach $10 billion by 2010 (a compound annual growth rate of 8.6%) (Trebilcock, 2007).

Supply chains are evolving to meet the changing requirements of the companies trying to manage them. A few years ago simply having full visibility of your own supply chain was seen as extraordinary. Now that visibility is no longer enough; companies need to be agile in respect to their supply chain (Croom, Romano, & Giannakis, 2000; Bartels, 2006). Companies need to make educated business decisions based upon the information captured in their information systems.

SCM systems are used to coordinate the movement of products and services from suppliers to customers (including manufacturers, wholesalers, and retailers). The system's main objective is to manage warehouses, transportation, trade logistics and various other issues concerning facilities and the movement and transformation of materials en-route to customers.

The components of SCM include (but are not limited to) supply chain event management and optimization, warehouse management, radio frequency identification (RFID), transportation management, demand management, supplier relationship management, and service parts planning. Beyond the traditional elements, SCM software has also incorporated modules for international management; this is the direct result of the growing need for businesses to manage supply chains that include a mix of global suppliers, manufacturers, and company owned plants. In fact, the bursting demand for global SCM has led the upsurge in the worldwide market for SCM systems (Aksoy & Derbez, 2003; Das & Buddress, 2007; Hill, 2007).

Why Compare?

Research has found that the typical U.S. manufacturer is managing an average of more than 30 contract relationships (Trebilcock, 2007). Wholesalers are distributing to worldwide retailers and jobbers for resale; and retailers now staff virtual storefronts that service customers globally. The growing supply chain requires a management system that is efficient and caters to the needs of each enterprise. The benefits of implementing an appropriate SCM system include: Increased top-line profit growth through supplier teamwork; Reduced inventory carrying costs and stock-outs; Increased customer service; Supply chain visibility; Optimization of the value chain respective to cost reduction and bottom-line improvement; Reduced corporate-wide operating costs; Increased competitiveness; and Quick adaptation to changing markets without detriment to customers.

However, since SCM system implementation is typically not a small scale operation, there are inherent managerial risks. For example, within businesses with several facilities, partners, and departments etc., a legacy or manual SCM system can lead to bottlenecks. There are cases where the appropriate SCM application is chosen but it does not sufficiently integrate with the rest of the enterprise software applications. In some cases, the wrong SCM application is chosen (perhaps to cut costs or due to poor information); the result is that the whole business from sourcing to distribution is negatively affected. Efficient SCM provides immense benefits; a well-run value chain should positively impact an organization's profitability and success.

SUPPLY CHAIN MANAGEMENT SOFTWARE

While there are a number of SCM software providers, the major players have maintained their top positions. For example, in 2005 the top 5 ranked providers were Manhattan, RedPraire, SSA Global, Swisslog, and SAP AG (O'Neill, 2005); in 2007 the top 5 spots were manned by Manhattan, RedPraire, SAP, Oracle and Infor (who swallowed up SSA) (Trebilcock, 2007). In selecting SCM software vendors to compare for this study, the following criteria were utilized:

- Limited to those providers offering worldwide solutions
- Limited to vendors whose SCM systems include the following minimum components: Warehouse Management Systems (WMS), Transportation Management Systems (TMS) and Warehouse Control Systems (WCS),
- Limited to 7 software vendors in the study (use of Expert Choice limited us to 7 alternatives).

Based on criteria outlined above we have elected to compare the following 7 software vendors:

- Aldata – Aldata SCM
- HighJump - HighJump SCM
- Infor – Infor SCM
- Manhattan Associates – Integrated Logistics Solutions
- Oracle – Oracle E-Business Suite Supply Chain Management - R12
- RedPrairie – E2e
- SAP – SAP SCM

Decision Tool

To aid in the comparison of our selected SCM systems, we have relied on Expert Choice 11.5 (EC11.5). The key functions of EC11.5 are: to structure by identifying objectives and criteria for evaluating the decision at hand and the potential alternatives; to evaluate the objectives and alternatives; to synthesize by combining hard numbers and intuitive judgments (math and psychology) to value the alternatives via sensitivity analyses and exploring "what if" scenarios (Expert Choice Inc., 2007). By relying on EC11.5 we can understand the trade-off of weighing certain choice criteria differently.

It is possible to yield the best alternative via EC11.5 using the Analytical Hierarchical Process (AHP). AHP is based on mathematics and human psychology; the process deals with complex decision making by providing a framework for arranging the criteria, quantifying them, and relating the elements to the overall goal. The AHP method breaks down the decision into a hierarchy of more clearly stated sub-issues (where each issue is treated independently); once the hierarchy is built, the numerous alternatives are reduced to a series of pair-wise comparisons for synthesis. Those judgments are converted to numerical values that are processed, evaluated and compared over the whole scope of the issue. Because a numerical priority (weight between 0 and 1) is assigned to each element, AHP allows non-comparative elements to be compared in a consistent way. Finally, AHP produces numerical priorities and the choice of the best alternative simply becomes ranking the software packages in order of preference (Saaty & Vargas, 2006; Saaty, 1980; 1996; 2001; 2005).

In the following section, we briefly discuss features offered in each of our seven chosen software alternatives. Based upon this information, each alternative software package will be scored with respect to our evaluation criteria; these scores form the basis for pair-wise comparisons used in the AHP.

Aldata (Aldata SCM)

Aldata is one of the global leaders in supply chain software for retail, wholesale and logistics companies. The company's comprehensive range of SCM and In-Store solutions enable more than 300 customers across 50 countries to enhance productivity, profitability, performance and competitiveness. The majority of Aldata's customers are located in Western Europe; they primarily service small and medium size supermarket chains but also provide service to larger companies including Bosch and Merck. Aldata has won the IT Europa's European IT excellence award (General Business News, 2008).

Aldata invests heavily in research and development within the SCM unit. The G.O.L.D. product family is being further developed and the current version six of the software will remain the core platform for the coming years. Major launches were the new G.O.L.D. Track modules, a federation module for providing integrated traceability across business networks, and G.O.L.D. Mobile, a module providing mobility in the retail store and enabling store operations such as stocktaking, receiving and price control using PDAs or radio frequency terminals (IHL Group, 2006). The company does not provide any other enterprise management solutions.

HighJump (HighJump SCM)

HighJump, a 3M Company, offers standard functionality but leverages best practices in order to meet the clients' immediate operational disciplines while increasing efficiencies. HighJump software highlights its vertical-specific adaptability which enables solutions to fit a variety of customer requirements in industries that include aerospace, automotive, consumer goods, direct store delivery (DSD), discrete manufacturing, food and beverage, wholesale distribution/industrial production, document management, and publishing.

HighJump implants a best-practice advantage implementation methodology which focuses on budgeting and aligning clients' interests. HighJump offers in-depth training courses aimed at preparing clients to administer their software solutions and 24/7 staffed customer support. Furthermore, HighJump organizes an annual user conference where HighJump industry analysts, employees, partners and customers meet to brainstorm the latest trends in execution; customers get the opportunity to learn how to leverage SCM solutions to achieve increased efficiencies and maintain competitive advantage.

The software architecture and hardware platforms include the following: Main Languages: C++; .net; C-sharp; DMBS; SQL Server; Oracle; and a 4GL: HighJump adaptability tool set. The software pricing ranges from $100,000 to $250,000 and is dependent on the number of concurrent users. The target market for HighJump includes logistics/distribution, batch, repetitive, job shop, discrete, process, continuous flow, and project manufacturing which translates to industries that include health care, pharmaceuticals, automotive, grocery, food, apparel, 3PL, and audio.

HighJump integrates source-to-consumption solutions that contain four critical elements including rapid return on investment, a global execution platform that allows all applicants to work together seamlessly, ease of configuration to empower strategic competitive advantage, and best practices based functionality to solve core logistic challenges

Infor (Infor SCM)

Infor is a large size software developer that provides very strong management resource solutions. The company offers its products as separate modules for various enterprise functions, including: Manufacturing, Supply Chain Management, Financials, Project Management (PM), Human Resources, and Customer Relationship Management. Infor also offers an all-inclusive Enterprise

Resource Planning Suite (ERP). Their products are implemented worldwide.

Built on Open SOA (service-oriented architecture), Infor's logistics software provides advanced customization, which is not limited to any specific platform.

Due to high levels of customization, there are high setup costs in switching to the Infor's software. Due to high setup costs, Infor has historically targeted medium and large size businesses with sales in excess of $50,000,000. Recently, Infor announced a new ERP solution targeting small to medium size distributors (ERP FACTS). In targeting smaller firms, Infor has developed numerous industry specific basic modules that do not need costly customization; this has put them in a very cost advantage position when compared with their industry competition. Infor's SCM solutions range from $2,000 to $100,000+; solutions at the higher end of the price range tend to be solutions that have been extensively customized.

Manhattan Associates (Integrated Logistics Solutions)

Manhattan Associates is a leading supply chain solutions provider. The company's supply chain planning, supply chain execution, business intelligence, and business process platform capabilities enable its more than 1200 customers worldwide to enhance profitability, performance and competitive advantage. Unlike some of the other companies that provide SCM tools in addition to other non-SCM solutions, Manhattan Associates is engaged almost exclusively in the SCM solutions field. Much of their operational results company acquisitions.

Manhattan Associates targets companies in the retail, distribution, transportation, and manufacturing industries; their modules include warehouse, transportation, trading partner, distributed order, and reverse logistics management applications. Manhattan also offers performance management and radio-frequency identification tools designed to enhance the functionality of its other products. Manhattan's "Atlanta facility lets customers evaluate technology and equipment before adding RFID to supply-chain operations" (Malykhina, 2005, P.1). The company sells third-party hardware, including bar code scanners and printers, and also provides professional services. Manhattan Associates has been expanding their operations through new product offerings. According to Trebilcock (2007), "In 2001 Manhattan was the No.1 provider of warehouse management systems, with just more than $100 million in revenue. Today, Manhattan is a nearly $300 million company, offering transportation management, supplier collaboration and supply chain planning" (P. 47). Manhattan offers customer service on a 24 hour /7 days a week basis.

Oracle (Oracle E-Business Suite Supply Chain Management - R12)

With Oracle SCM (OSCM), companies can build and operate world class value-chains for profitable growth. The Oracle E-Business Suite Supply Chain Management (R12) family of applications integrates and automates all key supply chain processes, from design, planning and procurement to manufacturing and fulfillment, providing a complete solution set to enable companies to power information-driven value chains. Companies can anticipate market requirements and risks, adapt and innovate to respond to volatile market conditions, and align operations across global networks. A unified data model provides a single, accurate view of your entire supply chain. Companies can implement lean, demand driven principles and manage their increasingly complex, global supply chains.

OSCM consists of a variety of separate applications which are categorized by supply chain segments. Depending on a company's needs, a wide variety of applications are available. Some of the basic benefits of OSCM include real time supply chain measurements as a result of a direct connection with suppliers and customers, expense management for all categories of goods and services, analytical support to monitor the performance of a company's supply and the ability to make adjustments.

Oracle has been rapidly expanding its SCM software business, primarily through the acquisition of smaller, more specialized businesses. Oracle has adopted an acquisition strategy in order to accelerate its software innovations. Previous acquisitions include People Soft and Demantra. As a result of the acquisitions, Oracle is focusing its next generation of products on integration and the ability for these programs to communicate and share information with each other.

RedPrairie (E2e TM Suite)

E2e offers customers supply chain execution, store management, logistics, and warehouse management software that can assist or manage all facets of their business. E2e allows for monitoring and control from inbound logistics and inventory management to order fulfillment and transportation. Collaboration tools are included to assist in a company's daily efforts to collaborate or interact with trading partners.

Every industry is being challenged with increasingly complex multi-channel demands, especially from the end consumer of their products. The ability to respond to create perfect, customized, and timely orders is a critical competitive advantage to meet consumer expectations, reduce inventory and storage costs, and streamline operations (Report, 2006).

RedPrairie considers themselves unique in the SCM software industry in their effort to incorporate change management, learning management, interactive training, comprehensive online help, and customized learning and reference materials into their offerings. Companies implementing their suite of tools can leverage real ROI, minimize downtime due to obstacles, and move toward near 100% efficiency which increases companies core advantage. RedPrairie's support centers are located globally and offer full language capabilities in addition to leading-edge call tracking capabilities for reliability.

RedPrairie's ability to configure their software suites into practical groupings and components allows them to offer build-to-order manufacturing solutions that include sophisticated in-line sequencing which can lead to reduced cost and increased efficiency. The result is that all component levels can be tracked, revised and/or updated keeping all elements in synchronization. This capability is enhanced when used in conjunction with RedPrairie's warehouse management system (WMS).

SAP (SAP SCM)

SAP is the world's largest business software company and the world's third – largest independent software vendor. By building the strongest technology, services and development resources, SAP is positioned to deliver a superior business platform that can access valuable information resources, while improving overall process efficiencies and strong customer relationships including end users, suppliers and vendors. SAP's integrated packages allow customers' needs to be identified quickly and precisely while comprehensive and personal solutions are developed and rolled out.

SAP's services assists companies in maximizing their success through a combination of SAP experts, methodologies, tools, and certified partners. Users of SAP SCM can benefit with the following: Faster response to changes in supply and demand that will give customers the chance to quickly capitalize on new opportunity; Increased customer satisfaction- SAP SCM enables clients to better adapt to changes and meet customer demand; Compliance with regulatory requirements; Improved cash flow; and Higher margins- SAP SCM helps companies lower operational expenses with more timely planning for procurement, manufacturing and transportation. Using SAP

SCM companies can also improve their overall performance and quality through better order, product, and execution synchronization.

SAP SCM delivers a complete set of futures and functions for building adaptive supply chain networks. SAP SCM includes features and functions to support collaborative supply chain planning processes, including strategic, tactical, and operational planning as well as service parts planning. By using SAP SCM, a company can optimize a full range of planning activities including: demand planning, safety stock planning, supply network planning, distribution planning, and supply network collaboration. The company can also handle service parts planning activities, which includes: parts demand planning, parts inventory planning, parts supply planning, parts distribution planning, parts monitoring. With SAP SCM the company can manage order fulfillment activities, support end-to-end procurement, manage key transportation processes, manage warehouse activities, support all production processes including engineer-to-order, make-to-order, and make-to-stock manufacturing. SAP SCM also supports supply chain visibility design and analytics with features and functions that enable supply chain design and analytics processes. Planners and key decision makers can perform strategic and tactical business planning.

RELATIVE COMPARISON

Criteria Revisited

In order to conduct our analysis we will use selected quality criteria to assess software characteristics. With the help of Expert Choice software, we will first compare the relative importance of each of the criteria against each other.

- Ease of Integration: the ability to integrate with any third party software platforms (vendors, government clearance computers, ocean carriers, etc.) and any other proprietary software or legacy systems.
- Reliability and Stability: any warranties provided by the vendor in addition to the degree of completeness, accuracy, and consistency of the package. The availability of any templates or custom models available for specific aspects of the supply chain.
- Efficiency: the level of accessibility and efficiency; how well the software functions are aligned with the general business objectives as well as the number of tools available.
- Customization and Expansion potential: the degree to which the product supports the specific business goal assumptions and the tools available for SCM respective to the specific needs of the client company. Also, the degree of augmentation ability and the ability to evolve over time and expand as well as any expert options or limitations.
- Service and Support: the availability of support services coupled with the time it takes to have a technician to be available on site or on the network. The availability of technicians that are specialized in the particular industry the SCM is being utilized (transportation versus warehouse management, retail versus wholesale etc.). Any extra perquisites such as annual conferences.
- Mobility and Portability: is a measure of platform independence; the number of support platforms and supported architecture as well as any software requirements needed to run the software.
- Ease of Interface: shows how well the software communicates with the outside world, the quality of human machine interface, and how results are displayed.
- Pricing: the base price of the product, and/or range of the price for “basic” packaging respective to the SCM applications.

Evaluation Model

Our evaluation criteria, as entered in Expert Choice, are as follows:

- Ease of Integration – evaluated in terms of:
  - Time
  - Number of platforms supported
  - Support for open source developers
  - Reliability and Stability – evaluated in terms of:
  - What classes of models does the application support?
  - If the application allows custom model creation, templates or both.
  - The reputation of the vendor supplying the tool
- Efficiency – measured in relation to:
  - How well the software supports the general business objectives?
  - Data processing capacity and speed.
- Customization – evaluated in terms of:
  - How well the product supports the general business goal assumption?
  - Specific tools available respective to the specific needs of the client company.
- Expansion – evaluated in terms of:
  - The degree of augment ability
  - The ability to evolve over time and expand (i.e. available upgrades)
  - Any expert options or limitations
- Service and Support – evaluated in terms of:
  - Any available demos
  - Turnaround time for on site or network tech availability
  - Specialization of the techs in the respective industry
  - Any additional perks (i.e. annual conferences, 24/7 service etc.)
- Mobility and Portability – evaluated in terms of:
  - Hardware platform
  - Software architecture
  - Software requirements
- Ease of Interface – evaluated in terms of:
  - Simplicity of human machine interface
  - Result displays
  - Graphical layout
- Price (where available) – evaluated in terms of:
  - The price range provided – the lower of the range and the mean served as the rating criteria.

PROCEDURE OF EXPERT CHOICE: SHORT EXAMPLE

Providing an example of Expert Choice on a small scale helps to describe the method behind pairwising and making the best decision regarding which SCM Software to choose contingent on our criteria. To provide a small scale example we implemented five criteria against our objective and compared three SCM software applications.

The pair–wise weights were assigned to the criteria initially chosen; the decisions were based on available information and which criteria outweighed their pair. The result is the prioritized listing of criteria respective to the objective – in this case selecting the best SCM software. Expert Choice allows for normalization in order to better understand the weighting scheme – in other words these small scale results recommend that Pricing is more than twofold the importance of Portability. In addition, the inconsistency is very low at only 2%; the logic behind assigning weights (importance) to each criterion remained consistent within each pair-wise comparison.

We chose three alternative SCM Software packages (Infor, SAP & Oracle) for the short example to exhibit the functions of AHP relied on by Expert Choice. We proceeded to perform a pair-wise comparison of all our software solution

Figure 1. Presents the prioritized criteria after the initial weight assignments

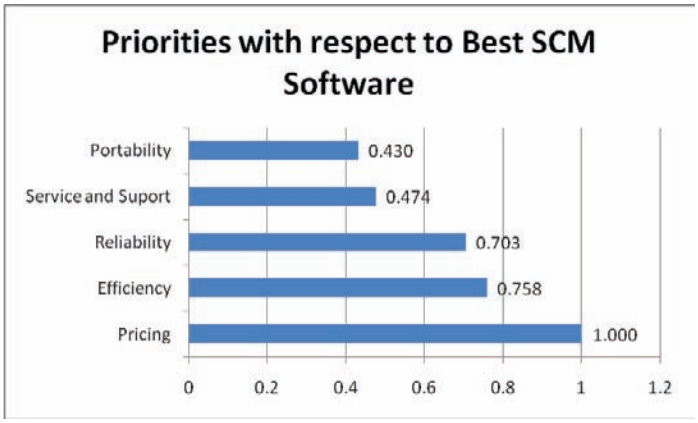
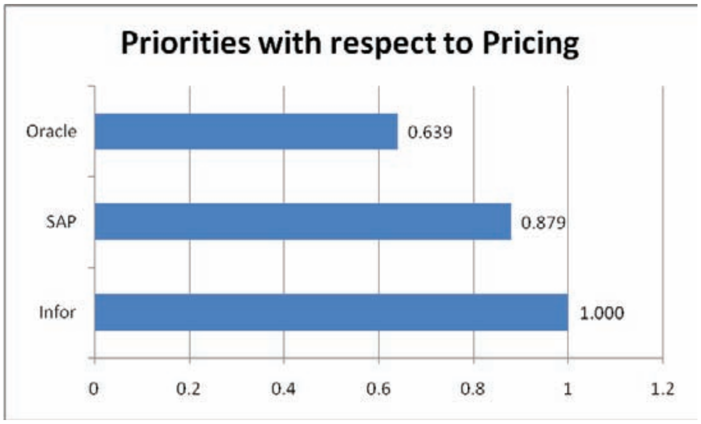


Figure 2. Presents the introduction of alternative SCM software packages analyzing pricing



alternatives based on each established criteria. Based on strengths and weaknesses determined about each software; we analyzed the components of each criterion on a case by case basis. The detailed level of analysis allowed us to obtain informative results about each software solution tool. The logic provided a prioritized listing of the software packages according to the criteria which held the highest weight. As an example, Figure 2 displays results obtained from Expert Choice when analyzing Pricing criteria.

However, this is minimal information when making a decision – sensitivity analysis provides a technique for determining the outcome of a decision if a key prediction turns out to be wrong. The analysis is a tool for analyzing the impact of key criteria; sensitivity blocks are used to generate tables and/or plots of simulation results as functions of feed stream, block input, or other input variables. Since there are various criteria, the following charts demonstrate the outcome of each SCM package against the chosen criteria. Expert Choice offers a variety of alternatives which facilitates the decision making process and offers alternatives for assessing the outcomes according to user preference.

We found that the dynamic sensitivity analysis tool can prove to be very useful when trying to estimate overall impact of each criterion on the final decision. The program allows users to graphically manipulate the relative weight of each criterion against one another by simply clicking and dragging. Furthermore, the program would simultaneously change the graphically presented outcome. Thus, if for the purposes of presentation, we assigned an unrealistically high weight to the price criterion in the example above the overall outcome would change from SAP being the best option to Infor software as the ultimate solution.

SCENARIO ANALYSIS

In this section, we compare the seven chosen SCM applications based on the seven criteria previously defined. The decision of optimal software choice involves multiple-objectives and will vary among customers based upon individual needs. It is not often that one SCM application suits the expectations of every industry, institution, or customer; therefore the integration of scenarios is an important tool of the decision making process.

In order to make the simulation realistic, various scenarios were examined that altered the size, needs, and global presence (amongst other aspects) of potential customers for the available SCM applications. We proceed with the hypothetical situations and demonstrate techniques and procedures to establish the best available alternative based on our set of defined criteria. In examining the importance of various criteria, size stood out as a decision making factor. In order to emphasize the importance of size as a decision making factor, we went further to implement three specific scenarios that visit opposite ends of the spectrum; large global presence versus small regional existence. Note, however, that when the size was manipulated, only certain criteria proved to be dependent on that factor, therefore the results below exhibit how other criteria were weighted similarly, despite the variations in size.

The number of SCM applications compared coupled with the number of evaluation criteria results in a significant number of pair-wise comparisons used in the AHP process. The following table summarizes the relative weights of each criterion in addition to the direct relationship between the synthesized weights in each column with their respective criterion. The higher the synthesized weight, the more a particular sized company (Large vs. Small) views that particular SCM software alternative.

When comparing above scenarios, the notable changes were the relative weights of each criterion when the size of the company is accounted for in the scenario. It is important to take into consideration that a real business environment comprises many different industries, as well as an array of different company types with different needs, goals and business objectives; all of which would impact relative weights and the ultimate SCM software decision.

The selection of the best software for a specific company should be based on the individual needs of the organization making the choice. The same software package will not be the best choice for every buyer. Different SCM solutions will provide the best fit depending on the applicable situation or scenario. Creating different hypothetical scenarios can be useful in the selection process.

To illustrate this point, we have created different scenarios which demonstrate the relevance of the individual organization’s environment and objectives in the selection process. In addition to size, the best SCM software package for an organization can differ based on characteristics like industry or sector, geographic diversity of operations and vertical or horizontal integration of the supply chain. We found that sector can be a crucial factor in the decision making process; we believe that an organization’s sector will drive the decision for an optimal SCM software package.

In addition to a total of 144 basic pair-wise comparisons in order to compare all alternatives with respect to all of the criteria, each scenario also requires an additional 21 pair-wise comparisons. Once all pair-wise comparisons are made, Expert Choice is used to synthesize the weights of all the criteria with the weights of all the alternatives

Table 1. Synthesized weights with respect to criteria or goal

Synthesized Weights with Respect to Criteria	Pricing		Service & Support		Reliability & Stability		Customization & Expansion		Easiness of Interface		Mobility & Portability		Easiness of Integration	
	Large	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large	Small
Manhattan Associates	0.138	0.162	0.140	0.090	0.143	0.143	0.181	0.173	0.223	0.223	0.205	0.205	0.215	0.215
RedPrairie	0.165	0.103	0.159	0.186	0.119	0.119	0.114	0.123	0.139	0.139	0.145	0.145	0.137	0.137
SAP	0.140	0.103	0.161	0.163	0.209	0.209	0.198	0.204	0.141	0.141	0.205	0.205	0.143	0.143
Oracle	0.143	0.228	0.161	0.156	0.211	0.211	0.199	0.202	0.165	0.165	0.212	0.212	0.171	0.171
Infor	0.089	0.078	0.105	0.119	0.146	0.146	0.143	0.151	0.167	0.167	0.073	0.073	0.166	0.166
Aldata	0.114	0.051	0.090	0.065	0.071	0.071	0.097	0.086	0.122	0.122	0.043	0.043	0.124	0.124
HighJump	0.212	0.275	0.183	0.221	0.100	0.100	0.068	0.062	0.042	0.042	0.116	0.116	0.044	0.044

Overall Synthesized Weights with Respect to Goal		
	Large	**Small**
Manhattan Associates	0.179	0.156
RedPrairie	0.135	0.133
SAP	0.176	0.169
Oracle	0.186	0.199
Infor	0.135	0.122
Aldata	0.094	0.070
HighJump	0.096	0.152

to determine the best solution for each scenario. In illustrating the impact of each scenario of the final decision, we have chosen different sets of SCM software packages for a more complete comparison.

Table 2 lists the weights of the pair-wise comparisons for government versus business entities. There is a direct relationship between the individual criterion and the weights displayed in each column. The higher the number displayed, the greater the weight placed on the criterion for that type of organization.

Based on the results of the weighted criteria calculations done by Expert Choice, the top

Table 2. Weights assigned to alternatives for both business and government use

Synthesized Weights - with respect to criteria	Portability		Reliability		Efficiency		User Friendliness	
	Business	Gov't	Business	Gov't	Business	Gov't	Business	Gov't
i2 Solutions	0.149	0.147	0.167	0.167	0.154	0.154	0.159	0.153
Logility	0.138	0.134	0.149	0.149	0.140	0.140	0.135	0.141
SYSPRO 6.0	0.114	0.116	0.085	0.085	0.112	0.112	0.138	0.138
Picaso	0.069	0.073	0.081	0.081	0.064	0.064	0.103	0.102
Manhattan Assoc	0.215	0.207	0.177	0.177	0.209	0.209	0.162	0.172
Oracle	0.238	0.182	0.201	0.201	0.251	0.251	0.154	0.131
ILOG	0.077	0.141	0.141	0.141	0.071	0.071	0.150	0.163

Synthesized Weights – Continued	Report Interpretation Simplicity		Customization Flexibility		Training & Support	
	Business	Gov't	Business	Gov't	Business	Gov't
i2 Solutions	0.164	0.164	0.153	0.153	0.143	0.143
Logility	0.117	0.117	0.165	0.167	0.153	0.153
SYSPRO 6.0	0.124	0.124	0.124	0.123	0.142	0.142
Picaso	0.097	0.097	0.105	0.098	0.118	0.118
Manhattan Assoc	0.215	0.215	0.150	0.150	0.206	0.206
Oracle	0.175	0.175	0.197	0.200	0.133	0.133
ILOG	0.107	0.107	0.106	0.110	0.105	0.105

three alternatives for a business entity would be Oracle, Manhattan Associates and i2 Solutions. This was in line with our expectations. We had expected Oracle and Manhattan Associates to be prime solutions for business and government operations, since they were the software solution tools that excelled in the areas of Efficiency and Reliability.

Table 3 summarizes the overall results obtained through Expert Choice for our case scenario. We previously placed emphasis on efficiency and reliability for which the weights obtained were very close to each other when comparing the three top alternatives. However, when the rest of the criteria are considered, the weights obtained under each business entity change influencing the type of software solution that best suit each type of organization. For example: under a business entity Oracle obtained the highest weight of .202 overall, as opposed to .180 under a government entity. Picasso on the other hand, although obtained the lowest weight for both type of entities, it obtained a better rating from the government sector with a weight of .092 as opposed to .086 from the business sector.

As demonstrated by the tables previously shown above, different entities have different preferences and priorities which leads to differences in optimal software selection. The following scenarios will further support this conclusion.

Scenario 1: A&D Wholesale Distributors, Inc

Let us assume this is a mid-size distribution company that operates throughout the United States, with 550 employees and operations in 20 different states. A&D is looking for SCM software that will

Table 3. Summary of synthesized results for government vs. business entities

Synthesized Weights -- with respect to goal	Business	Government
i2 Solutions	0.157	0.156
Logility	0.145	0.144
SYSPRO 6.0	0.113	0.117
Picaso	0.086	0.092
Manhattan Associates	0.189	0.189
Oracle	0.202	0.180
ILOG	0.109	0.121
Overall inconsistency ratio	**0.03**	**0.05**

Scenario 1.

Criteria	Weights
Efficiency	0.232
Customization Flexibility	0.228
Reliability	0.138
Report Interpretation Ease	0.126
User Friendliness	0.117
Training and Support	0.091
Portability	0.069

Alternative	Ranking
Logility	0.192
i2 Solutions	0.186
Manhattan Associates	0.156
Oracle	0.156
Syspro 6.0	0.115
ILOG	0.102
Picaso	0.093

support a distribution intensive type of business and assist them in reducing transportation and inventory retention costs leading to increased revenue and customer satisfaction. Based on this company's goals and objectives, we decided that the criteria they would focus on would be: Customization Flexibility, they need a software solution tool that would be able to customize to support their specific needs and Efficiency, their main objectives are to reduce transportation costs and inventory retention time.

Scenario 2: Start Up Online Company

Let us assume this is a small retail oriented start up internet company with 10 partners, no fixed location, no fixed relationship with outside parties and limited knowledge on the industry. This is a company that would need a software solution alternative that would offer them a high level of support with relation to hardware platform and software architecture, and one that would be able to provide a high level of training and support, since they are new in the industry and have a flexible SCM structure. Based on this company's needs, we decided that the criteria they would focus on would be: Portability, because they need a software solution that would support their internet based business, across different platforms and operating systems and Training and Support, because they need a software solution that will provide them with intensive training about the software as well as with aids to gain a better understanding of their flexible supply chain structure and demands.

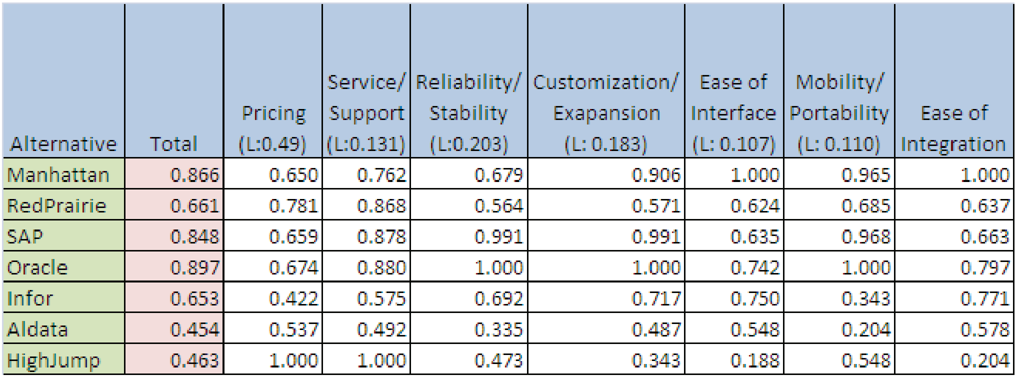
In the following tables, results for a number of additional scenarios are presented.

Scenario 2.

Criteria	Weights
Portability	0.239
Training and Support	0.183
Customization Flexibility	0.176
Efficiency	0.138
Reliability	0.103
Report Interpretation Ease	0.094
User Friendliness	0.067

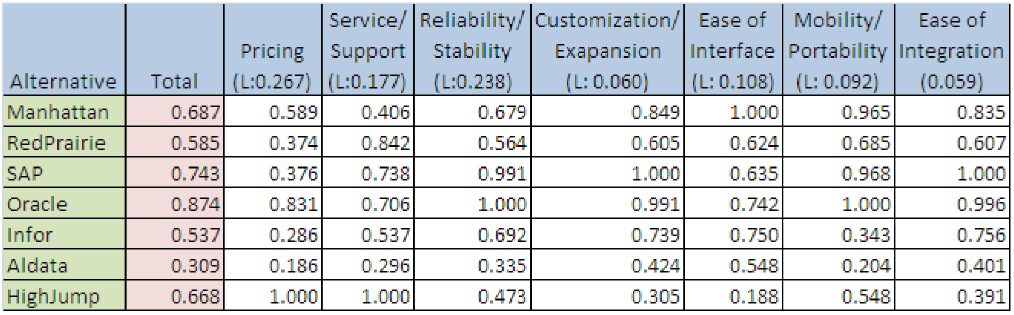
Alternative	Ranking
Manhattan Assoc	0.195
Oracle	0.191
I2 Solutions	0.166
Logility	0.159
Syspro 6.0	0.109
ILOG	0.095
Picaso	0.085

Table 4. Summary of a large scale retailer



Alternative	Total	Pricing (L:0.49)	Service/ Support (L:0.131)	Reliability/ Stability (L:0.203)	Customization/ Exapansion (L: 0.183)	Ease of Interface (L: 0.107)	Mobility/ Portability (L: 0.110)	Ease of Integration
Manhattan	0.866	0.650	0.762	0.679	0.906	1.000	0.965	1.000
RedPrairie	0.661	0.781	0.868	0.564	0.571	0.624	0.685	0.637
SAP	0.848	0.659	0.878	0.991	0.991	0.635	0.968	0.663
Oracle	0.897	0.674	0.880	1.000	1.000	0.742	1.000	0.797
Infor	0.653	0.422	0.575	0.692	0.717	0.750	0.343	0.771
Aldata	0.454	0.537	0.492	0.335	0.487	0.548	0.204	0.578
HighJump	0.463	1.000	1.000	0.473	0.343	0.188	0.548	0.204

Table 5. Summary of a regional grocery chain



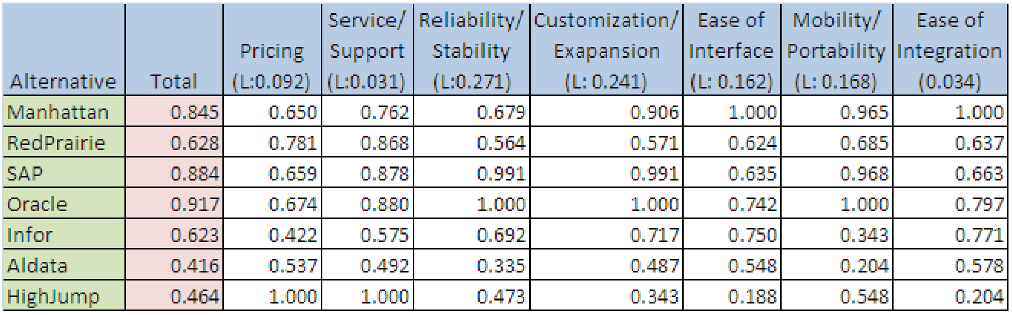
Alternative	Total	Pricing (L:0.267)	Service/ Support (L:0.177)	Reliability/ Stability (L:0.238)	Customization/ Exapansion (L: 0.060)	Ease of Interface (L: 0.108)	Mobility/ Portability (L: 0.092)	Ease of Integration (0.059)
Manhattan	0.687	0.589	0.406	0.679	0.849	1.000	0.965	0.835
RedPrairie	0.585	0.374	0.842	0.564	0.605	0.624	0.685	0.607
SAP	0.743	0.376	0.738	0.991	1.000	0.635	0.968	1.000
Oracle	0.874	0.831	0.706	1.000	0.991	0.742	1.000	0.996
Infor	0.537	0.286	0.537	0.692	0.739	0.750	0.343	0.756
Aldata	0.309	0.186	0.296	0.335	0.424	0.548	0.204	0.401
HighJump	0.668	1.000	1.000	0.473	0.305	0.188	0.548	0.391

CONCLUSION

The SCM software industry is gaining an increasing amount of attention as companies try to maximize return on investment and gain a competitive edge in their markets. The increasing focus on the industry is resulting in greater investment in SCM software and fueling innovation. In order to choose the best alternative among all of the choices available, potential users must clearly identify and prioritize their needs and preferences.

Expert Choice's technology, which utilizes AHP analysis, allowed us to compare seven SCM software alternatives according to seven select criteria in order to determine which software best meets the needs of each scenario. All of the potential factors involved in the selection process must be determined by the organization making

Table 6. Summary of an auto part distributor



Alternative	Total	Pricing (L:0.092)	Service/ Support (L:0.031)	Reliability/ Stability (L:0.271)	Customization/ Exapansion (L: 0.241)	Ease of Interface (L: 0.162)	Mobility/ Portability (L: 0.168)	Ease of Integration (0.034)
Manhattan	0.845	0.650	0.762	0.679	0.906	1.000	0.965	1.000
RedPrairie	0.628	0.781	0.868	0.564	0.571	0.624	0.685	0.637
SAP	0.884	0.659	0.878	0.991	0.991	0.635	0.968	0.663
Oracle	0.917	0.674	0.880	1.000	1.000	0.742	1.000	0.797
Infor	0.623	0.422	0.575	0.692	0.717	0.750	0.343	0.771
Aldata	0.416	0.537	0.492	0.335	0.487	0.548	0.204	0.578
HighJump	0.464	1.000	1.000	0.473	0.343	0.188	0.548	0.204

a decision on an individual basis. We expect continuous improvements and competition from the companies we have examined as well as new entrants into the marketplace looking to fill niches. The natural caveat to all this software is from the human side; the software is only as good as the users who truly understand how to properly use the application. Most logistics professionals and senior level management lack the knowledge or training to fully exploit the potential of their systems (Hannon, 2005). This ties in to a recent emphasis in moving away from pure planning and focusing on the execution aspects of managing a supply chain (Parker, 2007).

Since problems, criteria, needs, alternatives and other variables will vary from one entity to the next, there is no universal solution. In order to support an optimal choice, all of the key factors in the decision process must be identified and quantified. The methods and processes relied on in our research transfer easily to the comparison of other SCM software packages. The future for SCM software solutions is endless.

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Chapter 1.19

Negotiation, Trust, and Experience Management in E-Supply Chains

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ABSTRACT

This chapter reviews fundamentals of e-supplhy chain management and examines the transformation from the traditional supply chains to the e-supply chains (e-SC). This chapter applies experience management (EM) and experience-based reasoning (EBR) to intellegent agents in the e-SC and explores how to use experience in extablishing trust in other agents. The role of trust and deception in supply chains for real-time enterprises is discussed, and a logical framework for fraud and deception is explained in this chapter. EBR is considered as a way to manage trust in the supply network. This chapter explores cooperation and negotiation, trust and deception in e-supply chains by providing methodologies and intelligent techniques for multiagent trust, negotiation, and deception in an e-SC. Finally, a unified model is developed for integrating cooperation and negotiation, trust and deception in e-supply chains. Although primarily theoretical, the chapter highlights new areas of research which will impact supply chain management.

INTRODUCTION

Current supply chain management (SCM) is largely based on older information retrieval methods. It generally has not taken advantage of the 'dynamic' information that is now available due to developments in information and communication technology (ICT) and knowledge management (KM). The focus of SCM has also changed from a supply-side view of optimizing production efficiency to a demand-side view of consumers driving the process. Supply chains

(SCs) are developing into demand networks that adapt to consumer demand in almost real time (Silisque, Brito, Almirall, & Cortés, 2003). With moving towards real-time enterprises, there is an imperative need for rapid automated and intelligent response in the supply network. As discussed in this chapter, an e-SC can be considered as a form of agent society, with trust and negotiation between the intelligent agents as a significant issue.

Experience of suppliers and customers plays an important role in an SC. In particular, customer experience management (CEM) will become a major issue in e-SC because the latter is a customer-centered service in the Internet world (Sun & Lau, 2006). Further customer experience is a prerequisite for customer satisfaction in SC, which is highly dependent on the flexibility of the SC, such as its ability to respond to changes in demand. Because the selection and interaction space of customers in e-SC is theoretically infinite, how to manage customer experience in e-SC also becomes a significant issue for any e-SC providers.

Experience management (EM) is a new concept in information systems (IS) and information technology (IT), although KM has become well-established in business management and artificial intelligence (AI). However, experience has always played a similar rule to knowledge for organizations. Experience-based reasoning (EBR) is a reasoning paradigm using prior experiences to solve problems, and could be considered an advanced form of knowledge-based reasoning (Sun & Finnie, 2005a). This chapter will develop the concept of EM and EBR, and apply them to intelligent agents in the e-SC. In particular the use of experience in establishing trust in other agents will be explored. Any organization will have some history of dealing with problems relating to orders and perturbations in the network and the solutions applied, as well as some formal processes for dealing with these. To respond automatically, software must be capable of reacting, as one would expect a human agent to do. The information available to the agent can come from a variety of sources, including analysis of historical information/experience at the informational/planning level.

Multi-agent systems technology has been successfully applied in many fields such as e-commerce (Sun & Finnie, 2004a) and supply chain management (Finnie, Barker, & Sun, 2004). The trend for the future will be to increasingly autonomous behavior of agents. However, it is imperative that management considering relinquishing control of key aspects of the business to software systems be aware of the issues involved, in terms of how agents will need to operate and negotiate, as well as the potential for misuse of trust with adverse economic results. The increasing importance of strong IT governance and control procedures, and the possible criminal implications for failing to implement these, makes it essential that management be aware of developments in this area. The major contribution of this chapter is in establishing a basis for understanding the new field of experience management and the role it may play in the new supply chain environment. In addition the issue of trust and the role of experience in automating trust development should be appreciated. This chapter will resolve these issues by providing some methodology and intelligent techniques for multi-agent trust and negotiation in an e-SC based on EM. These include the use of EM to enable agents in an e-SC to learn from prior experience in dealing with suppliers and customers, and issues relating to trust and deception in the agent world of the e-SC.

The rest of this chapter is organized as follows: the next section examines fundamentals of e-SC management. We then review the concept of experience management, explore cooperation and negotiation in e-supply chains, and discuss trust and deception in e-supply chains. Finally this chapter proposes a unified model of integrating cooperation and negotiation, trust, and deception in e-supply chains, and the chapter ends with some concluding remarks.

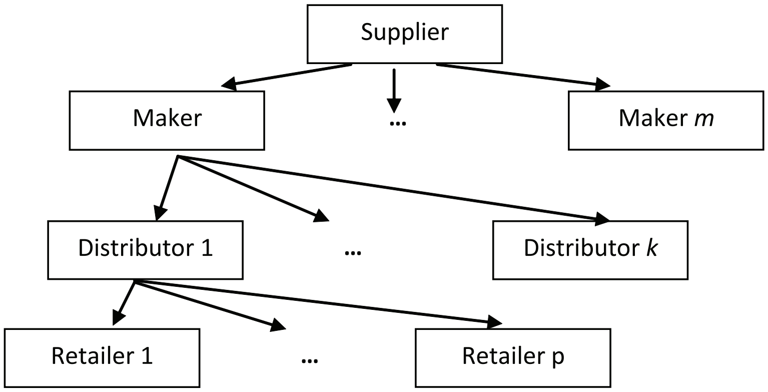
FUNDAMENTALS OF E-SUPPLY CHAIN MANAGEMENT

A supply chain can be broken into three parts: an upstream part, an internal part, and a downstream part (Turban, King, Viehland, & Lee, 2006). The upstream part encompasses all the activities involved in material and service inputs from suppliers, the internal part involves the manufacturing and packaging of products, and the downstream part involves the distribution and sale of goods to distributors and customers.

There are three different viewpoints for an SC: supplier viewpoint, intermediary viewpoint, and end-customer viewpoint. From a supplier viewpoint, the SC is a tree, the root of which is the supplier. We can consider this tree as a supplier-centered supply tree of the SC, as shown in Figure 1. The output degree of the root of this tree (supply flow) should be as large as possible from a supplier viewpoint in order to obtain the most number of orders from the SC. From an end customer viewpoint, the SC is also a tree, and the root of the tree is the customer. We call this tree a customer-centered source tree with respect to the SC. The input degree of the root of the customer-centered source tree should be as large as possible, in order to obtain the most satisfactory information and source from the SC. From an intermediary viewpoint, the SC is a double tree uniquely bridged by the intermediary. On the one side, the tree is the customer-centered source tree with its root being the intermediary, because it is the customer of the upper level supplier. On the other side, the tree is a supply-centered supply tree, also with its root being the intermediary, because it is the source and information supplier of the lower level customer. These three different trees co-influence the performance of the SC. In particular, the intermediary plays a vital role in any SC, because any inefficiency of the intermediary might lead to the breakdown of the SC.

The supply network integrates the value chain and the agent chain, and extends them into a complete graph-formed value-supply network (Sun & Finnie, 2004a). With the development of the Internet/Web technology, the traditional SC is being transformed into the e-SC. The e-SC brings together widely dispersed suppliers and customers to enhance coordination and knowledge sharing, and to manage upstream and downstream value chain channels (Poirier & Mauer 2001; Ross, 2003). e-SC enables firms to improve flexibility and move toward real-time operations by sharing information and collaborating dynamically among partners. e-SC management (e-SCM) can increase revenues or decrease costs by eliminating time-consuming steps throughout the online order and delivery process. It can also improve customer satisfaction by enabling customers to view detailed

Figure 1. A supplier-centered supply tree



information on delivery dates and order status. As an example, a mid-sized manufacturer of small loaders was reviewed. Materials management for loader assembly is extremely complex, with any shortage of required parts (e.g., pumps or engine blocks leading to significant additional costs in terms of unused labor, late delivery, possible disassembly of other components, etc.). By making the demand for specific types of loaders more visible to suppliers in an electronic form, it becomes increasingly efficient for suppliers to time the delivery of components when they are required. In addition, the manufacturer can look for alternatives if supply is impeded.

E-SCM has been a hot term for the past few years, but linking many business partners has been extremely difficult. Everyone from the raw material supplier to the ultimate seller in the chain must be able to get accurate information quickly and easily about orders, shipping, and customer responses to products and services. Business partners must decide which areas they will try to link first. Each partner then focuses on key internal groups that have the most to gain by adopting e-commerce.

Suppliers and customers in the traditional SC have been transformed into intelligent agents of suppliers or customers in the e-SC so that an e-SC can be considered as a form of agent society. Papazoglu (2001) provides a good typology of agents in such an e-business environment. Under this new situation, how to manage trust and negotiation between the intelligent agents within e-SC becomes a significant issue. This is because the trust and negotiation in the e-SC are based on interaction and communication between human suppliers and customers, between human suppliers (or customers) and their intelligent agents, and between intelligent supplier agents and intelligent buyer agents (Sun & Finnie, 2004). Experience management is also required for these activities in the e-SC.

EXPERIENCE MANAGEMENT

Experience is wealth for any individual or organization. Generally, experience can be taken as previous knowledge or skill obtained in everyday life (Sun & Finnie, 2004a, p. 13). Experience management (EM) has drawn increasing attention in IS and AI in the past few years (Bergmann, 2002; Sun & Finnie, 2005). This section will examine EM in some detail as it applies to intelligent agents in the e-SC. Although many managers are aware of the development in significance of knowledge management over the last few years, the role of experience management is still very new. Managers will be faced with a plethora of buzzwords in this area, and an intended contribution of this chapter will be to make managers aware both of experience management as a concept as well as its role in SCM. An example of experience in an organization may be in company buyers, for example, in retail who deal with a number of suppliers. Over time a buyer will learn from experience which suppliers are more reliable. This experience may be shared with other buyers, particularly inexperienced employees. In an automated environment in which suppliers and buyers are agents, the recording, management, and sharing of experience must also be automated.

Experience can be considered as a special case of knowledge. Methodologies, techniques, and tools for knowledge management (KM) can be directly reused for EM, because EM is a special kind of KM that is restricted to the management of experience. On the other hand, experience has some special features and requires special methods different from that of knowledge, just as a subclass Y of its superclass X usually possesses more special attributes and operations. Therefore, the following two issues are very important for EM:

- What features of EM are different from those of KM?
- Which special process stages does EM require?

In what follows, we will try to resolve these two issues. First of all, we define EM as a discipline that focuses on experience processing and its corresponding management (Sun, 2004), as shown in Figure 2. The experience processing mainly consists of the following process stages (Bergmann, 2002, pp. 1-14; Sun & Finnie, 2005):

- Discover experience
- Capture, gain, and collect experience
- Model experience
- Store experience
- Evaluate experience
- Adapt experience
- Reuse experience
- Transform experience into knowledge
- Use experience-based reasoning
- Maintain experience

Where management has permeated each of above-mentioned process stages.

It is significant to separate management functions from experience processing functions and then integrate them in EM (Sun, 2004).

The management of experience processing for each process stage includes analysis, planning, organization, support, collaboration (Sun & Finnie, 2005), coordination, and possible negotiation (Sun, 2004). Generally, management issues related to each or some of the experience processing stages include:

- Organization and control of experience
- Experience processing or management task assignment to specific person or teams

In the above experience processing stages, "maintain experience" includes updating the available experience regularly, while invalid or outdated experience must be identified, removed, or updated (Sun, 2004). Transforming experience into knowledge is an important process stage for EM, which is the unique feature of EM that is different from those of KM. In the history of human beings, all invaluable experience is gradually transformed into knowledge, which then is spread widely in the form of books, journals, and other means such as multimedia.

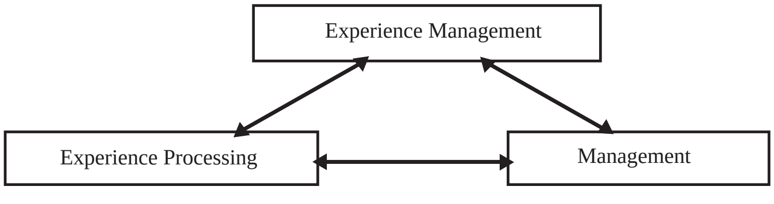
It should be noted that discovery of experience from a collection of knowledge or social practice is a significant issue for EM, just as knowledge discovery from a very large database (Sun & Finnie, 2005). Further, the processing of experience requires an experience base, where experience processing will be conducted.

EM research is providing a new way of looking at data, knowledge, experience, and its management for organizations and e-services (Sun & Finnie, 2005). This will include experience retrieval, experience similarity, and experience processing. Successful solution of these problems could provide the basis for new advances in both EM and e-SC.

As an application of EM, customer experience management (CEM) has been studied in business and commerce (Schmitt, 2003) and e-services (Sun & Lau, 2006).

Generally, CEM is the process of strategically managing a customer's entire experience with a product or a company (Schmitt, 2003, pp. 17-18). In this way, CEM changes traditional customer

Figure. 2. EM as an integration of experience processing and management



satisfaction from outcome oriented to process oriented. CEM also extends traditional CRM from recording transactions to building rich relations with customers and understanding the experiential world of customers, because it is imperative that organizations understand their customers' past experiences, current behaviors, preferences, and future needs (Brohman, Watson, Piccoli, & Parasuraman, 2003).

Schmitt proposes a framework to manage customer experience (Schmitt, 2003, p. 25) which targets the business managers or consultants. This framework consists of the following five steps:

1. analyzing the experiential world of the customer
2. building the experiential platform
3. designing the brand experience
4. structuring the customer interface
5. engaging in continuous innovation

The customer interface is one of the key implementation strategies for managing customer experience in e-SC, because it affects retention through the exchanges and interactions which further determine whether the customers are satisfied with the e-SC and whether they will buy the services again. Most CRM solutions merely record what can be easily tracked: the history and transactions of customer-company contracts (Schmitt, 2003, p. 141). However, this is not enough for managing customer experience in e-SC because the customer in e-SC believes that the interface of the e-SC is the agent of the e-SC, and s/he is communicating face to face with this agent. This is a new world, because the interaction between the customer and the agent of the e-SC is different from traditional face-to-face interaction or communication in traditional business or service. However, in such an interaction, the customer will still try to obtain human-like interaction with the interface agent in the e-SC.

Furthermore, humanizing and harmonizing the customer experience are important components for CEM. Humanizing the customer experience requires communicating with customers according to humanity rather than technology (Schmitt, 2003, p. 92). This is because the customer in e-SC hopes to experience a friendly human community in the virtual society such as the environment of e-SC. Harmonizing the customer experience allows the customers to increase their confidence in receiving the services or products from a company.

It should be noted that Schmidt's discussion of CEM is essentially based on his business consultation experience, in particular, in the traditional business sectors, without regards to any intelligent techniques. Sun and Lau (2006) argue that intelligent techniques can improve management of customer experience in e-services, just as had been done in other fields such as e-commerce. In the following sections we will argue that EM can facilitate cooperation, negotiation, and trust in e-SC.

COOPERATION AND NEGOTIATION IN THE E-SUPPLY CHAIN

Coordination among agents within e-SC has raised considerable interest, because cooperation across different entities is a central issue of SCM (Homburg & Schneeweiss, 2000). This is also because an agent cannot by itself just make a locally optimal decision, but must determine the effect its decisions will have on other agents and coordinate with others to choose and execute an alternative that is optimal over the entire SC (Fox, Barbuceanu, & Teigen, 2000). Therefore, agents within an e-SC should cooperate with other agents in finding a schedule or plan or a solution to a problem. A large number of tools facilitate collaboration and communication between two parties and among members of small as well as large groups (Turban et al., 2006, p. 283).

Negotiations within the SC have also drawn increasing attention in e-SCM. For example, Homburg and Schneeweiss (2000) propose a structure for a cooperative contract negotiation between the supplier and the retailer. Barker and Finnie (2004) examine cooperation and negotiation in supply networks based on multi-agent technology. Logistics agents will negotiate over contracts with the available contractors. In this case, several rounds of offers and counteroffers should be proposed before reaching an agreement (Fox et al., 2000). As an example, factors that might be traded off would be price, delivery times, quality, delivery costs, order quantities and discounts, and so forth.

The negotiation process might be affected by uncertain events. For example, failures in agents and communication channels can occur during negotiation (Walsh & Wellman, 1999). To optimize the performance, the agents within the e-SC should work in a coordinated manner. However, the dynamics of the enterprise, the market, and agents makes this difficult (Fox et al., 2000): materials do not arrive on time, or customers change or cancel orders and negotiation between intermediaries fails. Therefore, trust and deception have become an increasing issue in e-SC. Finnie, Sun, and Barker (2005) explore trust and deception in multi-agent trading systems including supply chains. Trust among the trading partners can generate speed, agility, and lower cost (Turban et al., 2006, p. 281).

In an e-SC there is a continuous process of planning, scheduling, and management of supply and demand which requires cooperation, coordination, and negotiation by human managers. Cooperation and negotiation are thus routine activities in the e-SC. Furthermore, in recent years, cooperation and negotiation with suppliers have become increasing important in order to establish an effective and efficient supply network (Schneider & Perry, 2001). However, delegating these responsibilities to an agent requires a great deal of autonomy and intelligence.

Any organization has some history of dealing with problems relating to orders and perturbations in the supply network and the solutions applied, as well as some formal processes for dealing with these. In order to automate the response to any stochastic event, the e-SC system must be capable of reacting as one would expect a human agent to do. In many cases, a human agent responds by working from and possibly adapting solutions to previously encountered situations similar to the present problem—that is, a process of reasoning from experience using prior cases such as case-based reasoning (CBR) (Finnie & Sun, 2003) or experience-based reasoning (EBR) (Sun & Finnie, 2005).

Multi-Agent E-Supply Chain Systems

Multi-agent systems (MASs) for e-commerce probably had their origins in the pioneering work of the Autonomous Agents group of the MIT Media Lab which resulted in the Kasbah and Market Maker (Chavez & Maes, 1996). Other simple online shopping agents followed, for example, shopping bots like “Ask Jeeves.” Applying multi-agent technology to e-SC has also been drawing attention since the end of the last century. Nissen and Mehra (1999) use ADE to develop a MAS for government supply chains. ADE is an integrated development environment to design, develop, debug, and deploy agents. Walsh and Wellman (1999) discuss some issues of using MAS to model supply chain formation, which is the process of bottom-up assembly of complex production and exchange relationships. However, agent interaction during SC formation might be complex, because agents do not generally have the incentive to truthfully reveal information. Papazoglu (2001) provides a good framework for intelligent agents in e-business. Singh, Salam, and Iyer (2005) describe an agent architecture for infomediary e-marketplaces which facilitates the flow of information among e-SC participants. The same group (Iyer, Singh, & Salam, 2005) further develop the concept of information exchange by agents to support collaborative business functions, using the concept of an agent-managed knowledge repository to maintain domain knowledge. This may include historical information on buyer experiences, "including the reliability and trustworthiness of the supplier." From a multi-agent viewpoint, an e-SC is composed of a set of intelligent agents, each responsible for one or more activities in the SC and each interacting with other agents in planning, bargaining, and executing their responsibilities (Fox et al., 2000). An agent is an autonomous, goal-oriented intelligent subsystem that operates asynchronously, communicating and coordinating with other agents as needed.

More and more multi-agent e-SC systems (MESC) are being developed in order to realize the transformation from conventional SC to e-SC, taking advantage of the Internet and e-commerce technology.

CBR-Based Cooperation in E-Supply Chain

Cooperation is an important characteristic of e-SC (Schneider & Perry, 2001). An agent with "perfect" knowledge and "complete" capabilities for a given task has no need to require the cooperation of other agents. However, normal agents do not have "perfect" knowledge and "complete" capabilities for a given task.

One approach to CBR-based cooperation is described by Martín, Plaza, and Arcos (1999). A cooperation mode establishes how two agents must behave to accomplish a particular task. Two cooperation modes between CBR agents are proposed in that research: Distributed CBR (DistCBR) and Collective CBR (ColCBR). The DistCBR cooperation mode is a class of cooperation protocols where a CBR agent is able to ask one or several other CBR agents to solve a problem on its behalf, and the ColCBR cooperation mode is a class of cooperation protocols where a CBR agent is able to send a specific CBR method to one or several CBR agents that are capable of using that method with their case base to solve the task at hand (Plaza, Arcos, & Martin, 1997). Therefore, the DistCBR cooperation mode enables an agent to share experiential knowledge acquired by an acquaintance by means of particular problem-solving methods, while the ColCBR cooperation mode allows a couple of CBR agents to share experiential knowledge.

CBR-Based Negotiation in E-Supply Chain

Negotiation in e-SC is a process where two parties (customers and suppliers) bargain resources for an intended gain. In order to adequately support customers, an e-SC system should possess negotiation capability. However, automated negotiation has had relatively little support to date because of the complexity of the negotiation process, which depends on the complexity of the product or service being negotiated.

The approaches to negotiation in e-SC can be classified into two classes: a cooperative approach and a competitive approach (Guttman, Moukas, & Maes, 1998). Competitive negotiation takes place if there is at least a conflict of interest between the buyer and seller/supplier. Consequently, there will be the minimum collaboration necessary between buyer and supplier to solve the negotiation problem, while cooperative negotiation tries to get as much collaboration as possible between the two parties. A competitive negotiation arises when an agent attempts to get the best deal possible, for example, to get goods at the lowest price. An example of cooperative negotiation between agents is in real-time load balancing of mobile cellular networks—all agents benefit from efficient network operation. In a supply chain environment, agents could cooperate in managing delivery across several companies to optimize utilization of trucks and so forth. However, both approaches present two extremes on a continuum of possible underlying problems. In practice, a negotiation usually lies between cooperative negotiation and competitive negotiation (Sun & Finnie, 2004a).

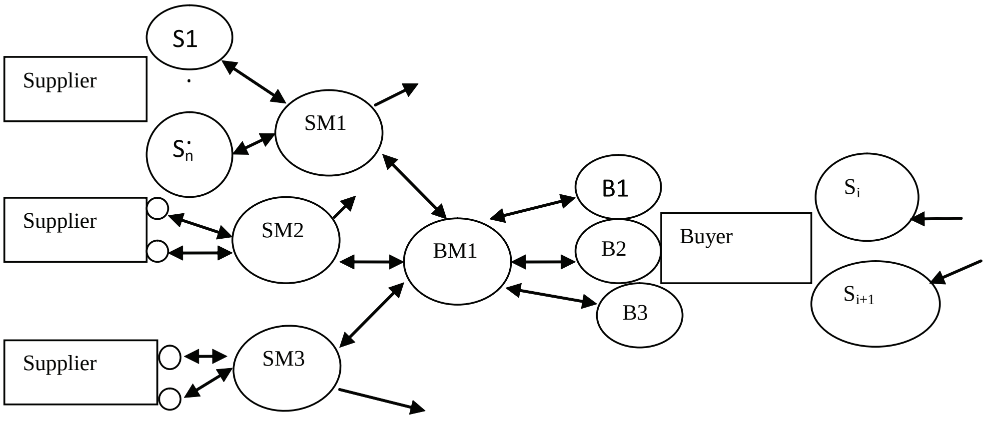
In the automated e-SC system, buyer agents search for a product that meets their demands. The goal of a CBR-based negotiation system is to identify these demands in cooperation with the supplier agents and to find a product that fulfils them (Sun & Finnie, 2004a, p. 186). During negotiation, the CBR-based negotiation system might suggest or even add some new demands or modify some weak demands for the purpose of finding an appropriate product. For configurable products, it is also possible for the CBR-based negotiation system to modify existing products during product adaptation to meet the customer's demands. Therefore, the task for the CBR-based negotiation system during the negotiation process is the combination of *iterative demand adaptation* and *iterative supply (product) adaptation*. The former is realized by making proposals for adjusting the demands from the buyer agent, while the latter is done by supply/product adaptation with the goal of finding an agreement point in the multidimensional demand/product space. During the negotiation, the agent or the CBR-based negotiation system is allowed to modify customer demands. If products in the product case base are configurable, it might also be possible to modify the products during negotiation.

An intelligent agent should be able to negotiate with the customer agents and to assist them during the search for an appropriate product in the e-SC. The buyer and supplier manager agents use CBR to negotiate; that is, they assess the similarity of the current negotiation to previous negotiation cases in their negotiation case base. Once a negotiation case is selected as the most relevant to the current negotiation, the agent might revise or adapt this case in order to meet any counter offer from the counterpart. Successful negotiation cases are kept in the case base for reuse in later negotiation case retrieval. These agents can use fuzzy rule-based adaptation to adapt the most similar negotiation case to the current negotiation situation (Sun & Finnie, 2004a, p. 207).

A MULTI-AGENT ARCHITECTURE FOR COOPERATION AND NEGOTIATION IN AN E-SUPPLY CHAIN

Based on the above discussion, we proposed a multi-agent architecture for cooperation and negotiation in e-SC, shown in Figure 3, in which S_i are supplier agents, SM_i are supplier manager agents, B_i are buyer agents, and BM_i is a buyer manager agent. The architecture is called MCNES (Multi-agent system for Cooperation and Negotiation in E-SC). In MCNES, CBR is used for intelligence

Figure 3. MCNES: Multi-agent cooperation and negotiation in an E-SC



at the buyer/supplier junctions within a specific supply network. A number of *buyer agents* control the interface between an organization and its suppliers, with each of the buyer agents using CBR to provide intelligent processing of supply needs on the basis of prior experience.

A *buyer manager (control agent)* coordinates and controls the activation and operation of the buyer agents utilizing CBR. It also uses CBR to select a suitable strategy for finding all components required for a particular product.

A *seller (supplier) agent* is at the supplier interface and is responsible for each product type. A request to purchase from an organization may itself trigger *adaptations* in the internal schedule for that organization and in turn cause its buyer agents to *negotiate* with its suppliers. To *coordinate* the actions of supplier agents, there is a supplier manager agent for each supplier which has responsibility for checking whether the product can be supplied. Each order processed for a specific customer forms part of the *case base* for that customer and provides a historical portrait of the relationship with the customer.

Each buyer agent has a local case (experience) base. Buyer and seller manager agents need more intelligence and have their own company case base. The supplier agents will check on the impact of an order which may in turn generate a procurement need. Agents will also need to have fallback positions—that is, if there is no suitable information in the case base, there must still be a response, either by appealing for human intervention or going to other forms of reasoning (e.g., rule based).

MCNES provides two levels of agent operation: the buyer/supplier manager agents at the enterprise level and the buyer/supplier agents at the logistics level. At the enterprise level, the agents are "middle agents" (Decker, Sycara, & Williamson, 1997) who "support the flow of information in e-commerce, assisting in locating and connecting the ultimate information provider with the ultimate information requester." At the logistics level, the supplier manager agents and buyer manager agents deal with product transfer and require learning cost-effective buyer/supplier dealings for specific products.

An agent in MCNES must be capable of reasoning and learning. The CBR approach is capable of reasoning and learning dynamically; for example, as new experience is gained, it will be added to the case base for that specific product in a specific company.

Agent Interaction in MCNES

As noted above, interaction between buyers and suppliers occurs at two levels in MCNES. At the buyer agent and supplier agent level (B_i, S_i), the interaction is product based with the focus on logistics/manufacturing. Buyer agents need to keep their production optimal while supplier agents need to determine the impact of re-scheduling.

At the supplier and buyer manager agent level (BM_i, SM_i), the interaction is inter-enterprise with the focus at the trading level. Both buyer manager agents and supplier manager agents are concerned with maintaining a good trading relationship to mutual benefit. For the buyer manager agent, this may mean retaining a range of alternative suppliers. For the supplier manager agent, this is customer relationship management (CRM). The supplier agent needs to have information on the likely impact of re-scheduling which it can feed into the CRM process so that any negative effects on a customer are minimized. In essence, this is using dynamic information for real-time CRM. Obviously in many situations this will only be part of the total picture and for some time to come will probably still require human intervention if any concerns are flagged. However, the need to incorporate the capability to gather and process dynamic information is obviously an issue that will need to be part of CRM, particularly in a virtual enterprise environment. Each order that is processed for a specific customer forms part of the case base for that customer and provides a historical portrait of the relationship with the customer. A key part of the knowledge capture relates to the formation of trust between a buyer and seller. As more experience is gained of a specific supplier or buyer, the more trust (or otherwise) can be established in the relationship.

Summary

The multi-agent system approach proposed in this section provides a suitable architecture for rapid and agile response to any event. MCNES is scalable, as there is no overall controller—each organization in the chain or network will have its own agent management structure.

The MCNES system requires further development and testing both in simulated and real environments. Although initial results are encouraging for the determination of a suitable supplier (Barker & Finnie 2004), the structure of supplier agents, their relationship to CRM, the use of profiling, and the development of negotiating capability needs to be explored.

It is to be noted that in current society, negotiation between the retailer and the end-customer is not common, in particular in the supermarket. However, negotiation between business and business still exists. In the MCNES, the negotiation usually occurs between supplier agent and manufacturer agent or retailer agent. For example, Homburg and Schneeweiss (2000) discuss a model for automated negotiation between a supplier and its retailer with supply chains.

TRUST AND DECEPTION IN E-SUPPLY CHAINS

Trust and deception have been of concern to researchers since the earliest research into multi-agent e-SC (MESC). Although much of the research in MESC assumes inherent benevolence, in practice a completely open agent society must allow for the possibility of malevolent behavior. In an open trading environment, trust can be established by external mechanisms (e.g., using secret keys or digital signatures) or by internal mechanisms (e.g., learning and reasoning from experience). As noted by Ramchurn, Huynh, and Jennings (2004), many current computer applications are following a distributed model with components available through a network like the semantic Web, Web services, and grid computing. The open multi-agent system with autonomous agents has been suggested as the logical computational model for such applications (Jennings, 2001). As a result, the implications of trust and deception have broader relevance than just e-SC systems.

This section will discuss MESC systems, explore how deceptions change the reasoning required in an MESC system/environment, and will illustrate several forms of logical reasoning that involve trust and deception in an MESC. It looks at a systematic classification of reasoning techniques which can be applied between buyers and sellers. As noted earlier, it is important that management understands the issues involved in autonomous agent systems. If agents have local control and act on behalf of the organization, then the need to understand and implement controls against deception is a management imperative.

Trust and Deception in MESC

As in any other form of society, agents can exhibit malevolent behavior in the MESC environment. With the focus moving to the distributed systems paradigm and the multi-agent programming model, the study of trust and deception in agent interaction has significant implications for the operation of these systems.

Ramchurn et al. (2004) provide an extensive review of research into trust in multi-agent systems. They define trust as follows: “Trust is a belief an agent has that the other party will *do what it says it will* (being honest and reliable) or *reciprocate* (being reciprocative for the common good of both), given an *opportunity to defect* to get higher payoffs." The authors conceptualize trust as (a) individual-level trust (agent believes in honesty or reciprocation of interaction partners) and (b) system-level trust (the agents are forced to be trustworthy by the system). They further characterize individual-level trust models as learning (evolution) based, reputation based, or socio-cognitive based. Learning models are based on interactions with other agents. Reputation-based models work by asking other agents of their opinion of potential partners, often based on some form of social network (Sabater & Sierra, 2002). Rather than relying on interaction with other agents, socio-cognitive models operate on subjective perceptions of opponents. Wong and Sycara (1999) address two forms of trust: trust that agents will not misbehave and trust that agents are really delegates of whom they claim to be. Vassileva, Breban, and Horsch (2002) consider the formation of long-term coalitions of customer and vendor agents using an agent trust model. Others have done research on agent learning in an untrustworthy environment—that is, agents who will attempt to deceive each other in trading. For example, Wu, Kimbrough, and Zhong (2002) show that trust can be established if agents learn which other agents exhibit poor behavior and hence which agents not to trust.

Trust and deception are twins in MESC. Trust in MESC can be sustained only if we can understand how agents commit fraud and deception in an MESC. Furthermore, how will agents in an MESC operate autonomously in such an environment, and what precautions will they need to take to protect their "owners" from fraudulent or malevolent acts? In traditional SC systems, "caveat emptor" or "let the buyer beware" is a well-known trading rule of thumb. Humans expect the possibility of fraud and deception in trades and accordingly take whatever precautions are possible. Less well known is the Latin maxim "caveat mercator" or "let the merchant beware." The latter is particularly relevant with the increase in Internet fraud, with online merchants carrying the cost of fraudulent transactions. If this is the norm in conventional trading systems, why should it be any different in multi-agent systems?

In business and social activities, fraud depends on deception, while deception is realized through fraud. Further, the aim of both fraud and deception is to get an advantage in an environment with conflicts of interest. Therefore, in what follows, we only refer to deception, rather than fraud and deception, if necessary.

With the development of the Internet, we find ourselves in hybrid artificial societies, where real-world assumptions and the whole range of possible behaviors including deception must be taken into account (Ramchurn et al., 2004; Wooldridge & Jennings, 1994). From an e-commerce viewpoint, there are three different kinds of deception in a hybrid artificial society: deception between humans, deception between humans and intelligent agents, and deception between agents in multi-agent societies such as MESC (Sun & Finnie, 2004b). In what follows, we focus on deception in MESC.

There are many agents operating in the MESC. Some agents are generally trustworthy, for example, market coordinators, search agents, transaction agents, and payment agents. All these agents are working as a lubricant for a healthy MESC. These agents work for buyer agents, seller agents, and others such as brokers and bidders in a neutral way in order to maintain the market trading order. However, the buyer agents, seller agents, and brokers may not be trustworthy. These agents may deceive other agents in the MESC in order to obtain the maximum advantage or profit, just as buyers, sellers, and brokers may use deception in a traditional house market, where the first house buyer is usually deceived to some extent by the real estate agent on behalf of the seller.

Furthermore, Internet technology provides new opportunities and ways to deceive, because intelligent agents will also participate in deception, and agents are and will be designed, selected, or trained to deceive in MESC, and people will be also deceived by intelligent agents (Sun & Finnie, 2004b). For example, e-sellers might use all the tricks to sell something and introduce new forms of deceptive advertising. Deception in the MESC can take a variety of forms, for example, pretending to be someone else, offering goods for sale which they do not have, and so forth. This is one of the reasons why some businesses fear using an e-SC. However, we would not stop driving because we saw a fatal car accident. Similarly, we cannot stop developing e-SC or MESC, although we find some cases of deception in them. The most important issue for us is recognizing and preventing fraud and deception in MESC. To this end, it is necessary to answer the question: What is the logical foundation of fraud and deception? The essence of fraud and deception depends on its logical foundation.

Finally, to detect and defeat fraud and deception requires a theory of deceptive communication, attitudes, and behavior (Castelfranchi & Tan, 2001). In what follows, we address this issue from a logical viewpoint.

A Logical Foundation for Fraud and Deception in MESC

This subsection will examine a logical foundation for fraud and deception, and then look at how the agents commit fraud and deception in the MESC from a logical viewpoint.

Inference rules play a fundamental role in any reasoning paradigm, because any reasoning is based on an inference rule or a couple of inference rules (Sun & Finnie, 2004b). For example, *modus ponens* and *modus tollens* are central to deductive reasoning. Sun and Finnie (2004, 2005) have proposed eight basic inference rules for performing experience-based reasoning (EBR) which are summarized in Table 1. These cover all possible EBRs and constitute the fundamental for all natural reasoning paradigms at the first level. The eight inference rules are listed in the first row, and their corresponding general forms are shown in the second row respectively.

Four of them, modus ponens (MP), modus tollens (MT), abduction, and modus ponens with trick (MPT) are well known in AI and computer science, but the other four need some clarification. First of all, we illustrate modus tollens with trick with an example. We may know that:

1. If Socrates is human, then Socrates is mortal.
2. Socrates is immortal.

What we wish is to prove is "Socrates is human." In order to do so:

Let $P \rightarrow Q$: If Socrates is human, then Socrates is mortal.

- ***P*:** Socrates is human.
- ***Q*:** Socrates is mortal.

Therefore, we have P: Socrates is human, based on modus tollens with trick, and the knowledge in the knowledge base (KB) (note that $\neg Q$: Socrates

Table 1. Experience-based reasoning: Eight inference rules

MP	MT	Abduction	MTT	AT	MPT	IMP	IMPT
P $\underline{P \rightarrow Q}$ $\therefore Q$	$\neg Q$ $\underline{P \rightarrow Q}$ $\therefore \neg P$	Q $\underline{P \rightarrow Q}$ $\therefore P$	$\neg Q$ $\underline{P \rightarrow Q}$ $\therefore P$	Q $\underline{P \rightarrow Q}$ $\therefore \neg P$	P $\underline{P \rightarrow Q}$ $\therefore \neg Q$	$\neg P$ $\underline{P \rightarrow Q}$ $\therefore \neg Q$	$\neg P$ $\underline{P \rightarrow Q}$ $\therefore Q$

is not mortal). From this example, we can see that modus tollens with trick is a kind of EBR.

Abduction with trick can be considered as a "dual" form of abduction, which is also the summary of a kind of EBR. Abduction can be used to explain that the symptoms of the patients result from specific diseases, while abduction with trick can be used to exclude some possibilities of the diseases of the patient (Sun & Finnie, 2004b). Therefore, abduction with trick is an important complementary part for performing system diagnosis and medical diagnosis based on abduction.

It should be noted that if one does not like to use trick or deception, he can use "exception" instead. The essence is that such kinds of inferences have not yet been examined in computer science and AI, although they are necessary for EBR.

Inverse modus ponens (IMP) is also an inference rule in EBR. The "inverse" in the definition is motivated by the fact that the "inverse" is defined in logic: "if $\neg p$ then $\neg q$," provided that if p then q is given (Sun & Finnie, 2004b). Based on this definition, the inverse of $P \rightarrow Q$ is $\neg P \rightarrow \neg Q$, and then from $\neg P$, $\neg P \rightarrow \neg Q$, we have $\neg Q$ using modus ponens. Because $P \rightarrow Q$ and $\neg P \rightarrow \neg Q$ are not logically equivalent, the argument based on inverse modus ponens is not valid in mathematical logic. However, the EBR based on inverse modus ponens is a kind of common sense reasoning, because there are many cases that follow inverse modus ponens. For example, if John has enough money, then John will fly to China. Now John does not have sufficient money, then we can conclude that John will not fly to China.

The last inference rule for EBR is *inverse modus ponens with trick* (IMPT). The difference between IMPT and *inverse modus ponens* is again "with trick"; this is because the reasoning performer tries to use the trick of "make a feint to the east and attack in the west"—that is, he gets Q rather than $\neg Q$ in the *inverse modus ponens*.

These eight inference rules provide a logical foundation for any EBR paradigms at the fundamental (or atomic) level, so that they can be applied to both benevolent and deceptive agent societies. In what follows, we give several examples to illustrate this view (Finnie & Sun, 2005).

We assume that in the MESC, the seller agent S will offer goods at a specific price, while the buyer agent B will agree to purchase a specific volume at a specific price. If the MESC provides a trustworthy trading environment, we can assume that conventional reasoning applies—that is, modus ponens, modus tollens, and possible abduction are used in the agents in MESC to conduct any trading activities. For the buyer agent B, his trustworthy reasoning could be as follows:

If a seller offers goods at a price, then those goods will be available at that price. We assume that G and D are propositions: G = goods offered at known price, D = goods are available for delivery.

Modus ponens is what the buyer agent or seller agent normally uses in the trading activities: bidding, brokering, and negotiation, because they believe that If G, $G \rightarrow D$ Then D. They also use *modus tollens* in the trading activities—that is, if goods are not available, then they will not be offered for sale by an agent.

If Not D (i.e., goods are not available), Then Not G (i.e., goods will not be offered for sale).

Abduction is another common sense inference rule underpinning the marketplace: if a seller agent S has goods available for delivery D, s/he will make them available for sale. That is:

D (Goods are available and will be delivered)
$G \rightarrow D$

Therefore, we have G (goods will be offered at a known price).

However, the environment provided by the MESC is not always trustworthy, because some agents (e.g., buyer agents, seller agents, bankers, solicitors, and brokers) may have a conflict of interests so that they will try to deceive their trading partners. In what follows, we look at several scenarios in the simple buyer/seller context where deception or fraud could apply and consider the variations on traditional logic, which could provide a logical basis for the deceptive reasoning. A number of scenarios will be proposed where the buyer agent is misled in their dealings with the seller agent in the MESC.

1. A seller agent may offer goods at a price *G*, but those goods are not available, which case is an obvious fraud. An example could be malevolent or fraudulent behavior by a competitor of the buyer company, for example, to delay production by ensuring that materials in the SC are not delivered. This could also apply to competitors of the supplier, for example, to reduce the chances that a competitor does not achieve the deal by offering goods at a lower price. This scenario could be described as *modus ponens with trick* (MPT) (see Table 1). It takes the form:

   G (goods at known price),
   $G \rightarrow D$
   Therefore, Not D (goods are not available for delivery).

   The essence behind this fraudulent behavior is that the seller agent has used MPT to deceive the buyer agent.

2. A second form of deception could arise in the MESC, if a seller agent does not offer goods at a price but the goods are in fact available at that price. This could arise if there are limited goods available and a seller wishes to preference another buyer (agent). This is referred to as *inverse modus ponens with trick* and takes the form:

   Not *G* (not offer goods at a price)
   $G \rightarrow D$

   Therefore, *D* (goods are in fact available at that price).

3. We could also have the situation where goods are not available but are offered at a specific price. This varies slightly from case (1) above in that the starting point is that the goods are not available. This could, for example, be a negotiating tactic if goods will be available within a short time. This is called *modus tollens with trick* and takes the form:

   Not *D* (goods are not available),
   $G \rightarrow D$

   Therefore, G (goods are offered at a specific price).

4. We could have the situation where goods are available for delivery but not at that price. This could be used to fool the buyer into intending to make a purchase—again as a possible negotiating tactic or delaying tactic. This could be termed *abduction with trick* and takes the form:

   D (goods are available for delivery)
   $G \rightarrow D$

   Therefore, Not *G* (goods are not offered at that price).

There are also a number of scenarios of deceiving the seller or seller agent in the MESC. As above, the seller assumes that if goods are purchased at a specific price, the seller will receive the amount in full. The most usual form of fraud and deception would be where goods are purchased, but the seller does not receive the full amount (or anything) (Finnie & Sun, 2005). This is theft or fraud and can be represented as *modus ponens with trick*. Other forms of inference rules do not apply easily to deceive the seller. *Inverse* *modus ponens with trick* or *abduction with trick* suggest that goods are not purchased at a specific price, but that the seller receives the full amount, which might be good for the seller but not that likely in practice.

EBR for Dealing with Trust in the E-Supply Chain

In conventional business practice, experience plays a key role in the selection of trading partners. We talk of learning from "bitter experience" when a disastrous mistake is made. Learning means that some record of past transactions together with success or failure must be made. As discussed earlier, CBR and EBR provide a practical approach to creating and manage an experience repository (Bergmann, 2002). All dealings with specific organizations would be recorded. These could then be analyzed over time to identify whether a partner is meeting the conditions of being a trustworthy collaborator.

From a buying viewpoint, buying a product in a marketplace, electronic or otherwise, can be an iterative bargaining process between an agent *S* acting on behalf of the seller and a buyer *B* initially. But it is not the only negotiation. It may also start an iterative bargaining process between *B* and bankers, delivery contractors, and so forth with the progress of the purchasing, as shown in Figure 4. First of all, *B* asks his informant (Internet agents, newspapers, acquaintances, and so forth) to search for the products for which he intends to buy. Then he will negotiate over the selling price with *S* for selling each of the products. This is also a trust and deception process between *S* and *B*, because *S* hopes to obtain the best interest by maximizing the price of the selling, while *B* also tries to obtain the best interest by minimizing the offer price to *S*. With the progress of the negotiation, the degree of deception of *S* to *B* becomes less, while the degree of trust of *B* in *S* becomes higher. If the deception degree of *S* and the trust degree of *B* can reach an equilibrium (like break-even point), as shown in Figure 5, then the price for the purchase will be fixed. Otherwise, the negotiation will be broken off and *B* will negotiate with another seller agent.

After the purchase price is fixed, *B* may ask his informant (Internet agents, newspapers, acquaintances, etc.) to search for suitable delivery contractors and then he will negotiate with each of these over the delivery price. However, *B* still uses negotiation to increase his trust in one of the contractors based on the knowledge and experience from his informant.

Although identifying partners who are not making the grade can be based on historical transactions, it would be preferable to be able to detect untrustworthy organizations fairly early in the trading relationship. One approach here relies on using data mining techniques to identify patterns of behavior which indicate possible difficulties. As one company on its own is usually

Figure 4. Bargaining process in marketplace

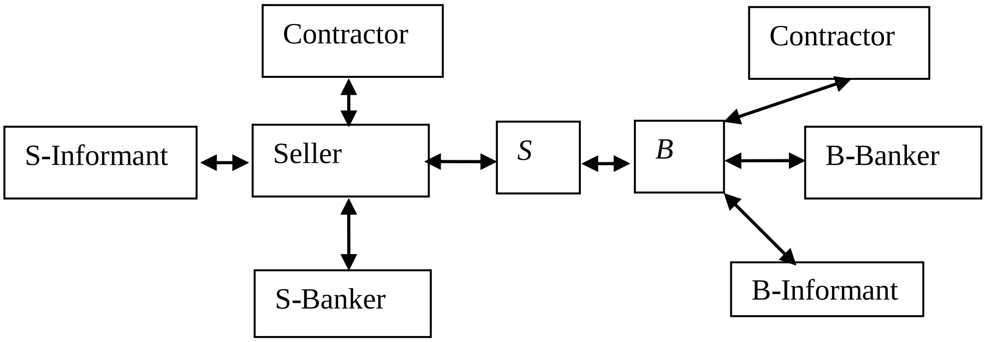
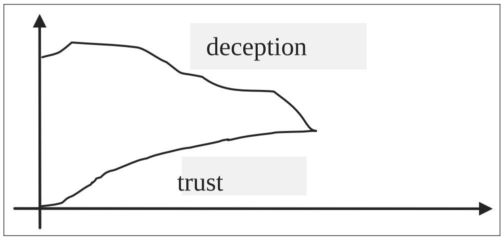


Figure 5. Trust and deception in negotiation



unlikely to have sufficient data for effective data mining, it is possible that some form of industry-level repository could be developed (e.g., in an industry marketplace) which could be used for analysis. Although collaborative filtering techniques could possibly be used to directly identify possible problem partners, it is likely that legal issues would limit the application of these techniques. However, an industry repository based on cleaned and anonymized information might provide a good basis for learning key features for identifying trustworthy partners. Management needs to be aware of the potential role of industry marketplaces in establishing suitable trust repositories.

Summary

In the e-supply chain (e-SC), most agent models and systems assume secure and reliable communication exists between them. This ideal situation may not hold in reality. This section examined agent behaviors, in particular trustworthy behaviors, and fraud and deception behaviors of agents in the MESC. Fraud and deception are an unavoidable phenomenon for engineering MESC. Failure to understand deception will lose the "biological" balance in MESC. Benevolent agent societies assume a fundamental basis of the conventional forms of reasoning (i.e., modus ponens). In situations with malevolent or fraudulent agents, it is useful to consider other forms of reasoning to better model the processes involved. Although heuristic techniques have been applied to learn which agents could be deceptive, this section looked at the underlying models of reasoning which might apply with such agents.

Recognition of deception in e-SC remains a big issue, because wherever negotiation exists, there are issues of deception, and any bargaining in negotiation implies some justifiable concealment and deception. IT can weaken trust relationships already holding in human organizations and relations, and aggravate problems of fraud and deception (Castelfranchi & Tan, 2001). The e-medium could make matters worse by weakening the usual bonds in social control. The habit or disposition to deceive will grow stronger, because the Internet is an anonymous medium. Agents in the e-SC will deceive the users or their delegated agents, for example, we have agents that bid on our behalf from a self-interested perspective. When our agent is bidding on something in an auction, we do not want it to honestly bid our reservation price for the good, if it could possibly get that good for less money.

Many techniques have been used over time to detect and prevent fraud and deception in human communications and e-SC, for example, increasing security by security protocols, authentication, cryptography, central control, and rigid rules. All these are useful and needed, but a technical solution to protect against deception and fraud in e-SC is unrealistic. Fraud and deception was a problem 2,000 years ago, it is a problem in e-SC today, and it will be a problem in another 100 years time. It is a game of chase, catch up, run ahead, and chase all over again. Therefore, exploration of the essence of fraud and deception is at least also crucial to solve these problems.

A UNIFIED MODEL OF COOPERATION, NEGOTIATION, TRUST, AND DECEPTION IN E-SUPPLY CHAINS

So far, we have explored cooperation and negotiation, trust, and deception in e-SC respectively.

These issues have drawn attention in multi-agent systems, e-commerce, and virtual society. Kraus (1997) explores cooperation and negotiation in multi-agent environments based on an intermedisciplinary approach. Sun and Finnie (2004a, 2004b) examine cooperation, negotiation, and deception in e-commerce. Weigand and van den Heuvel (2001) discuss trust, fraud, and deception in e-commerce. Castelfranchi and Tan (2001) investigate trust and deception in artificial agents and societies. However, no studies have been attempted to explore the interrelationships between communication, cooperation and negotiation, trust, and deception among the agents within the e-SC in a unified way. Without such attempts it is easy for the SC to be broken down by failures in agents, failure in communications, and intentional deception (Walsh & Wellman, 1999):

1. At least a link in an e-SC is broken or it is breakdown.
2. One part of an e-SC where many business partners involved is so weak that it is ignored.

The first case sometimes results in the bankruptcy of the lower level companies in the chain, because of delay of the materials' arrival to the company. Risk management can be used to avoid the occurrence of this case (Turban et al., 2006, p. 286).

The second case results from inefficiency of delivery of materials in the corresponding supply chain. The final results will affect the end products to end customers and negatively influence customer satisfaction.

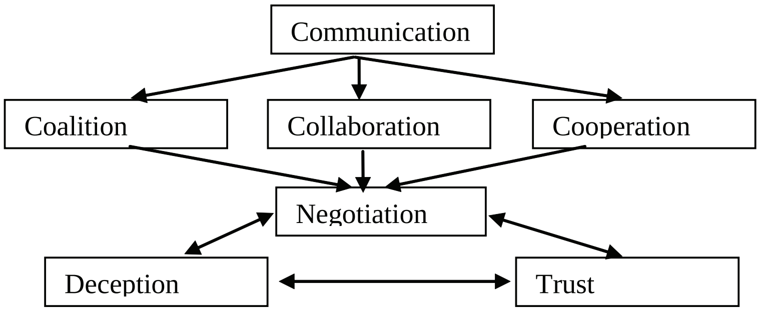
In what follows, we will propose a unified model of cooperation, negotiation, trust, and deception in e-supply chains, as shown in Figure 6, in order to explore the above-mentioned interrelationships.

In the e-SC, an agent first communicates with its adjacent agents. However, communication between agents is normally not transitive, because indirect communication between some agents (e.g, the buyer and the seller's solicitor) is illegal or unethical. However, the communication is fundamental for any activities such as collaboration, cooperation, and coordination in the e-SC.

Agents have to coordinate their activities and cooperate based on collaboration, coordination, and cooperation protocols (3C) in order to make materials and information flow in the e-SC effectively and efficiently. For example, product design and demand forecasting can be based on 3C among the business agents. The general case of these collaborations among the business partners constitutes collaborative commerce, which implies communication, information sharing, and collaborative planning done electronically through tools such as groupware and specially designed collaboration tools (Turban et al., 2006, p. 286).

Basically, agents work trustfully in order to form coalitions, collaborate, and cooperate with other agents. This is the reason why in the majority of cases, both traditional SC and e-SC run well. Sometimes, however, the coalition,

Figure 6. 3C, trust, and deception in e-supply chains



collaboration, and cooperation might terminate because one agent breaks the relevant protocols. Such a termination might lead to economic risk or breakdown of the e-SC. In this case, a negotiation mechanism has to be activated, in order to maintain effective communication, collaboration, and cooperation with the related agents. Negotiation is a bargaining process between two or more agents over prices or service items within the e-SC. In order to obtain the maximum benefit, one party in the negotiation usually hides some truths so that there are deceptions in any negotiation. Every party makes sufficient use of their knowledge and experience to avoid any possible deception in the negotiation. Any loss of benefit in the negotiation can be considered as a result of being deceived (Sun & Finnie, 2004b). Sometimes, negotiation is also a process of improving trust among the parties. The successful negotiation can bring new coalition, collaboration, and cooperation based on new 3C protocols with improved levels of trust. In other cases, the negotiation does not improve the trust among the parties, or create new coalitions, collaboration, and cooperation among them. One of the reasons is that at least one party has not shown sufficient compromise in the negotiation so that its deception strategy has not been successful. In this case, the negotiation is broken and the e-SC has to be relinked.

Coalition, collaboration and cooperation, trust, and deception comprise a dynamic process in the e-SC. They can be considered as a subchain (i.e., deception chain, negotiation chain, or trust chain) in the e-SC. In this subchain, any change in an entity will affect the activities of other items. Negotiation plays a pivotal role in this subchain, because it can improve the trustworthiness of other entities. Deception is a unavoidable part in this subchain. It can reduce the trustworthiness, coalition, cooperation, and coordination among the agents. However, removal of deception through negotiation can improve the trustworthiness, cooperation, coalition, and coordination among the agents.

CONCLUSION

This chapter first examined the transformation from the traditional SC to the e-SC and experience management. Then it explored multi-agent cooperation and negotiation, trust, and deception in e-SCs respectively. It also proposed a unified model of cooperation, negotiation, trust, and deception in e-supply chains. The approach will facilitate research and development of negotiation, trust, and planning in e-supply chains and multi-agent systems. The trend to the future will definitely lead to increasing autonomy for agents in the electronic supply chain. With such autonomy comes an increasing requirement for management to take responsibility for the actions of agents working on their behalf. Managers must be aware of the potential for fraud and deception in the supply chain and of research in this field.

Experience management is still a new concept for e-supply chains. How to manage experience of agents within the e-supply chain in order to improve cooperation, negotiation, and trust among agents, and to control deception, remains a significant issue in e-supply chains and one that decision makers in organizations need to be aware of. Experience management is currently where knowledge management was some five to ten years ago. A contribution of this chapter is to raise awareness of this developing field. In future work, we will develop algorithms and mechanisms of integrating cooperation, negotiation, and trust, taking into account deception in e-supply chains.

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Chapter 1.20

Using SA for SAM Applications and Design:

A Study of the Supply Chain Management Process

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ABSTRACT

In order to maintain a competitive position in today's marketplace, companies must demand a greater level of enterprise efficiency. In today's rapidly changing market, experts argue that it is no longer about becoming a powerhouse but simply about remaining competitive. That is why automating and linking the supply chain has become so imperative. Supply chain management systems link all of the company's customers, suppliers, factories, warehouses, distributors, carriers, and trading partners. These systems integrate all the key business processes across the supply chain of a company. This chapter explains the objectives of supply chain management and how SAP's supply chain management system helps companies fulfill these objectives.

INTRODUCTION

Supply chain management is the delivery of customer and economic value through integrated management of the flow of physical goods and associated information, from raw materials sourcing to delivery of finished products to consumers (Viradix, 2005). There are many enterprise resource planning (ERP) and supply chain management (SCM) vendors in the market. Some of these vendors design ERP packages while some design SCM packages. However, looking at the definition of supply chain management previously given, it sounds a lot like what an ERP system does. However, the difference between ERP and SCM systems is in the detail. Usually, SCM systems provide companies with planning capabilities for their supply chain. SCM systems can not only plan the supply chain but it can optimize the whole supply chain so that all the business processes are linked together to form part of one single activity. It does so because it can look at the demand, supply and the constraints simultaneously and then find an optimal solution. Traditional ERP vendors have started developing and supplying SCM solutions in order to gain a foothold in the SCM market. This chapter will look at the details of a SCM system more specifically SAP's SCM system.

The purpose of this chapter is to study the different features and functionalities in an SCM system. Users of this chapter will be able to understand the various modules in a SCM system and how these modules are used across the supply chain by different departments. Users will also be able to understand the flow of data, the underlying business processes, how the data is stored and retrieved and how the same data can be used by both an ERP and an SCM system. The objective of this chapter is to focus on the business processes in the SCM system. People reading this chapter will be able to understand how the SCM process actually works. Integrated systems usually have centralized databases and this allows for the free flow of information. Any activity that takes place somewhere in the supply chain affects the other activities someplace else in the supply chain. This chapter will look at how these activities are linked together to form part of one big picture.

This chapter can be used by the users to start understanding the different parts of a supply chain management system and how this system can be used in different business activities. Usually, SCM implementations are very complicated because it involves integrating the business processes of more than one company. By understanding the business processes in one company, users will be able to better understand how the business processes work in other companies and how these processes can be integrated. They will also know the different data that is used in an SCM system. The best way to use this chapter is to understand the business process explained in this chapter and then try to implement it on an actual system. By doing this, users will be able to understand the important details of a SCM system. The intended audiences for this chapter are the faculty and students in schools interested in learning about a SCM system. People involved in implementing a supply chain management system can use this chapter as a starting point for understanding the business processes that take place in a supply chain. Most importantly, this chapter can be used by beginners just starting to work on the system as a reference in understanding the different departments involved in a supply chain. This chapter can be used in any course teaching the concepts of ERP and SCM systems. The SCM process is important for any company and users have to know what happens in an SCM process. Learning about an SCM system will give the users an idea of how business transactions occur within a company and how the data from these transactions is sent upstream and downstream to the company's suppliers and customers respectively.

Since there are many vendors who provide supply chain management systems, it is difficult to explain all the supply chain management systems in detail. So, this chapter will focus on SAP's supply chain management system. This chapter starts off with an introduction to supply chain management and SAP's SCM system. It explains the different modules in SAP's SCM system and then takes a look at the different business processes in an SCM system. It looks at the different departments involved in a supply chain and tries to explain how these departments can use SAP's SCM system to add value to the organization. In conclusion, it looks at the future trends in the industry and how these trends are helping companies change the way they do business.

From an academic point of view, this chapter can also be used as a case study for instructional purposes. Instructors can use this chapter to explain the concepts of supply chain management and to explain how the different operations in a supply chain come together so that companies can deliver the right products to the right customers at the right time. The supply chain management course can be conducted over the period of a semester with a class size of typically 35 students. These students should have a basic understanding of the different departments in a company and should have an idea of the business processes within a company. However, this knowledge is not essential as students should be able to pick up any details that they do not understand just by reading this chapter. A very important point to be noted is that this course covers the different parts of the supply chain and how all these parts are used together by companies to tighten their supply chains. This course does not go into the practical aspects of the supply chain (i.e., it does not explain how to actually use a supply chain management software). It is up to the discretion of the instructor to incorporate practical exercises using supply chain management software. Please note that the chapter explains the topics that are covered in the course but instructors may have to use additional readings or exercises to explain each module of the course in more detail. Another point to be noted is that there are many SCM softwares available in the market and this course primary uses SAP's supply chain management system to explain the concepts associated with a supply chain. Again, it is up to the discretion of the instructors to use any software that they think will explain the supply chain management concepts. Though it is possible to explain the concepts in supply chain management without the use of any softwares, SAP's SCM system is used here so that students have a better understanding of how exactly an information system is used to handle the supply chain of any organization. In most modules of the course, the course theory and the module itself are linked together, that is, the theoretical aspects of the course are linked and explained together with some of the systems used in SCM systems so that students have a better understanding of how supply chain management systems (information systems) are used in order to improve an organization's supply chain. Much of the concepts are explained using modules of an actual SCM system. However, students will be able to understand the theoretical aspects of a supply chain. They will learn about the different departments in a company involved in the supply chain and how these departments work together to create more efficiency. They will also be able to understand what the different tools are offered by software vendors to manage a company's supply chain. The different modules that are covered in the course are as listed below. Each module is explained in detail in the topics that follow. Each module explains in detail the theoretical aspects associated with the particular part of the supply chain and then tries to explain how students are able to benefit from this information.

1. Background Information
2. Concepts in Supply Chain Management
   a. Supply Chain Planning
      (i) Demand Planning
      (ii) Advanced Planning and Scheduling
      (iii) Transportation Planning and Vehicle Scheduling
   b. Business Procurement
   c. Warehousing and Distribution
3. The Business Processes in a Supply Chain
   a. Product Design and Development
   b. Sales
   c. Procurement
   d. Production
   e. Distribution and Logistics
4. Future Trends
   a. Suggestions to Learn the Supply Chain Management Process
   b. Lessons Learned
   c. Strengths and Weaknesses of a Supply Chain Management System
5. Conclusion

BACKGROUND INFORMATION

Supply chain management involves coordinating and integrating the business flows both within and among companies. Thus, supply chain management can be viewed as a pipeline for the efficient and effective flow of products/materials, services, information, and financials from the suppliers' suppliers through the various intermediate organizations/companies out to the customers' customers. The inbound and outbound logistics are very important components of the supply chain and this helps in making any company financially viable. Supply chain management (SCM) integrates marketing, sales, and manufacturing with logistics. The integration of each business function helps to reduce lead times, making companies with supply chain management systems more competitive in the marketplace. However, implementing supply chain management systems involves spending a lot of time and money. Companies have the option of creating their own SCM system, but it makes more sense for companies to buy an SCM system from a vendor and then get it customized according to their needs. Many companies offer complete supply chain management systems, which can be used by companies without too much customization.

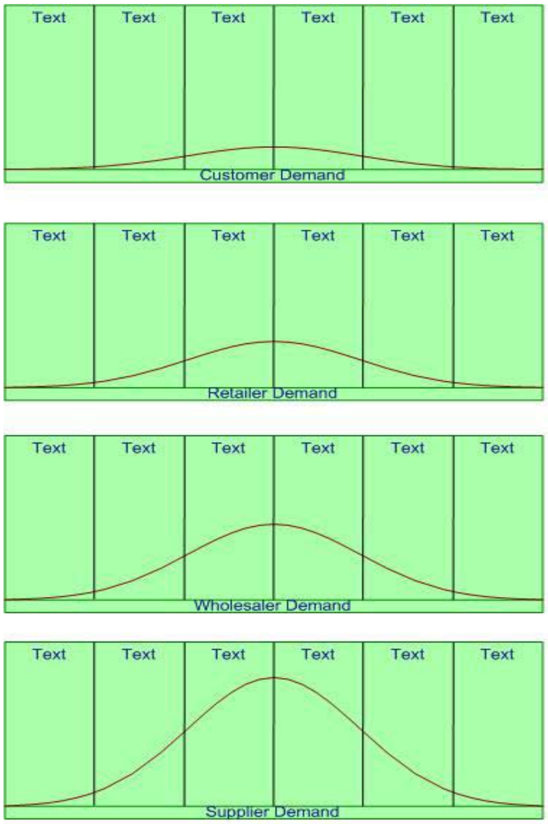
Though all these companies offer supply chain software, this chapter focuses on the supply chain management system offered by systems, applications, and products (SAP) in order to explain the different concepts associated with the supply chain. The advantage of SAP's SCM system is that it uses an adaptive supply chain network. What this means is that this network consists of many customer-focused companies that share resources and knowledge so they can better adapt to changing market conditions (SAP). These supply chain networks connect all the operations within a company like planning, manufacturing, distribution, etc and the data within these departments is visible immediately so decisions can be made and carried out immediately. The results are cost reduction, productivity gains, and higher profit margins. This chapter will focus on how a supply chain management (SCM) system helps companies fulfill its objectives. We will also look at some SCM components, look at the various business processes that can take place in a supply chain and see how these components fulfill those business processes. The main objective of SCM is to get the right product to the right place at the right time and at the right price. Some of the other broad objectives of SCM are to:

- Reduce lead times
- Increase customer satisfaction by providing products and services at the lowest possible cost
- Reduce operating expenses
- Understand the value chain and understand and eliminate those activities, which do not add value to the company's business processes
- Share information both up and down the supply chain in real-time
- Have accurate and flexible operations, which can be totally integrated with the suppliers' value chain

All these objectives can be achieved in a supply chain if information about product demand and service requirements is shared within the shortest possible time. These objectives arise out of the need to eliminate the "bullwhip effect." In the bullwhip effect, relatively small fluctuations in the actual demand among consumers is magnified through the supply chain which in turn has negative effects on the planning of transportation of the products and services and also on the production of the company's products.

Figure 1 explains how there is a distortion of demand information as this information passes up the supply chain and this is the bullwhip effect. The supply chain in the figure consists of customer, retailer, wholesaler, and supplier. The curve in the figure is the demand information that is received by each component of the supply chain.

Figure 1. The bullwhip effect — a distortion in demand



One of the main causes of the bullwhip effect is the break in the sharing of information between the different partners in the supply chain. Some of the solutions for reducing the bullwhip effect are to have real-time data up and down the supply chain, have just-in-time supply, reduce lead times, and so forth. Companies have come up with many solutions to reduce the bullwhip effect and to share information between the different partners of their supply chain. One of the solutions is to have an efficient and responsive supply chain system, which will integrate the different parts of the company's supply chain. However, just knowing that there is a bullwhip effect taking place is not the most important thing. Companies have to understand and change their business processes in order to reduce or eliminate this effect. Though it is important to understand the ramifications of the bullwhip effect and its possible solutions, it is more important to understand how supply chain management works within a company. There are many business processes, which take place when a company receives an order or wants to purchase an item from a supplier. In order to understand how supply chain management works, it is necessary to look at the various business processes within a company because it helps users understand how the flow of information takes place up and down the supply chain.

This is the background information that is explained to the students over the first week of the course. This helps the students understand the objectives of the course, that is, understanding how a company manages its supply chain. This background information helps the students to understand what the objectives of a supply chain management are and why companies decide to implement supply chain management systems.

Please note that the topics in the rest of the chapter covers the theoretical aspects of the course (i.e., the topics that are taught to students).

CONCEPTS IN SUPPLY CHAIN MANAGEMENT

As previously explained, the main use of a supply chain management system is to link all of the company's customers, suppliers, factories, warehouses, distributors, carriers, and trading partners in one virtual enterprise. By doing this, a company can use an SCM solution to achieve a competitive advantage and broaden its profit margin. By providing greater visibility throughout the supply chain — from planning and procurement to point-of-purchase — businesses can reduce expenditures, improve operational efficiency, and respond more quickly to customer demands (Borck, 2001). A supply chain management system should have the capability to plan, implement and control any strategy that is necessary to advance the company's objectives. What this means is that the system should be able to respond to the corporate strategy (i.e., the SCM plan should be in sync with the plans of all the other departments in the company). The system should be good enough to put the plan into action (i.e., implementation should not be too much of an effort). The system should also be able to carry out checks of the processes and inform the personnel whether the plan was good or not and whether it was properly implemented.

Supply Chain Planning

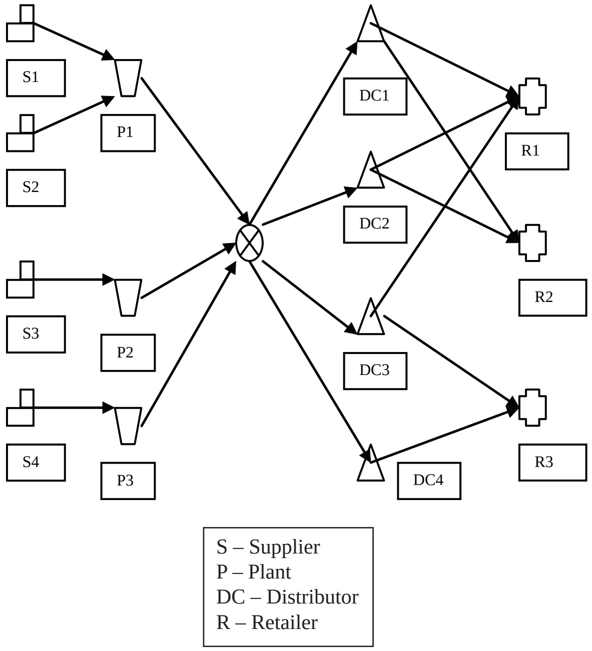
The first thing to be done in any supply chain system is to have the capability to plan the supply chain functions. A supply chain planning system should house the functionalities to schedule and monitor all the processes that are necessary in the planning phase. It should also have a single common database and several modules that share this common database. It should also provide the visualization capabilities for planning the inter- and intra-company logistical networks. All this is explained to the students using SAP's advanced planning and optimizer (APO). The different modules used in supply chain planning softwares are explained using SAP's software. The graphical user interface for SCM planning softwares in the SAP environment is explained to the students as given next:

- **Supply chain cockpit (SCC):** The SCC module is like the graphical user interface of SAP's SCM initiative. It consists of built in algorithms that can be used to optimize company networks. With the help of these algorithms, modeling of any logistics network [based on nodes (locations) and arcs (transportation lanes)] can be carried out and different business scenarios can be evaluated. It also has pre-defined exception conditions. When these conditions occur, the SCC sends a message to the workers or managers informing them of the problem in the business scenario. Since the SCC can be used to model a logistics network using advanced algorithms, managers can use these algorithms to access demand forecasts and to create business plans based on the supply and demand in each individual business unit (node). The detailed version of the SCC can be used for scheduling and control of products, which can then be assigned to specific locations.

Figure 2 explains a supply chain cockpit with locations and transportation lanes. It shows how the different parts of a supply chain are linked together. It also shows that information and materials can be passed through any part of the supply chain.

Supply chain planning consists of demand planning, advanced planning and scheduling and transportation planning and vehicle scheduling.

Figure 2. A supply chain cockpit with locations and transportation lanes (Knolmayer & Zeier, 2002)



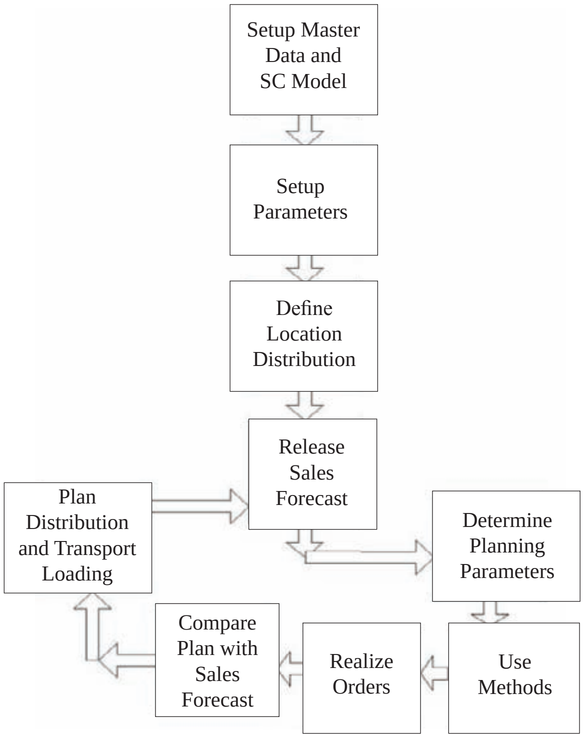
- **Demand planning:** Given the constraints within each company, the ability to forecast demand is one of the key functions in any SCM system. The demand planning sub-module in a supply chain is used to forecast the products that will be sold in the market. Then a sales plan is generated for any particular market. This forecasting and sales plan creation may be based on historical data collected over the years. This data can be taken from a business warehouse, point-of-sale systems, or online analytical processing servers providing the users with functionalities of data analysis. The demand planning is done based on the collaborative planning, forecasting and replenishment (CPFR) model. This model and in turn the demand planning sub-module is based on the idea of reducing the bullwhip effect (i.e., the effect of any problem at one end of the supply chain felt at some other end of the supply chain). If companies in the supply chain improve coordination and avoid multiple administration and repeated use of planning methods and databases, they can reduce the bullwhip effect. This increases the coordination between the different partners of the supply chain and helps them to make decisions which can benefit the whole chain. With demand planning systems in place, the supply chain partners are able to develop an outline plan in which core process activities can be assigned to the participating companies. These companies then jointly prepare a forecast of the consumers' demands. This forecast serves as a basis for the schedules to be agreed on. Finally, the partners try to avoid inappropriate schedules in the material flow.
- **Advanced planning and scheduling (APS):** This sub-module contains functions by which different planning methods for different time zones can be examined and appropriate steps taken. It consists of sup-

ply network planning which determines the procurement, production and distribution schedules. It also determines the optimal quantities that can be shipped and the advantages of using external suppliers. The APS also consists of deployment functionalities which can be used to determine the optimal usage of existing distribution and transport resources taking into account all the constraints. Finally, it contains the production planning and detailed scheduling system which is used to plan the sequence of the production and the scheduling of orders. This can be done with a very high amount of accuracy usually with accuracies as high as 99% (Morris, 2000).

Figure 3 explains the different parts of the advanced planning and scheduling cycle. It starts off with a company planning their supply chain model and setting the limitations and constraints. The company then defines its different locations for supplying products. It then prepares a sales forecast, that is, deciding the amount it plans to sell. It then determines the parameters for its sales plan, that is, the limitations for sales and distribution, then it looks at the orders that it gets and then compares the actual orders to its sales forecast. It then executes its orders. By comparing its actual and forecasted orders, it is then able to fine-tune its supply chain so that the next time around, it is able to try and equate demand and supply for its goods and services.

- **Transportation planning and vehicle scheduling (TP/VS):** The TP/VS sub-module helps in the simultaneous consideration of transportation constraints using the company's transport fleet or using external carriers. This module allows different

Figure 3. APS cycle (Knolmayer & Zeier, 2002)



members of the supply chain to design their transportation activities in such a way that everybody benefits because of the optimal use of transport loads, routes and carriers.

- **Available-to-promise (ATP):** The ATP sub-module can be used to investigate whether a promised delivery can be made. It can be used to determine whether an existing order can be fulfilled accurately. It takes into account all the market forces and determines the most favorable result for both the company and the customer. It works on the principle that the customer is always right and that the customer has to be satisfied under any circumstances.

By learning about the different aspects of supply chain planning, students are able to get an idea of the different terms factors involved in supply chain planning. They are able to grasp the fact that just to plan a supply chain; a company has to plan many different factors like demand and transportation. They are also able to understand the fact that implementation of a supply chain management system involves understanding the factors involved in the demand of a product. They understand that in order for a product to reach the customer the company has to start the supply chain in the planning stage and then move over to the execution stage.

Business Procurement

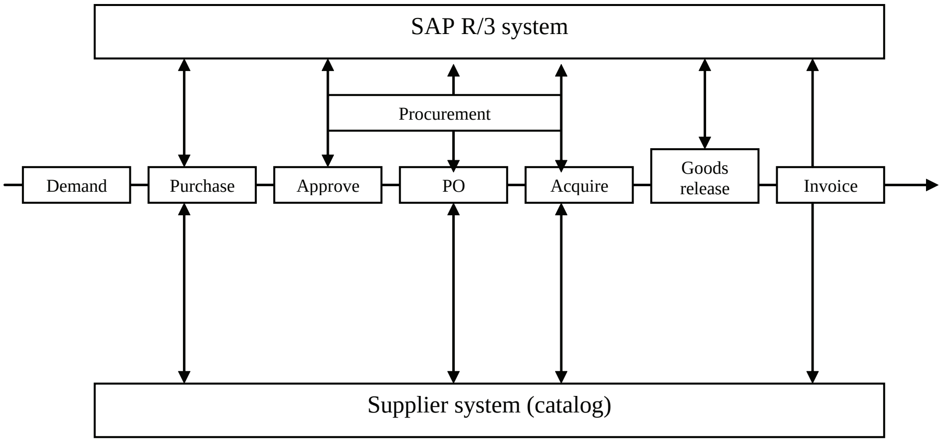
In today's business world, companies need to get raw materials at the right time so that they do now have to maintain excess inventory. Companies are realizing the importance of linking their processes to those of their suppliers so that there is free flow of information. By doing this, suppliers will be able to supply materials needed by the company at exactly the time that the company needs those materials. This concept is explained using SAP's business-to-business procurement module. The business-to-business module takes care of the electronic support for the procurement of goods and services and helps in integrating the purchasing process into the overall flow of goods and information. The advantage of this module is that purchases can be made by individual members of the company using the Internet from their own workplace. Since these tasks can be carried out by individual members of the company, the actual purchasing department can use their time on making strategic decisions beneficial to the company. This module can be used to control and monitor the purchasing process. Since the purchase orders are made by individual members without involving the purchasing department, the receipt of goods is streamlined. This also helps in making the invoicing and payment tasks simpler. It can also be used to connect various product catalogs so that there is a direct interaction between a purchasers and suppliers. This is based on the principle of free market economy where the order is one by the company, which offers the lowest price and the best quality product.

Figure 4 depicts a sales order process from demand of the product to the invoice. This sales order is fulfilled by the company by ordering products from its suppliers using and online catalog on the Internet. This is again linked to an internal ERP system within the company so that there is free flow of information between the different departments of the company.

Warehousing and Distribution

Once the company receives the raw materials and produces finished goods, it has to supply those goods to the customers where and when they need it. The company needs to have a good inventory management system in its warehouses and logistics system so that it does not have to maintain excess inventory while at the same time is able to supply its products to customers at the right time. This is the concept that is explained using SAP's logistics execution system (LES). The logistics execution system helps in efficient

Figure 4. Procurement of parts using the Internet (Knolmayer & Zeier, 2002)



warehousing and distribution using the warehouse management system (WMS) and the transport management system (TMS). The warehouse management system supports the use of various warehouse equipment like rack storage areas. This system is used to monitor the movements in the warehouse and for the management of warehousing activities like unloading, packing, dispatching loading vehicles to the appropriate ramps and the printing of necessary documents. It is also used to maintain the inventory in the warehouse. When dangerous materials have to be handled, this system can be used for creating the regulations and circumstances for the handling of these materials. Warehousing technologies include the use of wireless terminals and mobile barcode scanners. SAP R/3 provides a tool called the radio frequency component which uses radio frequency terminals with scanning devices attached so that the data can be accurately and immediately transferred. These radio frequency terminals have the advantage that they can be mounted almost anywhere and that they receive the data directly from the SAP R/3 system.

The transport management system uses the plans and ideas developed in the transport planning and vehicle scheduling (TP/VS) system and using these ideas helps in providing the functionalities for scheduling, shipping, route planning, calculating freight charges and handling of the products. The transport management system also helps in selecting the best transport companies, determines the best possible routes for transporting materials and helps in scheduling the shipping of the materials. This system takes into account the various constraints imposed on the transportation process because of the nature of the goods being transported and gives the user the best possible solution. It takes into consideration the fact that transportation costs signify the largest portion of costs in any logistical system and so calculates the transportation costs in such a way that these costs are always minimized. It relies on the Internet to communicate with the suppliers and the customers and so can be used to transfer appropriate data in the minimal time possible.

Though the section above gives the user an idea of the different components that can be utilized to effectively fulfill some supply chain objectives, it is still not sufficient. It is more important to understand the flow of business processes within a company. The flow of business processes within a company can be integrated with the help of an enterprise resource planning (ERP) system. Though the ERP system will help to link the different departments within a company, the necessary information has to be transmitted to the company's supply chain partners so that there is a smooth flow of information to suppliers and customers. A company can have all the resources and systems but a system that is implemented on top of a flawed business process is bound to fail and in the long run, create even more problems for the company. In order to implement a good supply chain system, a company has to know which business processes can be improved and then think about how to go about it.

THE BUSINESS PROCESSES IN A SUPPLY CHAIN

The first step to study the company's business process is to understand the company's value chain. The value chain can be seen as a necessary tool for identifying the areas where a company can gain a competitive advantage over its rivals (Porter, 1985). Every firm can be broken down into a series of activities or categories that start at the design of the product and ends with customer support. By looking at each and every detail in terms of the value chain, a company will be able to understand its business process and identify potential sources where it can gain an advantage over its competitors.

Figure 5 depicts the value chain for a company with primary activities that process inputs and produce outputs and the support activities which support the primary activities.

A company's value chain can be divided into primary and support activities. The primary activities are concerned with manufacturing, sale and distribution of the product and can be divided into five categories viz. inbound logistics concerned with inventory, transportation, product returns etc, operations concerned with manufacturing etc, outbound logistics concerned with orders, deliveries etc, marketing and sales concerned with marketing the product or service and service concerned with customer service activities. The support activities support the primary activities and consist of procurement, human resources, technology, and procurement. These activities are again broken down further into different business processes and by understanding these business processes, a company can focus on the area it wants to improve.

Figure 6 illustrates the different departments within a company and the various activities that take place in each department. It depicts how information flows from one department to the other in order to fulfill the sales order. This shows the value chain thinking in action.

Using all the components of a supply chain management given above, a company will be able to design its network and supply chain effectively. However, the design part has to be followed by proper execution of the design. In order to maintain a competitive advantage, a company has to be able to improvise depending on the fluctuations

Figure 5. Porter's generic value chain (Porter, 1985)

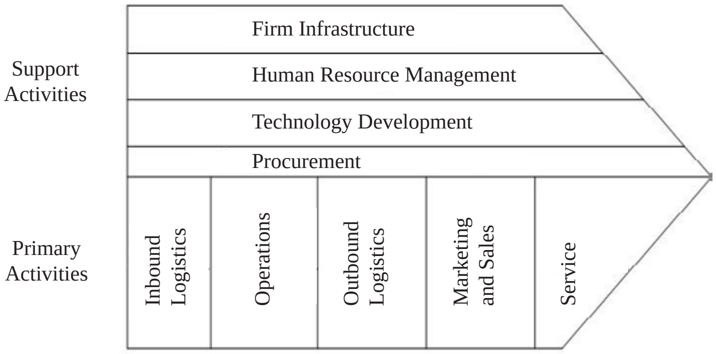
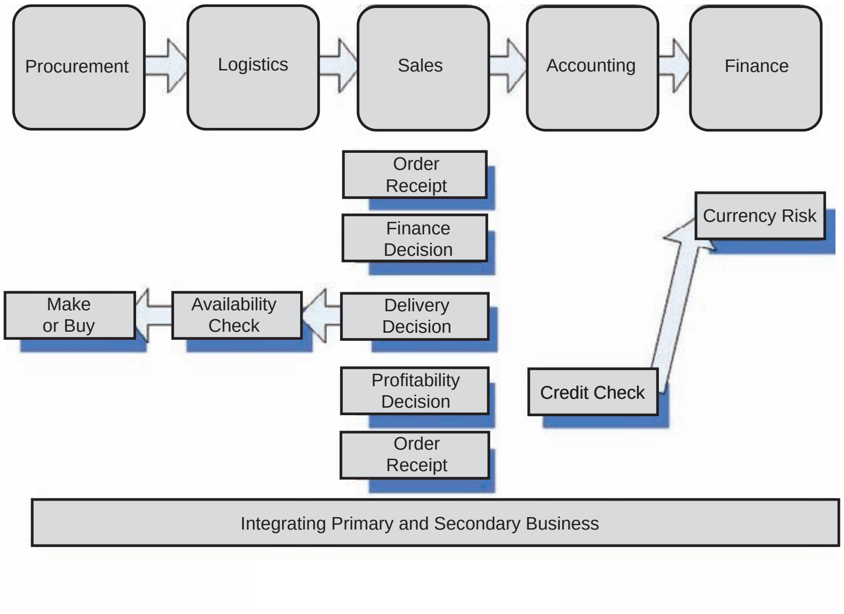


Figure 6. Value chain thinking (Curran, 2000)



in demand for its products and services. In order to understand how the supply chain works, let us look at the different departments that process the sales order and which ends with the delivery of the products to the customer. By looking at this process, students are able to understand the different processes within a supply chain and also have a general overview of different departments and its functions within a company and how the different SCM and ERP modules help these departments do their job more effectively and efficiently. Logistics, scheduling transportation and materials, procurement from external suppliers, warehousing, inventory management, production, and so forth are some of the areas in a supply chain. But the supply chain also includes areas like product design, sales, procurement, production and distribution.

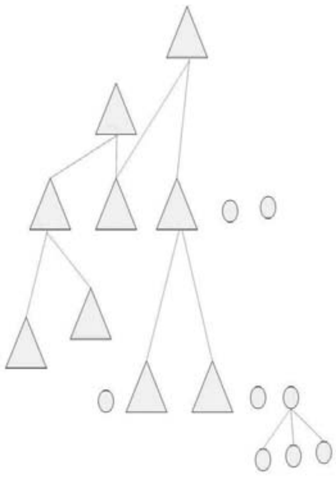
Product Design and Development

Product design and development is one of the most important activities carried out within a company. This includes research and development (R&D), design of the product and so forth. The reason why this part is so important because the data developed initially is sent to different systems to be used. For example: the bill of material (BOM) is sent to the materials resource planning (MRP) module, design data is sent to the computer aided design (CAD) systems and so forth. It is always better to have people from different companies and if possible employees from supplier and customer firms to work together in the design and development of a product. Having different people from different companies and departments in the development stage is beneficial because it will save the company time and money on the modifications of the products, if and when it comes up. Customers have their own preferences for products and this is always the main concern for the sales and marketing teams. Therefore, it is necessary to introduce a few variations in the products so that the customer is fully satisfied. However, by introducing variations in the product, the cost for the companies increases. This happens because it is difficult to forecast the demand for the products with variations, there may be differentiations in the logistics part and so forth. So it is always better to introduce these variations as late in the production process as possible. This concept is explained using SAP's product variant structure (PVS). Students are able to understand the importance of having standardized products as far as possible so that companies are able to cut down on their expenses and as a result, increase their profits. "In SAP, the Product Variant Structure (PVS) can be used to describe the different types of variants. PVS provides filter mechanisms to define function specific variants of products and structures" (Knolmayer & Zeier, 2002).

In Figure 7, each triangle is a part produced by the company and the circles next to the triangles represent the variations in the product. It shows how even though different products can be linked together during design and manufacturing, the variations are separate and may require a separate assemble line which in turn costs the company additional time and resources.

"Every triangle represents a part and points placed next to triangles indicates an alternative" (Knolmayer & Zeier, 2002). In addition to product variations, computer aided design (CAD) systems are used to develop the product. For product design, students are introduced to the CAD interface so that they understand that an SCM system contains not only the planning and execution components of the supply chain but also the design components of the supply chain. The SAP system includes an open CAD interface. It can be used to link different CAD systems so that the data needed to design the product and materials can be taken directly from the SAP system. After the design part of the system, students are explained that an SCM system also has components for documentation and project management. This is explained using SAP's product data management (PDM) sub-module. This sub-module helps in administering the documentation, master data for product classifications and project management.

Figure 7. Visualization of the product variant structure (Knolmayer & Zeier, 2002); triangle — part, point — alternative



Sales

Sales is another area which is very important to optimizing the supply chain. Among other things, sales include the pre-sale activities, the actual sales order, delivery, and customer relationship management.

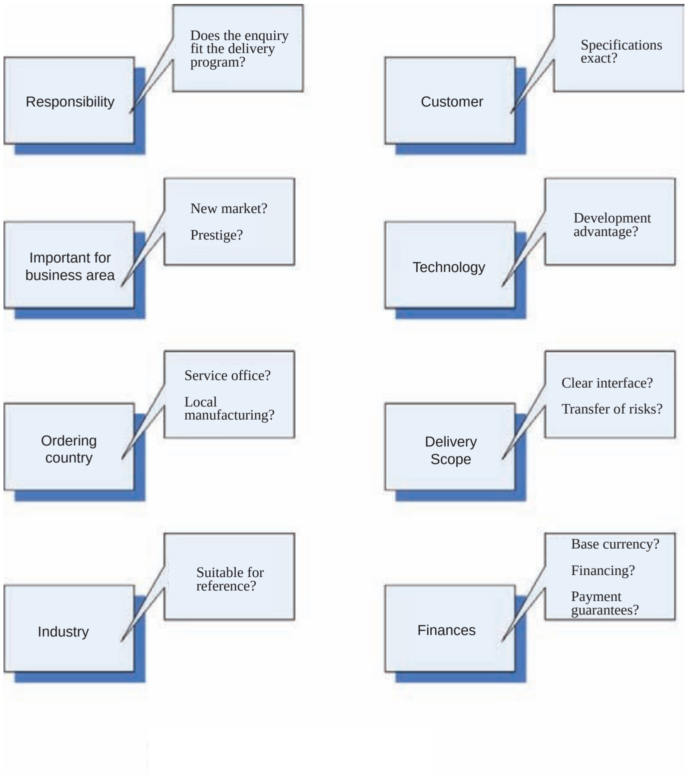
The aim of marketing is to increase the customer base and at the same time reduce the costs of marketing the products to customers. This can be done by targeting specific customers, which reduces the costs of customer visits. The best way to do this is to tap into a large database and select customers to be targeted. Data mining can be used to create customer groups and identify patterns of customers within existing groups. It can also be used to forecast marketing strategies by looking at patterns between complimentary products. For example: companies selling furniture will be able to forecast future sales by looking at customers who purchase a house based on the fact that people who buy a house may at some time in the future decide to purchase furniture. Companies can target these customers for specific marketing strategies. SAP has included many marketing strategies like one-to-one marketing, data mining etc in its mySAP customer relationship management (CRM) module. Data mining can be run on a data warehouse for better results.

Depending on the number of customers in a company, recording a customer enquiry and processing customer quotations may be very important from the company's point of view. This is so because there are many quotations that may have to be processed every day and if the company can use standard quotation elements for processing quotations, it will be able to save a lot of money. Since the quotations involves taking data from materials management, customer master data and inventory management, it is important for the company to have a good system in place for developing quotations. This forms an important part of knowledge management. A data warehouse can contain data from many different sources and this data can be drawn upon to create new quotations.

In Figure 8, each box represents a factor to be considered for a sales quotation while the boxes above the original boxes represent the data within the different factors. This figure explains how data is drawn from different sources within the company to create new quotations.

Large, multinational corporations have a range of products and some of these products are designed even if there is no customer demand for these products or if the customer is not willing to pay enough for these products. In such cases, companies use something called product costing which depends on the maximum price a customer is willing to pay for a product rather than the costs of manufacturing the product. Depending on the market requirements, the products are designed and the maximum price that the customer is willing to pay is taken into account. Since the customer is not willing to go beyond

Figure 8. Checklist for quotation selection (Knolmayer & Zeier, 2002)



a specific price, the company and its suppliers have to come up with ways to reduce the costs of developing and transporting the product. This involves a high degree of coordination between the different parts of the supply chain. Product costing can be carried out with the help of SAP's project system (PS) (Knolmayer & Zeier, 2002). Depending on the maximum allowable limits for the costs in the different business processes, the system generates messages when these limits are exceeded. This system is customized according to the customer requirements which help in building the customer base. Another way of providing total customer satisfaction is to introduce the concept of mass customization. Mass customization can take place successfully only when there is a free flow of information between the suppliers, the company, and the customers. If this happens, as soon as the customer places the order, it triggers an assemble-to-order process and by doing this, companies will be able to satisfy even the smallest customer demand thereby increasing its customer base. SAP provides the "Order Entry with configuration" system in which data is directly entered into the SAP system using the Internet and which triggers the production process immediately (Knolmayer & Zeier, 2002).

When an order is received from a customer, there are many checks that have to be performed before the order can be processed. If the customer requires a customized product, then checks have to be performed to see whether the company can manufacture the product on time and deliver it to the customer. Credit checks have to be performed in order to see whether the customer has a good credit standing with the company. SAP has credit management functionalities in the sales and distribution (SD) and the financial accounting (FI) modules. Also, these modules contain functionalities by which the customer can pay for the order using different kinds of payments. The important part here is that these systems are integrated with many different kinds of customer-centric systems and all the data is stored in a central database. Another check that has to be performed is whether the company will be able to meet the customers' required delivery date. If it does not, then the company has to schedule the production process and inform the customer accordingly of the new delivery date. In order to do this, it has to coordinate fully up and down the supply chains so that the production process and the logistics process can work simultaneously in tandem with each other. SAP permits the planned delivery time to be calculated depending on the availability of a product by calculating the inventory, production capabilities, resources, and so forth. It does this using the available-to-promise (ATP) module of the advanced planning and optimizer (APO) system. With the advent of the Internet, communication between different companies has become a lot easier and if a company has business customers (B2B e-commerce), then it can use the Internet to communicate with its business partners. Electronic trading exchanges and portals are one of the best ways to interact with business partners. SAP has developed the business-to-business procurement solution which uses the Internet for communication (Knolmayer & Zeier, 2002). "The Internet helps companies in the obtaining the raw materials, processing sales orders, the billing process, and so forth. In addition to this, e-commerce has grown on a large scale and has become a widely used form of selling products and services. Online stores are a predominant way of getting in touch with the customers and making a sale. This involves credit card transactions online and security measures like secure socket layer (SSL) and digital signatures are of paramount importance" (Knolmayer & Zeier, 2002). The SAP online store can be used to create an online product catalog on a company's Web site on the Internet (Knolmayer & Zeier, 2002). The data entered by customers on the Web site is transferred to a transaction server and this in turn is transferred to the SAP database where these orders are processed (Knolmayer & Zeier, 2002).

After the order is processed, it is necessary to have a good customer service system which involves the products to be stocked in stores and how much space to allocate to each item, good replenishment systems, good marketing and promotion systems and efficient new product introduction systems (Knolmayer & Zeier, 2002). Value can be added to the value chain only when all these things can be implemented correctly and this can occur only when there is total trust between the suppliers, the company, and the customers and when there is free flow of information in all parts of the supply chain. This can take place when the vendor manages the inventory so that any fluctuations in customer demand are directly visible in the vendor systems and by which the vendor can take immediate action to satisfy customer demand. The SAP APO system provides the tools for vendor managed inventory (VMI) and which is a very popular and efficient way of satisfying customer needs. In order to take care of customer needs, SAP offers tools to the sales people in a company as part of its mySAP customer relationship management (CRM) system. The sales people are able to retrieve to customer data anywhere from the data warehouse. They are also able to configure products based on a customer's needs and run queries and reports on the data warehouse in order to extract the exact data that they want.

Procurement

Procurement is an important part of the supply chain because only when the raw materials arrive on time is the company able to start producing the products. In procurement, it is very important to have a close relationship between the sales departments and the purchasing department. By sharing information, the demand can be anticipated by the sales department and this can be transmitted to purchasing which can take the necessary steps to procure the materials needed to complete an order. Just-in-time procurement and vendor managed inventory (VMI) are two methods by which companies can cut down on procurement lead times and fulfill customer orders. The advent of the Internet has greatly enhanced the way companies procure raw materials from its suppliers. By having a direct line of communication with its suppliers, a company is able to share demand information with these suppliers. By using procurement portals over the Internet, a company is able to provide a single point of access for its suppliers and at the same time share information cheaply using the Internet. The SAP business-to-business (B2B) component allows all the procurement tasks and activities to be conducted over the Internet. It also allows product catalogs to be offered over the Internet.

Figure 9 explains how users use Web browsers to access and search a company's online store. This search is done using a search engine on the company's online store and this search engine is linked to the company's product catalog and the company's online database in order to retrieve customer queries in the shortest possible time.

Good procurement techniques come into effect when all the parts of the supply chain including all the systems are linked together to form part of a big, cohesive system. This will allow the free flow of information between all parts of the supply chain and will go a long way in adding value to the value chain of a company.

Figure 10 shows how the different components of an information system are linked together right from an online store to the company (its value chain) and the different components of its SCM system. This results in a free flow of information up and down the supply chain.

Production

Once all the materials are available, the production process has to be started. The main goals of production are to reduce the lead times, to manage inventory in the production process and utilize all the resources efficiently (Knolmayer & Zeier,

Figure 9. Use of the Alta Vista search engine in the SAP online store (Knolmayer & Zeier, 2002)

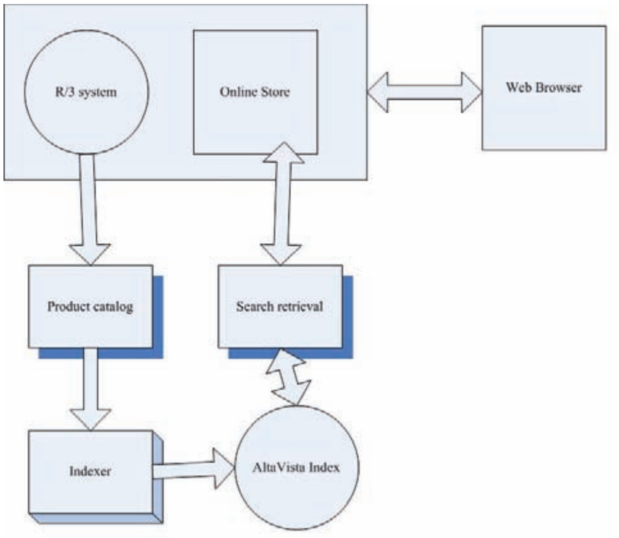
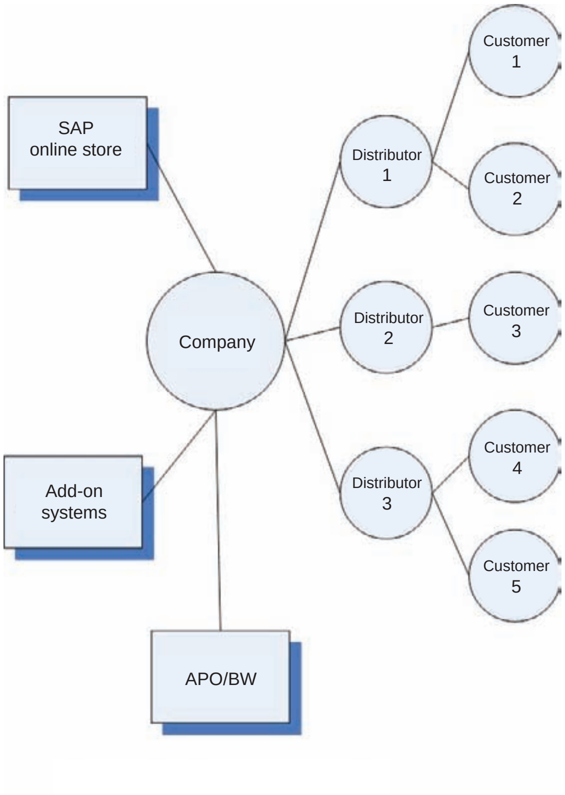


Figure 10. Cooperation of SAP components (Knolmayer & Zeier, 2002)



2002). This can be achieved using the materials requirements planning (MRP) functionality in the production planning (PP) module. Projects can be managed using the project management (PS) system. It may so happen that a company may have different manufacturing facilities in different parts of the country or the world and it is necessary for the distribution of production to be partially or fully centralized. This will allow the company to get all the data required for production without the need to worry about where the data and materials are stored. However, MRP within standard ERP systems is used to plan the production within a company while SAP's advanced planning and optimizer (APO) provides algorithms that can be used to support the entire supply chain (Knolmayer & Zeier, 2002). The advanced planning and scheduling (APS) module provides much different functionality that can overcome the shortcomings of standard MRP systems. Production can also be improved using the Kanban and just-in-time systems. The production planning (PP) module in the SAP system supports the Kanban principle and this allows the external and internal procurement, production and supply from a warehouse (Knolmayer & Zeier, 2002). The

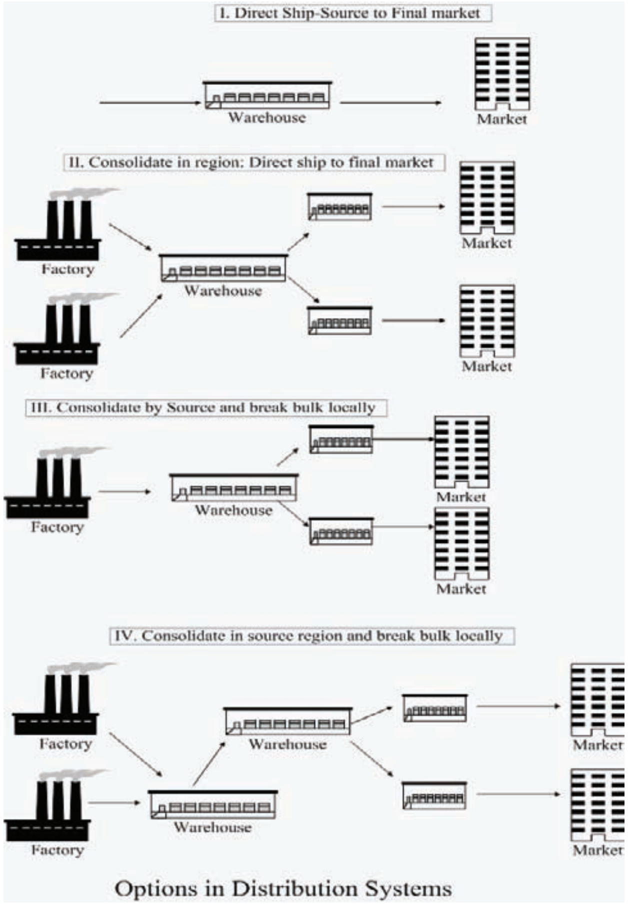
SAP APO uses mathematical models which takes into account the problems in capacity planning, constraints in production, material stock-outs, inventory levels etc and tries to come up with an optimal solution that will allow the company to streamline its production process.

Distribution and Logistics

Once all the products, materials, and services are ready, it is necessary to package and distribute them to the company's warehouses and outlets and from there transport these products to the customers. Usually, products are supplied to the customers either from a central warehouse or from local warehouses. A systems called cross-docking distribution tries to combine the advantages of both these types of distribution (Knolmayer & Zeier, 2002). This works in such a way that even though goods are transported to warehouses, they pass through as fast as possible because these goods have already been assigned spaces in the warehouses and storage locations and the picking and delivery parts have already been decided. "This concept has been developed by Wal-Mart. The warehouses use laser-controlled transportation systems where barcodes indicate to which trucks the incoming goods have to be routed" (Knolmayer & Zeier, 2002).

Figure 11 explains the different options that a company has in order to distribute its products from its production facilities to its markets using different components like wholesalers and retailers who make up the supply chain.

Figure 11. Options in planning of distribution systems (Knolmayer & Zeier, 2002)



The distribution systems include transport models which look at the optimal transportation techniques and route planning models which look at which vehicles should be used to satisfy demand. The SAP logistics execution system (LES) is an important component of the SCM system. Route planning is the trigger point in LES and by selecting the mode of transport; the resulting routes are calculated by the system. It also provides a graphical display of the planned routes on the screen for better visualization. It also includes distribution requirements planning systems, fleet management systems and shipment tracking systems. To determine where a company's vehicle is on the road at a given time, the fleet management systems are linked to global positioning systems (GPS). Using satellite technology, the exact location of a vehicle can be determined and this information is passed on to the customer using shipment tracking systems so that the customers know exactly where their ordered products are and the expected time of arrival of the products. For customer service, SAP also has a SAPPhone interface to provide data to call center personnel (Knolmayer & Zeier, 2002). "In addition, a help desk can be organized using SAP Call Center Components" (Knolmayer & Zeier, 2002). Logistics and distribution also involves reverse logistics by which goods that are damaged or not required by the customers can be returned back to the company. These goods travel up the supply chain and the system makes sure that this is done in the least possible time and at the minimum possible cost. The system automatically updates the data in all the modules of the ERP and SCM systems.

FUTURE TRENDS

The Internet is changing the way companies do business by providing a cheap and efficient form of communication. One of the most important trends to be noted is the convergence of ERP, SCM and CRM systems. Customers always like to have systems that compliment their existing systems for example; customers with SAP's ERP system prefer to have a supply chain management system developed by SAP so that they can be sure that both their systems will be compatible. So, ERP vendors are providing SCM and CRM solutions while SCM and CRM vendors are developing ERP solutions. In order to contain supply chain costs, it is necessary for companies to look beyond their existing borders and try and collaborate with different supply chain partners (Srikanth RP, 2003). Outsourcing has become very common in today's business world and companies look at ways to cut labor costs with outsourcing. Since companies outsource their business processes to different countries throughout the world, it has become all the more important to have an efficient and responsive supply chain to satisfy customer demand. Most companies have stand-alone business solutions for certain departments. However, companies are now realizing the benefits of having an integrated approach in which all the different software solutions are part of the same package. The Internet has made sure that geographical boundaries do not exist anymore and companies are able to track the cheapest suppliers anywhere in the world and also reach a customer anywhere in the world. This has led to a significant increase in the number of suppliers and also the number of customers. An increase in the number of suppliers and customers has led to an increase in the number of transactions carried out everyday. In order to maintain these transactions and gain a competitive advantage over their rivals, companies are investing in supply chain planning and supply chain execution systems. These systems not only help a company develop its customer base but also help in maintaining it over an extended period of time.

SUGGESTIONS TO LEARN THE SUPPLY CHAIN MANAGEMENT PROCESS

There are many details, which the user can use in order to successfully learn the business processes involved in a supply chain. Some of these suggestions are:

1. In order to understand how a supply chain works, users should try and understand the business processes in a supply chain.
2. To understand the business processes in a supply chain, users can look at the business processes that take place within a company and try and understand those business processes. After understanding the business processes within a company, it will be easier to understand the processes that take place between two or more companies.
3. There are many similarities in the transactions in an ERP system and an SCM system. If users are able to understand the transactions in an ERP system, they will also be able to understand the processes in an SCM system.
4. A good way to learn how the system works is to actually work on the system. Users should try to implement what they learn in this chapter on an actual system.
5. Another good way to learn about the SCM process is to create many companies within the system and carry out transactions between those companies.
6. Before carrying out the transactions, users should try to use the design part of an SCM system. By using the different modules of a supply chain management system, users will be able to design their own supply chain between suppliers and customers.
7. Once the supply chain is designed, users will be able to visualize how an actual supply chain looks like and how a change in one part of the supply chain affects all the different parts of the supply chain.

LESSONS LEARNED

There are many things that a user should be able to follow after going through this chapter. Users should:

1. Understand the different modules in a SCM system and know how each module helps create an efficient supply chain
2. Have an understanding of the business processes in a supply chain
3. Understand how the SCM process and the processes within an ERP system are linked together
4. Know how to fix the errors that may come up. By fixing these errors, users will be able to better understand the flow of data within the system
5. Know the different departments that can be involved in a company's supply chain and how these departments can use the modules of an SCM system

STRENGTHS AND WEAKNESSES OF THE SYSTEM

Each system has its own strengths and weaknesses. Some of the strengths and weaknesses for a SCM system are listed next:

Strengths

1. The main purpose of a training SCM system is that users can make mistakes and learn from the system rather than making a mistake during an actual implementation which can prove to be very expensive for the company.
2. By understanding the different departments that can be involved in a supply chain, users will be able to grasp the significance of each department and focus on the business processes that interest them the most.

3. By understanding the business processes, users can create their own companies and carry out transactions between those companies. Users will be able to learn the importance of having an efficient supply chain and know how a small change at one end of the supply chain is reflected at the other end.

Weaknesses

1. The main problem with an SCM system is that users should have access to such a system. The design modules form an important part of the SCM system and users should be able to access those modules to learn how a supply chain can be designed from scratch.
2. Another problem that the users can face is the lack of technical support or technical documentation. But by going through this chapter, users will have a basic understanding of how a supply chain works and this may help them in overcoming technical difficulties.
3. Some users may encounter errors while going through the SCM process in the system. This happens because in a supply chain management process there are many different companies involved and users have to learn to coordinate between different departments.
4. For users who are new to the system, getting familiar with the system may be time consuming. However, by going through this chapter, users should be able to understand the system better.

CONCLUSION

Companies are changing the way they do business by moving from vertically integrated enterprises to horizontally integrated enterprises. They do so by increasing the number of suppliers and procuring products and services from may different suppliers rather than produce everything in-house. This is achieved by having good supply chain management systems, which help in reducing waste between the company and its suppliers and the company and its customers. By having good supply chain management systems, companies can focus on their core competencies and improvise on it. This chapter looked at some SCM initiatives and how it can be used by companies to satisfy customer demand. However, though all these things are important from a broad perspective and though we have looked at the different components in a SCM system and studied their importance, it is always better to work on an actual implementation to gain a thorough understanding of how an SCM system operates. This will help the user to implement the theoretical knowledge and will go a long way in making certain that the user has totally understood the different internal and external business processes that take place in a company.

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Chapter 1.21

Supply Chain Risk Management:

Literature Review and Future Research

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ABSTRACT

Supply chain risk management has increasingly becoming a more popular research area recently. Various papers, with different focus and approaches, have been published since a few years ago. This paper aims to survey supply chain risk management (SCRM) literature. Paper published in relevant journals from 2000 to 2007 are analysed and classified into five categories: conceptual, descriptive, empirical, exploratory cross-sectional, and exploratory longitudinal. We also looked at the papers in terms of the types of risks, the unit of analysis, the industry sectors, and the risk management process or strategies addressed. The literature review will provide the basis for outlining future research opportunities in this field.

INTRODUCTION

The practitioners and scholars believe that the effective supply chain management has become an important enabler to improve organization performance and valuable way of securing competitive advantage (Chirderhouse et al, 2003; Li et al, 2006). The intensifying business competition since 1990s has forced companies to improve efficiency in many aspects of their business. On the other hand, the increasing uncertainty requires them to spend more resources to anticipate for demand, supply, as well as internal uncertainties for better sustainability of their supply chain. Interestingly, such an increasing uncertainty is not solely induced by the external business environments, but also due to increasing complexity of the supply chain structure and varying mechanism initiated by the supply chains in their business. The trend of companies outsourcing their activities to outside parties has certainly created a new source of uncertainty. The chance of having a delay in raw materials delivery is increasing if a company relies to outside parties to do most of the inbound logistics activities. Likewise, the trend of supply base reduction has exposed some companies to more risks than the associated benefits.

Risk and uncertainty has always been an important issue in supply chain management. Earlier literature consider risks in relation to supply lead time reliability, price uncertainty, and demand volatility which lead to the need for safety stock, inventory pooling strategy, order split to suppliers, and various contract and hedging strategies (see Tang (2006a) for an excellent review of various quantitative models considering supply chain risk). Although supply chain management has always had a strong emphasis on risk, the notion of supply chain risk management has gained an increasing popularity in recent years due to increasing supply chain complexity, including the use of global contract manufacturers and suppliers. Faisal et al.(2006b) and Tang (2006a) believe that effective supply chain risk management (SCRM) has become a need for companies nowadays. Companies like Ericsson (Norrman and Jansson, 2004) and Nokia (Li et al, 2006), have long realized the need for an effective risk management in their supply chain operations.

According to Chopra and Sodhi (2004), the supply chain risks could be in the form of delays of materials from suppliers, large forecast errors, system breakdowns, capacity issues, inventory problems, and disruptions. Another classification is provided by Tang (2006a) who categorized supply chain risks into operations and disruptions risks. The operations risks are associated with uncertainties inherent in a supply chain, which include demand, supply, and cost uncertainties while disruption risks are those caused by major natural and man-made disasters such as flood, earthquake, tsunami, and major economic crisis.

Numerous articles on supply chain risk management have been published in the last 20 years, the oldest being the article by Kraljic in 1983 (Paulsson, 2004). An attempt to review articles on supply chain risk management was done by Paulsson (2004). The author classified the articles using three dimensions: the unit of analysis, type of risk, and risk handling. From our observation, there are many more SCRM articles published since the appearance of Paulsson's review, making it beneficial to provide a more up to date review to include more recent articles. Tang (2006a) reviewed SCRM articles, but he focused on quantitative models. The author classified articles according to four basic supply chain areas: supply management, product management, information management, and demand management. The purpose of this article is to provide an extensive literature review on supply chain risk management. In particular, we aim to:

- Classify SCRM articles according to their approach and methodologies
- Discuss opportunities for future research

REVIEW METHODOLOGY

Search Methodology

In this review, we did exhaustive search of the articles related to supply chain risk management. We collected articles published from 2000 to 2007, focusing on risk management issues pertinent to manufacturing and supply chain management. There are two reasons for not including papers published prior to 2000. First, although traditionally risk and uncertainty have always been an important issue related to supply chain management literature, the term “supply chain risk” is relatively new to the literature. Our search in two major literature databases (Science Direct and Emerald Online) using a keyword “supply chain risk” revealed no result for papers published prior

2000. Second, the issue of supply chain risk management has gained much attention after a series of events having major impacts on supply chain, including fire in one of the Ericsson's supplier in New Mexico in 2000 that led Ericsson to a loss of about 400 million Euros, insolvency of one of Land Rover's supplier in 2001 causing this company to lay off 14000 workers, and certainly the tragic terrorists attack on the World Trade Center on September 11, 2001 causing major supply chain problems to the world (Norrman and Jansson, 2004; Paulsson, 2004; Tang, 2006b).

The literature search was done through various electronic databases, including Science Direct, Emerald Fulltext, EBSCO, ABI/INFORM Global Pro-quest, and Inderscience. The keyword used for the search was "supply chain risk". This search revealed nine articles in Science direct (abstract, title, and keywords), 30 articles in Emerald, 5 articles in EBSCO (abstract, title, and keywords), 10 articles in Inderscience, and 154 in ABI/inform Global Pro-quest academic database (full text documents and scholarly journals, including peer-reviewed) in August 2007. A total of 208 articles were found. After looking at the types of articles, we discarded those not belong to refereed journal articles such as prefaces, editorial notes, book review, and interview. Finally, we ended up with 82 relevant articles to be reviewed in this article.

Classifications

A total of 82 articles (from 39 journals in 5 journal databases) have been reviewed. Thirty eight percent of the SCRM articles have been published in the following four journals.

- International Journal of Physical Distribution & Logistics Management
- International Journal of Production Economics
- European Journal of Operations Research
- Production and Operations Management

It is interesting to note here that the SCRM articles are published in so many different journals, indicating the multi-disciplinary nature of the problem. In table 1, the distribution of articles published in various years and the publishing journals are shown. The International Journal of Physical Distribution & Logistics Management has much more articles on SCRM than other journals as it published two special issues (volume 34 (5) and volume 34 (9), both in 2004), covering this issue. Other well known journals, such as the Journal of Operations Management, have also called papers for a special issue on SCRM, suggesting that the distribution of SCRM papers among relevant journals would be more even in the future. As depicted in figure 1, the number of articles is generally increasing during the period of 2000 – 2006 and there is a big jump from 2004, indicating that the research on SCRM attracts attentions of many researchers.

ANALYSIS OF RESULTS

Methodologies

Different methodologies used by various researchers are divided into five categories, according to Malhorta and Grover (1998) which include conceptual, descriptive, empirical, exploratory cross-sectional and exploratory longitudinal. The distribution of supply chain risk management papers according to the various methodologies is shown in Figure 2. As it is shown, almost half of the papers applied the descriptive approach in their methodology. In the second place is the empirical research, and is by far lower than the two are conceptual and exploratory researches. The descriptive and empirical researches together account for 80% of the methodologies used.

The conceptual is meant to represent a research methodology that describes basic/fundamental concepts on supply chain risk management. In this classification, most papers propose a conceptual

Table 1. Distribution of articles by years and journals

Journal	**2000**	**‘01**	**‘02**	**’03**	**’04**	**‘05**	**’06**	**‘07**	**Total**
Automatica							1		**1**
Business Process Management Journal							1		**1**
California Management Review		1							**1**
Chemical Engineering Science						1			**1**
Computers in Industry							1		**1**
European Journal of Industrial Engineering								1	**1**
European Journal of Operational Research						1		3	**4**
Industrial Management & Data Systems							1		**1**
International Journal of Electronic Customer Relationship Management								1	**1**
International Journal of Integrated Supply Management						1			**1**
International Journal of Logistics Economics and Globalization								2	**2**
International Journal of Logistics Management					1	1	1		**3**
International Journal of Logistics systems and Management							1		**1**
International Journal of Logistics: Research and Applications				1			1		**2**
International Journal of Management and Enterprise Development								1	**1**
International Journal of Manufacturing Technology and Management								1	**1**
International Journal of Operations & Production Management							1	1	**2**
International Journal of Physical Distribution & Logistics Management			1	1	11	2	1		**16**
International Journal of Production Economics			1		2		4		**7**
International Journal of Production Research						2			**2**
International Journal of Retail & Distribution Management						1			**1**
International Journal of Risk Assessment and Management								**2**	**2**
Journal of Enterprise Information Management							1		**1**
Journal of Manufacturing Technology Management							1		**1**
Journal of Operations Management							1		**1**
Journal of Purchasing & Supply Management				1		1	1		**3**
Journal of Supply Chain Management				1		1			**2**
Management Decision	1								**1**
Manufacturing & Service Operations Management					1				**1**
McKinsey Quarterly								1	**1**
MIT Sloan Management Review					1	1			**2**
Production and Operations Management						4			**4**
Risk Management					1		1		**2**
Strategic finance							1		**1**
Supply Chain Management	1				1				**2**
Supply Chain Management Review						1			**1**
Supply Chain Management: An International Journal					2		1		**3**
The International Journal of Management Science					1				**1**
Transportation Research Part E: Logistics & Transportation Review						1		1	**2**
Total	**2**	**1**	**2**	**4**	**21**	**18**	**20**	**14**	**82**

Figure 1. Number of articles of supply chain risk management in 2000-2007 periods

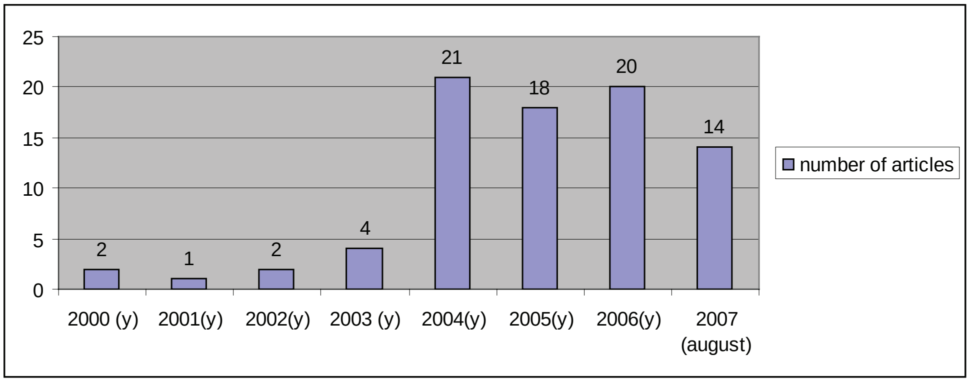
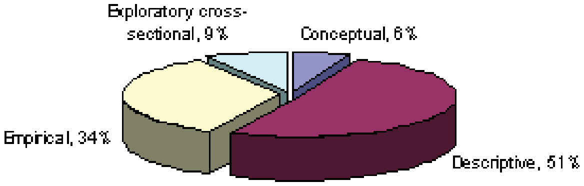


Figure 2. Research methodology used in SCRM articles



methodology for managing supply chain risks. For example, Cucchiella and Gastaldi (2006) developed a framework for the management of uncertainty in the supply chain in order to minimize firm risks. The authors employed a risk option approach to increase firm's flexibility as a means for dealing with uncertainty within a supply chain. Some papers in this category also clarify some matters related to supply chain and supply chain risk management, including their definition. Peck (2006) examined the term supply chain, supply chain management, and then the fusion of supply chain management with risk. The author then argued that the supply chain risk should not be addressed solely within a functional SCM perspective, but required cross-functional concerns.

Descriptive is a methodology that descript, formulates, and develops model in supply chain risk management. For example, there are models that have been developed as a supply chain management framework that include identification, analysis, and prioritizing mitigation actions. Some popular tools such as failure mode and effect analysis (FMEA) and analytical hierarchy process (AHP) have been used for this purpose. Wu et al.(2006) and Gaudenzi and Borghesi (2006) for example applied the AHP model, Sinha et al. (2004) applied the FMEA approach, and Cucciella and Gastaldi (2007) applied the real option model. Some authors also developed mathematical models to analyse risk behaviour in supply networks (for example Nagurney and Matspura, 2005; Nagurney et al, 2005).

Empirical is a methodology in which the data for study is taken from existing database, case study, literature review, and taxonomy or typology approaches. Some of the studies in this category are in the form of a survey study involving practitioners as respondents. Zsidisin and Ellram (2003) did a survey involving respondents of purchasing professional associated with the Institute for Supply Management ^{TM} (ISM). The authors investigated the concept of agency theory within the context of supply risk management.

Juttner et al. (2003) conducted a field research involving interviewees from manufacturing companies, retail sectors, and logistics service providers. The researchers first interviewed the companies' representatives separately for each company and then they were invited for a focus groups discussion. The study seek to identify future research agenda and then to clarify the concept as well as to propose a working definition for supply chain risk management.

Exploratory cross-sectional is a methodology where the information is collected at one point in time. Peck (2005) proposed a framework, based on the results of the exploratory study, for analyzing the scope and dynamics of supply chain risks. The framework is consisted of four levels of supply chain elements, i.e., value stream / product / processes, asset and infrastructure dependencies, organizations and inter-organizational networks, and then the environment. The author argues that a robust or resilient supply chain can not be done by merely good design and management of supply chain processes, but should also taking into account the system more widely to include the other three levels.

Exploratory longitudinal is a survey methodology where the data collection is done at two or more points over time in the same organizations. We found no paper applying this methodology. The fact that the supply chain risk management has just received much attention quite recently could be an explanation for why this methodology has not been applied in this field.

Industry Sectors

SCRM articles appear to be spread over many industrial sectors. Most of the applications have been in the electronics and aerospace sectors. It is understandable that the supply chain risk management has been mostly applied to the electronic sector. As suggested by Sodhi (2005), the electronic industry is prone to risk due to short product life cycle and high demand uncertainty. Ericsson supply chain risk management model (Norrman and Jansson, 2004) which was developed after a fire at its sub-supplier is one of the mostly discussed cases in the supply chain risk literature. The aerospace on the other hand is exposed to risk due to its complexity. The product complexity as well as the supply chain structure complexity brings much risks and uncertainty to the aerospace sector. Sinha et al. (2004) developed a framework for mitigating supply chain risks in an aerospace industry. The authors suggest that such risks as lack of common terminology among supply chain players, conflict in OEM requirements, and lack of raw materials are examples of risks that could happen in this sector. To a lesser extent, supply chain risk management have also addressed the automotive, telecommunication, semiconductors, machinery and machine tools, metal industry, and other sectors. Table 2 presents the classification of the papers according to the industry sectors where they are applied. Based on scale of the companies, the SCRM are mostly biased toward large rather than small and medium enterprises.

Unit of Analysis

We also categorized the papers from the perspective of the unit of analysis following Norrman and Lindroth (2004). The unit of analysis describes the complexity of the entities from which the supply chain risks are viewed. This article uses the level of complexity from a single logistic activity to a supply network. Logistics is that part of SCM process that plans and control between the points of internal company such as: traffic and transportation, warehousing and storage, industrial packaging, etc (Coyle et al, 1992). Thus, risks can be evaluated from a single supply chain function such as procurement, planning, transport, warehouse, etc. Dyadic relations represent a relationship between two organizations within a supply chain. For example, the relationship between a manufacturing company and one of its suppliers can be considered as a dyadic relation. The supply

Table 2. Classification of industry sectors

Industry sectors	Articles (see references)	Count
Electronics (Cellular phone, computer, etc)	Zsidisin et al (2000), Hallikas et al (2002), Papadakis (2003), Zsidisin (2003a) (2), Zsidisin (2003a), Zsidisin et al (2004) (2), Appelqvist and Gubi (2005), Sodhi (2005), Zsidisin et al (2005a), Choi and Krause (2006), Ojala and Hallikas (2006), Papadakis (2006)	14
Aerospace	Zsidisin et al (2000), Zsidisin (2003a), Zsidisin (2003b), Sinha et al (2004), Zsidisin et al (2004), Blackhurst et al (2005), Juttner (2005), Peck (2005), Zsidisin et al (2005a), Zsidisin and Smith (2005)	10
Automotive industry	Zsidisin (2003b), Svensson (2004a), Svensson (2004b), Blackhurst et al (2005), Hallikas et al (2005), Juttner (2005), Berry and Collier (2007),	7
Telecommunications	Zsidisin et al (2000) (2), Agrell et al (2004), Norrman and Jansson (2004), Zsidisin et al (2005a)	5
Semiconductor	Zsidisin et al (2000) (2), Zsidisin (2003a), Zsidisin et al (2004)	4
Machinery and machine tools	Atkinson (2004), Mills and Camek (2004), Faisal et al.(2006b)	3
Metal industry	Hallikas et al. (2002), Hallikas et al.(2004), Ojala and Hallikas (2006)	3
Textile and garment industry	Brun et al.(2006), Faisal et al.(2006b)	2
Chemicals and pharmaceutical industry	Blackhurst et al.(2005), Juttner (2005), Kleindorfer and Saad (2005)	3
Film industry	Watson (2004)	1
Medical and dental devices	Gaudenzi and Borghesi (2006)	1
Packaging industry	Atkinson (2004)	1
Toys industry	Faisal et al.(2006a)	1
Other industry (leather, office equipments, tobacco, agricultural, construction, marine transport, and commerce/trading, third party logistics (3PL) providers, cosmetics	Allen and Schuster (2004), Mills and Camek (2004), Blackhurst et al.(2005) (2), Hendricks and Singhal (2005), Nagurney et al.(2005), Sheffi and Rice (2005) (2), Faisal et al.(2006b), Choy et al.(2007), Cucciella and Gastaldi (2007),	11
Total		66*

*Note: * While 82 articles were reviewed, there are papers without application to any sector*

chain, on the other hand, is considered here as a set of three or more entities which work together to produce and deliver products from sources to customers (Mentzer et al, 2001). The most complex unit of analysis is the supply network. Choi and Krause (2006) define supply networks is “all inter-connected companies that exist upstream to any one company in the value system”.

Our categorization shows that most SCRM literature addresses a supply chain as a unit of analysis followed by a dyadic relationship in the second place. We found only one article which exclusively looking at risk from solely a single logistic activity, i.e., Wilson (2007). The author investigates the effect of transportation disruptions on supply chain performance using system dynamics simulation. Although there are many articles, which looked at only one side of the supply chain (e.g., supply risk or inbound risks), we consider them to fall within a dyadic relationship as some risk sources are from other organizations (e.g. from supplier). On the other extreme, we also found only limited articles looking at risks within a supply network. The complexity of the structure and relationships obviously prevents ones to be able to capture a network when addressing supply chain risks. Table 3 shows the categorization of papers according to the unit of analysis, excluding those papers which do not use any unit of analysis in their study.

Types of Risks

There are various types of supply chain risks. Chopra and Sodhi (2004) categorized supply chain risks into disruptions, delays, systems, forecast, intellectual property, procurement, receivables, inventory, and capacity. In the aerospace industry, Sinha et al. (2004) classified four areas of risks which include standards, supplier, technology, and practices. In each of these four areas, there is a number of supply chain risks that could happed. Finch (2004) classified risks into three broad categories which include the three levels of coverage: application level, organizational level, and inter-organizational level. At the application level, the risks include natural disasters, accidents, deliberate acts, data/information security risks, and management issues. At the organizational level, such risks as legal and strategic changes in decisions could happen, while at the inter-organizational level, there are possible uncertainty from the outside of the organization which could pose risks. Other classification of risks can be found in other articles, including for example Mason-Jones and Towill (1998), Juttner et al.(2003), Peck (2005).

Following the classification in Norrman and Lindroth (2004), we categorize the type of risks addressed in the SCRM papers into operational accidents, operational catastrophes, and strategic uncertainty. The operational accidents are those

Table 3. Unit of analysis

Unit of Analysis	Articles (see references)	Count
Single Logistics Activities	Wilson (2007)	1
Company Logistics	Giaglis et al.(2004), Kleindorfer and Saad (2005)	2
Dyadic Relations	Zsidisin et al.(2000), Johnson (2001), Hallikas et al.(2002), Svensson (2002), Zsidisin (2003a), Giunipero and Eltantawy (2004), Sinha et al.(2004), Svensson (2004a), Watson (2004), Zsidisin et al.(2004), Rao et al.(2005), Towill (2005), Zsidisin and Smith (2005), Giunipero, et al.(2006), Wu et al.(2006)	15
Supply chain	Ritchie and Brindley (2000), Juttner et al.(2003), Papadakis (2003), Zsidisin (2003b), Agrell et al.(2004), Allen and Schuster (2004), Atkinson (2004), Barry (2004), Cavinato (2004), Chopra and Sodhi (2004), Christopher and Lee (2004), Christopher and Peck (2004), Finch (2004), Mills and Camek (2004), Norrman and Jansson (2004), Qi et al.(2004), Spekman and Davis (2004), Svensson (2004b), Appelqvist and Gubi (2005), Blackhurst et al.(2005), Guillen et al.(2005), Hendricks and Singhal (2005), Juttner (2005), Peck (2005), Sheffi and Rice (2005), Sodhi (2005), Zsidisin et al.(2005b), Atkinson (2006), Beasley (2006), Brun et al.(2006), Chen, et al.(2006), Chen and Seshadri (2006), Cucchiella and Gastaldi (2006), Faisal et al.(2006a), Faisal et al.(2006b), Gaudenzi and Borghesi (2006), Papadakis (2006), Peck (2006), Sutton (2006), Tang (2006a), Wagner and Bode (2006), Wilding and Humphries (2006), Choy et al.(2007), Faisal et al.(2007b), Krishnan and Shulman (2007), Ritchie and Brindley (2007)	46
Supply network	Hallikas et al.(2004), Hallikas et al.(2005), Nagurney et al.(2005), Nagurney and Matsypura (2005), Choi and Krause (2006), Glickman and White (2006), Ojala and Hallikas (2006), Cucciella and Gastaldi (2007), Goh et al.(2007), Li and Chandra (2007)	10
Total		74

affecting the operational process or resources related to logistics / supply chain, such as fires, truck accidents, machine failures, labor strikes, etc (Norrman and Lindroth 2004). Most companies are facing day-to-day operational accidents, but the frequency of those risks happening depends on how good they manage supply chain risks. Operational catastrophes are risks associated with rare and difficult to predict events, but once occurred; they have severe impacts on the company. Such risks as natural disaster, socio-political instability, economic disruptions, and terrorist attacks are examples of operational catastrophes. Finally, the strategic uncertainties are the type risks that are generally difficult to address and affect the company not at the operational level, but strategically. The strategic uncertainty could be in the form volatile demand, supplier default/bankruptcy, increasing competition, market constraint, and technology change.

Certainly, each company would have a different set of typical risks. In aggregate terms, there is a common pattern in the types of risks the companies/supply chains are facing. For example, the operational catastrophes are less likely to happen compared to the other two types. However, recently the operational catastrophes are happening with an increasing rate, making it a necessity for companies to have well prepared mitigation strategies for this type of risks. We witness increasingly more frequent natural disasters, which cause operational catastrophes in recent years, including for example the earthquake, tsunami, floods, etc. Table 4 shows the types of risks addressed in the SCRM literatures.

As table 4 shows, operational accidents and strategic uncertainty are discussed in about the same number of papers, while the operational catastrophe has received relatively less attention. Interestingly, only 7 papers addressed all three types of risks (Juttner et al. (2003), Zsidisin

Table 4. Type of risks

Type of risks	Articles (see references)	Count
Operational accidents	Zsidisin et al.(2000), Svensson (2002), Juttner et al.(2003), Zsidisin (2003a), Zsidisin (2003b), Allen and Schuster (2004), Atkinson (2004), Chopra and Sodhi (2004), Christopher and Peck (2004), Finch (2004), Mills and Camek (2004), Norrman and Jansson (2004), Sinha et al.(2004), Spekman and Davis (2004), Zsidisin et al.(2004), Appelqvist and Gubi (2005), Hallikas et al.(2005), Hendricks and Singhal (2005), Nagurney et al.(2005), Nagurney and Matsypura (2005), Peck (2005), Rao et al.(2005), Sodhi (2005), Zsidisin et al.(2005a), Zsidisin and Smith (2005), Choi and Krause (2006), Cucchiella and Gastaldi (2006), Gaudenzi and Borghesi (2006), Papadakis (2006), Wagner and Bode (2006), Wu et al.(2006), Berry and Collier (2007), Wilson (2007)	17
Operational catastrophes	Juttner et al.(2003), Papadakis (2003), Zsidisin (2003a), Barry (2004), Chopra and Sodhi (2004), Christopher and Peck (2004), Norrman and Jansson (2004), Spekman and Davis (2004), Hendricks and Singhal (2005), Juttner (2005), Kleindorfer and Saad (2005), Peck (2005), Sheffi and Rice (2005), Zsidisin et al.(2005a), Papadakis (2006), Tang (2006a),Wagner and Bode (2006), Wu et al.(2006),	10
Strategic uncertainty	Johnson (2001), Hallikas et al.(2002), Juttner et al.(2003), Zsidisin (2003a), Zsidisin (2003b), Agrell et al.(2004), Christopher and Lee (2004), Christopher and Peck (2004), Giaglis et al.(2004), Giunipero and Eltantawy (2004), Norrman and Jansson (2004), Qi et al.(2004), Watson (2004), Zsidisin et al.(2004), Blackhurst et al.(2005), Guillen et al.(2005), Hallikas et al.(2005), Peck (2005), Rao et al.(2005), Sheffi and Rice (2005), Sodhi (2005), Towill (2005), Chen et al.(2006), Chen and Seshadri (2006), Choi and Krause (2006), Cucchiella and Gastaldi (2006), Faisal et al.(2006b), Gaudenzi and Borghesi (2006), Ojala and Hallikas (2006), Tang (2006a), Wagner and Bode (2006), Wu et al.(2006), Choy et al.(2007), Tapiero (2007)	24
Total		51

(2003a), Christopher and Peck (2004), Norrman and Jansson (2004), Peck (2005), Wagner and Bode (2006), Wu et al.(2006)). Certainly, it would be interesting to develop more analysis to see if different types of risks are associated with different industry sectors. For example, one would think that the strategic uncertainty could be very much a concern of innovative industries as product life cycles are becoming shorter and shorter with rapid technology development. On the other hand, operational accidents could be associated with low awareness of internal risks which is often attributable to weak management systems. The future studies should attempt to look at a more detailed level the typical risks each industry sector is facing.

Risk Management Process or Strategies

Risk management processes refer to the stages a supply chain or a company could follow to reduce the supply chain risks. It normally involves such activities as identifying supply chain risk events, assessing the probabilities and the severity of impacts, prioritizing the risk event to be dealt with and developing actions for mitigating risks or planning for backup actions. In the identification stage, one may use various techniques or tools to list various risk events that possibly occur in the supply chain. Most of the techniques at this stage are qualitative in nature. Brainstorming within the research team or which include experts from industry are common practices that have been used at the identification stage (see Hallikas et al., 2002; Zsidisin, 2003b; Norrman and Jansson, 2004; Sinha et al. 2004; Wu et al, 2006 for examples of articles using brainstorming). Some models have also been used to assist in identifying supply chain risks at this stage, such as IDEF0 (Sinha et al, 2004) and AHP (Wu et al, 2006). Some other tools such as Fault Tree Analysis (FTA) and Event Tree Analysis (ETA), which have been used in technical areas such as maintenance, have not been popularly used in the supply chain risk management.

In the assessment stage, a number of approaches are possible including brainstorming, process mapping, risk impact analysis, and scenario planning. A popular model used in the assessment stage is the failure mode and effect analysis (FMEA) where we can assign a priority list to each risk based on the multiplication of the probability of occurrence and the severity of the impact caused. Some authors have developed an innovative model for supply chain risk management where assessment is a critical stage within it. For example, Norrman and Jansson (2004) described a model called ERMET (Ericsson Risk Management Evaluation Tools). Brun et al.(2006) described another model called SNOpAck (Supply Network Opportunity Assessment Package).

In assessing supply chain risks, authors use different scales. Some authors (Hallikas et al, 2002; Norrman and Jansson, 2004) use a 1 – 4 scale while Hallikas et al.(2004) use a 1 – 5 scale. Each number corresponds to a verbal definition. For example, in defining the magnitude of impacts (severity), the values of 1, 2, 3, 4, and 5 represent low, medium, high, very high, catastrophic impacts respectively. Zsidisin (2003b) and Sheffi and Rice (2005) only use two levels, i.e., high and low, to assess the magnitude of risks.

Mapping the risks into a graph or a matrix could be useful in the analysis stage. Such visualization is particularly desirable to assist management in a company communicating risks internally as well as to other parties within the supply chain. The traffic light analysis such as the one presented by Norrman and Jansson (2004) is a good visualization of risks. They use colors to highlight the different magnitude of risks and hence, prioritization can be easily judged from the colors.

The risk management involves the course of actions to consider in order to reduce the risks. This can be done by reducing the probability of occurrence, the severity of impacts, or both. Generally, risk management involves such options as transferring it to or sharing it with other parties, accepting it as it is, or avoiding the risks. Transferring risk to other parties is a common supply chain management practices nowadays. An example would be the outsourcing / subcontracting practices where some types of supply chain risks are transferred to the parties providing the products or services. Some global players outsource the whole production processes to outside parties which automatically means that such a company does not need to deal with labor and production facility problems. Risk sharing maybe developed in terms of a joint collaboration for risks involving two or more parties in a supply chain. Juttner et al.(2003) suggested that cooperation with supply chain partners is one of the mitigation strategies for supply chain risks. The cooperation can be in terms of joint efforts to improve supply chain visibility and understanding, joint efforts to share risk related information, and joint efforts to prepare supply chain continuity plans. Dropping specific products, geographical markets, suppliers, or customers can be considered as a way to avoid risks.

One major action that each company should do is to develop an alternative plan or contingency plan to mitigate the supply chain risks. Such an alternative, which is also called as business continuity management (Juttner et al, 2003), is developing well in the area of supply chain risk management recently. According to Norrman dan Lindroth (2004), business continuity planning / business continuity management (BCP/BCM) cover wider scopes than the supply chain risk management. BCP/BCM includes crisis management, disaster recovery, business recovery, and contingency planning which are often not considered to be the main focuses of supply chain risk management.

As presented by table 5, the SCRM articles address the four general risk management processes well.

CONCLUDING REMARKS AND OUTLINES OF FUTURE STUDIES

We have presented a classification of articles on supply chain risk management (SCRM) published in recent journal papers based on the classification methodology of Malhorta and Grover (1998). The review shows that SCRM is a rapidly grow-

Table 5. Stages of risk management process

Stages of risk management process	Articles (see references)	Count
Risk identification/ analysis	Hallikas et al.(2002), Zsidisin (2003b), Cavinato (2004), Finch (2004), Hallikas et al.(2004), Norrman and Jansson (2004), Sinha et al.(2004), Juttner (2005), Wu et al.(2006)	9
Risk assessment	Zsidisin et al.(2000), Hallikas et al.(2002), Zsidisin (2003b), Finch (2004), Hallikas et al.(2004), Norrman and Jansson (2004), Sinha et al.(2004), Zsidisin et al.(2004), Juttner (2005), Kleindorfer and Saad (2005), Sheffi and Rice (2005), Gaudenzi and Borghesi (2006), Sutton (2006), Wu et al.(2006), Berry and Collier (2007), Li and Chandra (2007), Li and Hong (2007), Burn et al.(2006)	18
Risk management	Ritchie and Brindley (2000), Zsidisin et al.(2000), Johnson (2001), Chopra and Sodhi (2004), Christopher and Peck (2004), Finch (2004), Giunipero and Eltantawy (2004), Hallikas et al.(2004), Norrman and Jansson (2004), Sinha et al.(2004), Hallikas et al.(2005), Juttner (2005), Kleindorfer and Saad (2005), Sheffi and Rice (2005), Sodhi (2005), Atkinson (2006), Cucchiella and Gastaldi (2006), Gaudenzi and Borghesi (2006), Ojala and Hallikas (2006), Peck (2006), Berry and Collier (2007), Faisal et al.(2007a), Faisal et al.(2007b), Iakovou et al.(2007),	24
Business continuity management	Juttner et al.(2003), Norrman and Jansson (2004), Juttner (2005), Sheffi and Rice (2005), Zsidisin et al.(2005a), Zsidisin, et al.(2005b), Peck (2006)	7

ing area since a few yeas ago. Papers on supply chain risk management address various types of supply chain risks and authors developed various risk classifications. In this article we follow the classification of Norrman and Lindroth (2004) where the supply chain risks are categorized into operational accidents, operational catastrophes, and strategic uncertainty. Understanding the types of risks and their probability of occurrence as well as the associated impacts is a starting point for companies to develop effective risk management strategies. From methodological point of view, most published papers were based on empirical and descriptive, while very few based on exploratory research.

Since supply chain risk management is still in the infancy stage and the need for better supply chain risk management is high, this field will continue to be placed on top list of future research agenda. We discuss here a number of possible research opportunities in this area.

The first agenda is related to the use of technology in relation to supply chain risk management. As suggested by several authors (Atkinson, 2004; Giunipero and Eltantawy, 2004; Tang, 2006a; Wilson, 2007), the use of technology such as RFID and ERP will become an important facet of supply chain risk management. More research should be conducted to learn how technologies could be used to mitigate risks in a supply chain. In general, the use of information technology could improve information visibility across the supply chain. Certainly, with better ability to see what is happening in the upstream and downstream stages of the supply chain, each player would be able to anticipate for delay in delivery of materials, swings in demand, act of competitors, and even for some disruption risks. How technology could contribute to the management of supply chain risks, would technology also pose other supply chain risks, how technology can be used to monitor supply chain risks are among interesting questions to answer in future studies.

Zsidisin (2003b) suggests that managerial perception of risk from different perspectives is an area for future research. It is indeed important to understand what different people in an organization or across different organizations within a supply chain perceive about supply chain risks. Different perception about supply chain risks from marketing and from operations could pose a conflict in deciding what mitigation actions to choose in an organization. Likewise, as suggested by Zsidisin (2003b), if sales representatives perceive risks in a similar manner than the purchasing professionals in a supply chain relationship, then strategies to manage the risk in that link could be created within the dyadic relationship and may be easier to implement due to the similar perception from both sides. Certainly, it would be interesting to explore differences and similarities in perceptions toward supply chain risks inside an organization and across organizations in a supply chain.

Another fertile area of research is decision making process related to supply chain risk management. Risk management process is a complex issue that could involve risky decision making processes. Some papers suggest that risk management may involve such decision as risk transfer (for example using outsourcing), risk sharing (through joint collaboration for risks), and risk avoidance (through, for example hedging currency). From our observation, there is no paper that has a focus on decision making process for selecting the best course of action in dealing with supply chain risk management. Deciding which options to choose among various possible alternatives such as risk transfer, risk sharing, or any types of risk mitigation strategies could be a difficult decision making problem within a supply chain. Cucchiella and Gastaldi (2006) present a real option model for risk management. Application of other decision making models for making risk management decision is an interesting research topic for the future. As Juttner et al.(2003) suggest, guiding supply chain trade-off decision making is an important agenda for future research in supply chain risk management. Standard decision making models such as the AHP or ANP could be further explored for decision making application in supply chain risk management.

To the best of our knowledge, there is no paper that specifically addresses collaborative risk management in the supply chain. In contrast, the discussions on collaborative planning and forecasting (for example through CPFR initiatives) or other collaborative schemes (such as in the context of quality control as presented in Tapiero 2007) are gaining more attention in the literature. Future research should then be expanded to explore how collaborative risk management between companies in a supply chain could work. The possible research could be the design of a framework for collaborative risk management and various possible schemes for collaborative risk management between organizations in a supply chain.

Research on supply chain risk management that attempts to compare strategies to manage risk or to create a robust supply chain across different sectors is still limited. Juttner et al.(2003) also suggest that it is important to develop risk management approaches for specific supply chains / industries. To enable this, it is necessary to first understand different types of risks that are dominant in different supply chains / industry sectors. Generally, it is conceivable that the types of risks, and then the appropriate mitigation actions, vary with supply chains / industry sectors. For example, in the electronic sectors, the competitions due to many players and the rapid development of technology force products to have shorter life cycle. These pose various supply chain risks such as forced markdown prices and inventory obsolescence. In the pharmaceutical industry, on the other hand, long product development time (time to market) could be a major issue related to supply chain risk management. Thus, it would be important to expand supply chain risk management research into these issues.

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Chapter 1.22

Implementing Supply Chain Management in the New Era:

A Replenishment Framework for the Supply Chain Operation Reference Model

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ABSTRACT

Combining with the collaborations between business customers and suppliers, traditional purchasing and logistics functions have evolved into a broader concept of materials and distribution management, namely, supply chain management (SCM) (Tan, 2001). This chapter reviews the literature of SCM from several paths that can be the basis of a proposed framework for SCM within academic and managerial contexts. In addition, it includes the approaches of supply chain operations reference (SCOR) model, which was developed by the Supply Chain Council and is recognised as a diagnostic tool for SCM worldwide. This chapter also summarises the literature of performance control and risk issues in SCM and the SCOR Model and discusses a proposed framework for the future research.

INTRODUCTION

A supply chain is established when there is an integration of operations across its constituent entities, namely, the suppliers, partners, and business customers (Narasimhan & Mahapatra, 2004). It is an observation that individual firms compete as integral parts of supply chains in the global markets. Moreover, the evolution of information technology (IT) has particularly generated growing attention on searching for ways to improve product quality, customer services, and operation efficiency and remaining competitive by supply chain collaboration. As noted by Strader, Lin, and Shaw (1999), ". . .there has been a general movement towards organizing as partnerships between more specialised firms or business units as IT enables the costs of coordination decrease" (p. 361), implying the impact of IT and potential advances of supply chain management (SCM). A number of researchers and practitioners have, therefore, devoted their efforts to various approaches to manage the constituents and activities of a supply chain since the early 1980s. Yet conceptually, the management of supply chains has not been well organised or understood. Academia has continuously highlighted the necessity for clear definitional constructs and frameworks on SCM (Croom, Romano, & Giannakis, 2000; New & Mitropoulos, 1995; Saunders, 1997).

However, SCM research, which draws on industrial economics, information systems, marketing, financing, logistics and interorganisational behaviour, has a fragmented nature and lacks a universal model. Hence, what we set out to construct in this chapter are the general theoretical and managerial domains of SCM, thereby, attempting to contribute to the development of such discipline. The literature is surveyed to identify the cognitive components of the current subject, as it is a key question for any applied social research that concerns the strategic approach taken to its mapping (Tranfield & Starkey, 1998).

Theoretical models are needed in order to inform the understanding of the supply chain phenomena. An illustration of industrial dynamics in Forrester's (1958) model in fact instantiates the possibility of such applications that aid the comprehension of material flows along the supply chain. Further, it has remarkably laid the foundation for subsequent advancement of supply chain analyses and understandings (e.g., Min & Zhou, 2002; New & Payne, 1995; Sterman, 1989; Towill, Naim, & Wilker, 1992). SCM is not only concerned with the extraction of raw materials to their end of useful life, it also focuses on how firms utilise their suppliers' processes, technology, and capability to enhance sustainable competitive advantage (Farley, 1997). When all organisational entities along the supply chain act coherently, operation effectiveness is achieved throughout the systems of suppliers. Cooper, Ellram, Gardner, and Hawk (1997) advocate such a concept, and further indicate that much of SCM literature is predicated on the adoption and extension of extant theoretical concepts.

Our chapter is not so much a critical review of the literature as a taxonomy with which to map the subsequent research. In this context, it is our intention to try to provide a framework for conducting a project of supply chain management.

This chapter is organised into five sections corresponding to the initial idea of the book layout. In the first section, the supply chain operations reference (SCOR) model is introduced (SCC, 2001), underlying the common aspects and approaches, as it has gradually become a widely accepted standard of supply chain management in industry from its initial launch in 1996. One of the goals in this chapter is to identify the limitations of the SCOR Model and, therefore, to suggest a framework and supply chain implementation. Aligning with the SCOR model, we map the possible research areas by proposing a framework as a domain of research in supply chain design and for the managerial concerns in a project of supply chain management. The next section considers the bodies of literature associated with the stakeholder theory and network theory in organisational studies, which are applied to the interorganizational context (e.g., Premukumar, 2000; Rogers, 2004; Windsor, 1998). Then, we focus on the how to bridge the gaps towards the integration of the supply chain. We further explain the elements for facilitating transformation of the supply chain associated with business processes, organisation structure, and performance control in the following section. The chapter concludes with a summary with some conclusions that can be drawn from the content in terms of moving towards a coherent approach to supply chain management.

FINDING THE SUPPLY CHAIN CHALLENGES WITH THE SCOR MODEL

There is a profusion of literature related to the landscape of supply chain management. Various aspects can be found as the constituents of this subject, which leads to a confusion of meaning (New & Payne, 1995), thus causing difficulty in laying out the scope and content of supply chain design. The term *supply chain management* has not only been associated with logistics activities in the literature but also with the planning and control of materials and information flows of an enterprise, both internally and externally. Additionally, strategic issues, resources, interorganizational relationships, and even governmental intervention have been addressed in extant studies (e.g., Thorelli, 1986; Wang & Heng, 2004), and others discuss the effects of network externality (e.g., Gulati, 1999). These research domains are indeed relevant to the understanding of supply chain context; however, in this chapter, we consider the direct challenges that an enterprise may encounter in order to implement supply chain management. Therefore, the issues in the subsequent discussion follow the logical sequences of SCOR that have been widely adopted by industries such as AT&T, Boeing, and ACER for supply chain diagnosis and design.

The Supply Chain Operations Reference Model

Developed in 1996, SCOR is a standard model of supply chain processes and is used similarly to International Organization for Standardization (ISO) documents for intra-enterprise processes. The SCOR model also builds on the concepts of business process reengineering (BPR), performance measurement, and logistics management by integrating these techniques into a configurable, cross-functional framework. It is a model that links business processes, performance indicators (metrics), and suggested actions (best practice and the features). It was developed to be configurable and aggregates a series of hierarchical process components that can be used as a common language for enterprises to describe the supply chains and communicate with each other (Huang, Scheoran, & Keskar, 2005; SCC, 2001).

The SCOR model follows a set of "top-down" procedures, commencing from the corporate-level strategy that the procedures can help to identify thousands of business activities inside an organisation and spanning across the boundaries of the supply chain entities. The document of the SCOR model includes the following elements as a communicative platform among enterprise owners, project leaders, and corporate consultants of the supply chain planning activities:

- Standard descriptions of each business process along the supply chain that are categorised as "Plan," "Source," "Make," and "Delivery." There are also other two categories defining the product return as "Return"[1] and the supportive activities as "Enabler."
- Key performance indicators (KPI) are defined and classified by the attributes accompanying with each of the business processes; for example, "Total Source Cycle Time to Completion" is a KPI in the attribute of "Supply Chain Responsiveness" of Source activities.
- Best practices are brought up in the SCOR model as recommendations if the diagnosis of certain processes by KPI shows the necessity for improvement.

- Identification of the associative software functionalities that can enable the best practices for business processes reengineering.

This SCOR model consists of four levels as the analytical stages leading to the implementation of an effective SCM strategy. The five distinct business processes, Plan, Source, Make, Deliver, and Return, are within the Level 1 stage and should be further decomposed into processes categories pending on the activities involved. Hence, Level 2 defines the core process categories that can be found in an actual and idealised supply chain around an enterprise. For example, the "source" category includes "source stocked products," "source made-to-order (MTO) products," and "source engineered-to-order (ETO) products" (Table 1). These different types of channel activities derive from the three major customer demands. Making stocked products corresponds to the situation of unknown demand quantities and expects easily procurement of the raw materials, while making MTO and ETO products requires the accuracy of demand forecasting and transparent market estimation.

Because of the customer-oriented nature, the delivery processes actually affects the associated Make and Source activities, and hence the SCOR model spans at least the interactions of information and material flows from the understanding of aggregate demand to the fulfillment of each order. To portrait the business processes by recording down the Level 1 and Level 2 activities of current supply chain is also called "As-Is" stage, which requires the project team to canvas the business environment of an enterprise that should normally include two ties from the core firm (the centre of a supply chain, definition can be seen in Banerji & Sambharya, 1998, and Wang & Heng, 2002), that is, "the customer's customer" and the "supplier's supplier."

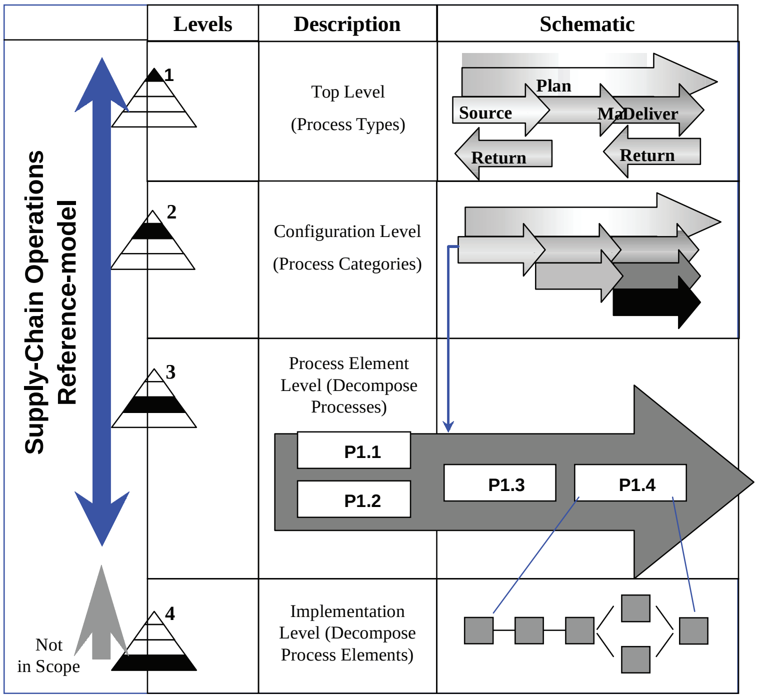
To begin with, it suggests an analysis to prepare the Level 1 document as to geographical context so as to reveal the transportation costs and trading relationships between the legal entities. Then, the diagram at Level 2 can be developed to describe the information flows of forecasts/orders and the material flow with the types of goods produced and delivered by connecting the business processes involved. Software has recently been developed to computerise the SCOR elements in enacting the interrelations of the processes, for example, ScorWizard, IBS Business Intelligence (BI), and i2 Enterprise Resource Planning (ERP) solutions. These are relatively helpful in simulating different scenarios based on the business strategies.

The SCOR model at Level 1 and Level 2 reveals the supply chain in a simplified way, thus enhancing its overall flexibility (Huang et al., 2005). Level 3 represents the decomposition of Level 2 processes in an interrelated way. For instance, there are four Level 3 components

Table 1. Supply chain activities based on SCOR level 1 & 2 (Adapted from SCC, 2001)

Plan		**Source**		**Make**		**Deliver**	
P1	Plan Supply Chain	S1	Source Stocked Product	M1	Make-to-Stock	D1	Deliver Stocked Product
P2	Plan Source	S2	Source MTO Product	M2	Make-to-Order	D2	Deliver MTO Product
P3	Plan Make						
P4	Plan Deliver	S3	Source ETO Product	M3	Engineering-to-Order	D3	Deliver ETO Product
Source Return				**Deliver Return**			
SR1	SR2	SR3		DR1	DR2	DR3	
R1: Return Defective Product			R2: Return MRO Product			R3: Return Excess Product	

Figure 1. The "top-down" approach in implementing the SCOR model (Adapted from SCC, 2001)



Notes: P1.1—Identify, prioritize, and aggregate supply-chain requirements; P1.2—Identify, assess, and aggregate supply-chain requirements; P1.3—Balance production resources with supply-chain requirements; P1.4—Establish and communicate supply-chain plans

decomposed from P1 (Plan Supply Chain), as shown in Figure 1:

- P1.1 – identify, prioritize, and aggregate production requirements
- P1.2 – identify, assess, and aggregate supply chain resources
- P1.3 – balance supply chain resources with supply chain requirements
- P1.4 – establish and communicate supply chain plans

To accomplish the Level 3 activities, the "To-Be" (future) processes model is developed to support strategic objectives that should work within the new supply chain configuration at Level 2. At this level, all SCOR processes are interconnectively designed and running as an operation cycle of planning, execution, and enabling by certain frequency. The supply chain components at Level 4 are acting as the work statement that is expected to be set up by the project team without standardised documents. Eventually, the completed four levels become the guidelines for implementing supply chain management.

The SCOR model has become a topical issue, attracting not only the interest of enterprises themselves, but of industrial associations and government. Contrary to the industrial emphasis, there is a scarcity of academic literature regarding the application, adoption, benefits, and limitations of SCOR model, except for very few reports such as Huang et al. (2005) and Wang, Ho, and Chau (2005). The aspects of the framework that are of interests for further study in the literature are discussed in the subsequent sections.

THE PARTICIPANTS' ROLE IN SUPPLY CHAIN MANAGEMENT

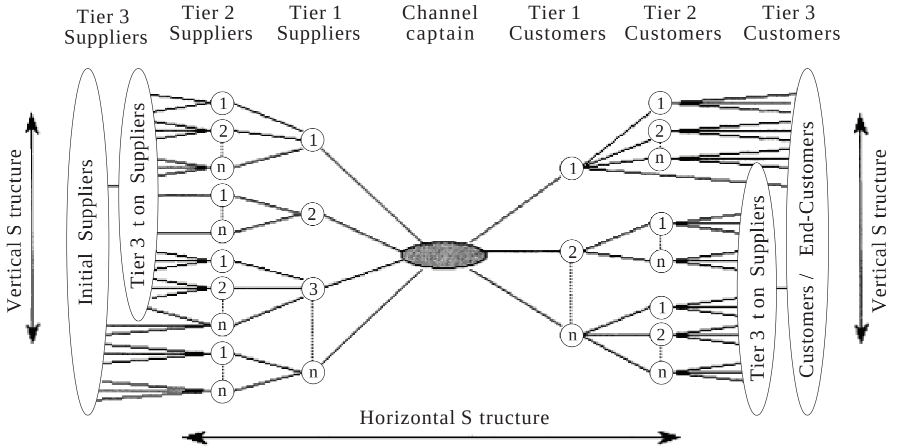
When configuring a supply chain, it is necessary to identify who the stakeholders within the channel context are. However, an inclusion of all potential partners might complicate the analysis of the complete supply chain, since it may explode the number of partners added from one tier to another (Cooper et al., 1997; Min & Zhou, 2002). The key is to target the supply chain entities that are critical to the value-added processes and are manageable by the core firm, that is, the centre of a supply chain targeted and is influential and powerful to its affiliate firms (Banerji & Sambharya, 1998; Wang & Heng, 2002).

As noted by Lambert, Cooper, and Pagh (1998), marketing research has contributed to identifying the members in a supply chain context, describing the needs for channel coordination, and drawing a marketing network. There are also studies with similar aspects from the area of strategic alliances and business network (e.g., Liu & Brookfield 2000) that are concerned about the germination of channel structure and participants. Lambert et al. (1998) further claim that the extant literature has not built on early contributions to put an emphasis on the complete supply chain from suppliers, manufacturers, distributors, and product brand owners. Indeed, one of the major weaknesses of SCM literature is the assumption that everyone knows the participants within the scope of SCM.

In a complete supply chain, there are primary stakeholders of SCM who actually perform operational and managerial activities in the channel processes and secondary stakeholders playing the roles of supporting entities such as the banks and freighters (Lambert et al., 1998). Although such classification may not be clear in all cases, it helps to identify the key customers who trigger the supply chain flows from demands and the major suppliers for value-added activities. From this starting point, the current SCOR model that only spans two tiers of the core firm becomes insufficient for analytical purpose, since the channel structure is quite often not a linear type and the supporting participants are not included in the analysing scope of the SCOR model.

Understanding the structural dimension of supply chains is a prerequisite for analysing and configuring the process links among channel members (Min & Zhou, 2002). The supply chain is derived from the interrelationships of its stakeholders that actually cause a multidimensional structure. Lambert et al.'s (1998) supply chain

Figure 2. Supply chain network structure



network indicates that there are two structural dimensions: horizontal and vertical, as shown in Figure 2. The horizontal structure represents the numbers of tiers along the analytical scope of a supply chain, and the vertical structure represents the number of partners within each tier.

Based on such aspect, a change of channel partners will alter the dimension of the supply chain. For example, the horizontal spectrum may become narrower when some entities merge with others. Outsourcing decisions may further change the scope and structure of supply network. In fact, some outsourcing firms can form various network formations other than the tier structure, such as rings, stars, or fans (Liu & Brookfield, 2000; Wang & Heng, 2002). The shifting of the supply chain scope (or, in some literature, the boundaries of the business network), which is normally caused by the strategic moves toward channel partners, eventually affects existing design and current managerial performance of SCM. A recent example is the case of the ACER Group which is associated with the shifting of channel structure that is reported by Wang and Ho (2005).

Despite a delicate design and implementation of global SCM and ERP systems, the ACER Group has suffered from a low retention rate of IT professionals of ERP systems and a lack of patterns for business processes reallocation in new manufacturing bases. These challenges are actually due to insufficient ante-consideration of potential business reallocation. When a sudden rundown occurred at several subordinates with reduced production volume in The Philippines and operation scale in Canada, it was somehow too late to adjust the plans of SCM. Therefore, it is necessary to identify the proper scope for a SCM project with the entities involved and then determine which aspects (e.g., geographical ranges and time period) of the supply chain network should be configured (Min & Zhou, 2002). Comparing the SCOR model, there are at least three limitations that can be found; they are:

- SCOR can only present business flow in between legal or geographical entities, not any matrix organisational structure or the concept of "virtual enterprise".
- SCOR is limited to the presentation of one single supply chain, while most enterprises may be associated with multiple channels of markets and products.
- The activities of collaborative design and customer relationships management are not defined in SCOR.

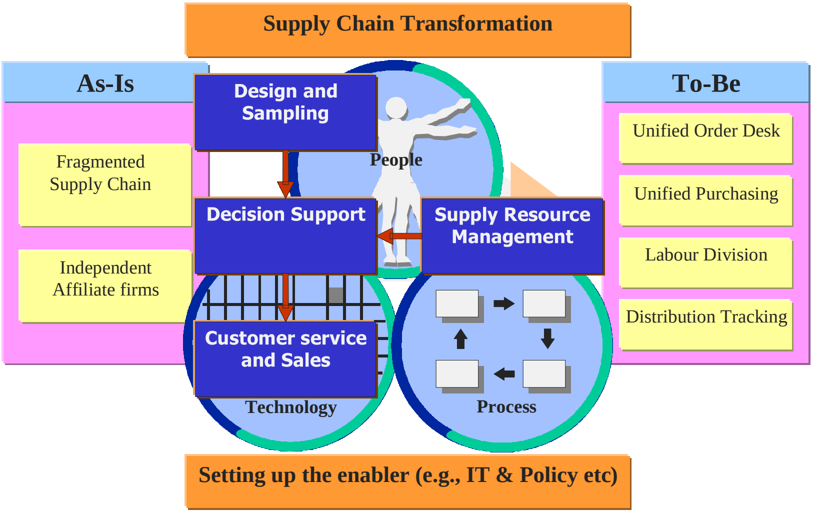
In brief, modeling a supply chain requires the analysis of relationships among channel participants and the structures formed. Thus, a clear picture for defining the scope of a SCM project can be presented. Moreover, these processes may connect multitiered supply chains as the core firm is actively involved in tier one and a number of other links beyond it. The direct involvement of a core firm may not only allocate physical resources but also interorganizational powers, technology, and knowhow to its trading partners. There is also indirect involvement from non-integral parts of the supply chain structure, but it can influence the operations of channel participants. Those different characteristics of trading relationships affect the firms' decisions regarding resource allocation that lead to the concerns in supply chain configuration.

IMPLEMENTATION OF CHANNEL INTEGRATION

The Transformation toward the "To-Be" Stage

Subsequent to the right analysis and design of supply chain management, this section discusses issues in the implementation of SCM. Using the terminology of the SCOR model, it is the "To-Be" stage. Figure 3 shows the most common goals and components of the transformation that

Figure 3. The components of implementing SCM projects from As-Is to To-Be



involves human factors, business processes, and the technology, so as to build up a unified order desk, purchasing channels, delivery tracking, and so on, for the support of supply chain decision. Although the SCOR model is a widely adopted industrial standard—and possibly the only one—it has not successfully addressed a transforming framework from the stages of "As-Is" to "To-Be" for SCM projects. In particular, it merely handles the components of business processes and technology without tackling any social factors or human issues.

The previous section has portrayed the "top-down" approaches by utilising SCOR model as a standard. That approach requires the team of a SCM project to lay out existing business processes and use the suggested SCOR metrics to diagnose current problems for the implementation of ideal SCM. At least the Level 1 and Level 2 business processes should be confirmed so that hundreds of metrics can be then applied to measure the current operation excellence along the specific supply chain, such as "day of inventory" (Level 2) in the category of cash-to-cash cycle time (Level 1) and "supplier on time and in full delivery" (Level 2) in the category of delivery performance (Level 1). The step of measuring KPI of the supply chain activities belongs to the second stage of SCOR, namely "gap analysis," which underpins the design of "To-Be" processes. In other words, the differences between current status and ideal performance are actually the opportunities for improvement based on the expectation of target firms and on the comparison with competitors.

Nevertheless, such a way of bridging the gap between "As-Is" and "To-Be" might not be applicable to many circumstances. There are at least two reasons, as discussed below. First, the KPI analysis, which depends on recording operation outcomes, is actually a measuring tool from a basis of productivity, efficiency, and profitability. There is a myth that the figures of operation excellence and actual responsibility can and should be combined in an ideal business situation. However, it is clear that they are at least partially contradictory.

First, on the one hand, the business units within a supply chain must try to achieve operation excellence for survival, and each of the enterprises has the pressure and duty to earn a higher return on its shareholders' equity than occurred before the SCM project. The KPI figures that are made create trust on the part of investors and are usually reflected in short-term operation efficiency, making it easier to project to an image of corporate success. These indicators are not only a sort of management result, but also a source of enterprise competitive health and wealth at a supply chain context.

On the other hand, supply chain participants are networks of parties that work together by trading relationships toward both a shared goal and individual interests without being merely economic machines. Although an SCM initiator (mostly the core firms) represents a major role of the value of channel participants, it does not necessarily have enough power to force its partners to follow the integration contents. Likewise, it is also important for trust to develop between the SCM initiator and its external partners and other interest groups. Such trust can only be built up from ensuring that the perceived value of all entities and stakeholders along the supply chain are taken into account. However, it may be difficult to have a unique standard of KPI measurement across the boundaries of enterprises.

Second, the KPI of SCOR is not always available in the SCM initiator, particular when it involves the sharing of interorganizational information. It may be caused by lack of information readiness in other trading partners (Iacovou, Benbasat, & Dexter, 1995; Lee, Clark, & Tam, 1999; Wang et al., 2005). For instance, the calculation for the indicator of "Complete Manufacture to Order Ready for Shipment Time" might need the information of several tiers of suppliers and collaborative manufacturers, since there are usually several working segments before the delivery of final products. As such, the SCM initiator must gather operation information from various suppliers in time for a precise estimation of this KPI. Unfortunately, in the brick-and-mortar world, it is not easy to ensure equal systems readiness between an SCM initiator and its trading partners, albeit even the headquarter may find it difficult to obtain confidential information from its subordinators because their interests are potentially contradictory.

Last but not the least, KPI analysis has a limitation in corresponding to the strategic choices. For example, a SCM initiator may consider "Perfect Order Fulfil Rate" to be the most important target in the very beginning, when the distributors have equal or much more power than it does. This occurs in the supply chain of the Taiwanese IT industry (e.g., Wistron, Accton, and Asus); many of them initiate their projects of global logistics management with the major players such as Dell and IBM. They have to give in to the benefits of reducing inventory level for channel competency. Only when they ensure the higher bargain power with their customers would they adjust the ratio of some KPI evaluations along the supply chain.

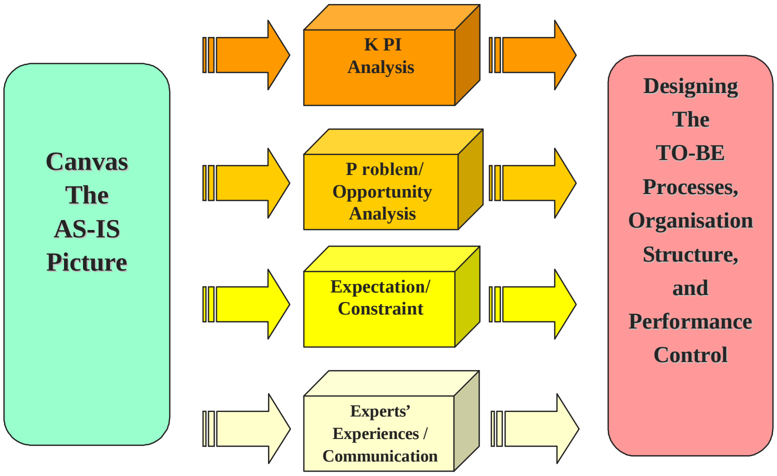
Major Approaches of the Transformation

In a matrix of two-dimensional content analysis, Croom et al. (2000) highlight four major categories of supply chain elements for trading exchanges by summarising the extant literature. These categories are assets, information, knowledge, and relationships. In Croom et al.'s (2000) framework, SCM elements are further divided into three levels of dyadic, chain, and network forms. These elements are much richer than those defined in the SCOR model, which are very limited in the categories of assets and information and still less than the two-dimensional framework just mentioned. For example, SCOR does not include the analysis of total cost ownership (asset), business network redesign (information), human resource planning (knowledge), or trust/power/commitment (relationship). However, there is, in particular, a scarcity of research on knowledge elements for SCM that lead to their unclear and inconsistent presence in the literature. The few examples are the subjects of knowledge with time-based capabilities in production activities (Handfield & Nichols, 1999) and configure-to-order for customised sales (Ton & Liao, 2002). The last category of Croom et al.'s (2000) framework is associated with "soft" elements, since relationship is a social tie existing among the supply chain entities. Although there have not been any widely accepted methods in industry (nor in SCOR) for managing the supply chain relationships, some scholars have considered it to be the most important figure in SCM. For example, Handfield and Nichols (1999) indicate that the efforts of other elements for implementing SCM in managing the flows of information and materials are likely to be unsuccessful if there is not a solid foundation of effective relationships in the channel context.

In order to mark up the insufficiency of the SCOR model and to map the Croom et al.'s (2000) elements, we propose a method in bridging current gaps for the SCM transformation processes. As shown in Figure 4, there are four major approaches, namely, KPI analysis, problem/opportunities analysis, expectation/constraints, and the experts' opinions, which can be amended to the SCOR model as explained next.

- **KPI analysis:** This approach follows the typical "top-down" SCOR analytical processes and is relevant when most operation figures are recorded and updated regularly. Since it requires information across the boundaries of firms, the SCM adopters may often encounter difficulties by merely using such an approach. It is even true in the situation in which most channel participants are subordinates or in joint ventures of a particular adopter because of unequal readiness of IT infrastructure or conflictions of management interests.
- **Problem/opportunity analysis:** When identifying the processes "gaps" by KPI information becomes less achievable, it is possible to find out the existing problems and difficulties by interviewing the employees from both upstream and downstream of the supply chain. Contrary to the KPI analysis that starts by enacting the supply chain strategy and comparing existing performance and the targets, problem/opportunity analysis is rather a "bottom-up" approach. It is suggested that the SCM project participants record various feedback and then map them into the different levels of SCOR processes. For instance, the KPI of "day sales receivable outstanding" in the Delivery element of SCOR Level 2 is related to the processes performance of the sales department. The same goal of identifying the SCM gaps can thus be achieved by directly finding problem/opportunity through individual interviewing and observation.

Figure 4. Bridging the gap of the supply chain transformation



- **Expectation/constraint:** One of the successful key factors in implementing an SCM project is the participants' attitude with commitment to collaborative improvements. It will affect the information gathering for KPI and problem analyses and the subsequent actions for supply chain modification that is sometimes accompanied by the adjustment of existing benefits among channel members. For example, the delivery routes, supply chain policies of pricing and return of goods, and requirements of forecasting between buyers-suppliers may be altered after the SCM implementation. It is, therefore, necessary to find out the expectations/constraints of channel participants so as to avoid the potential conflictions among supply chain entities.

Another example is that examining the demand management processes of the SCM initiator might lead to a tentative solution of implementing collaborative planning, forecasting and replenishment (CPFR) systems as suggested by SCOR model. However, doing so might require the adoption of new IT infrastructures and cause changes to the existing demand management processes in some of the suppliers. It is inevitable that compromises will have to be made in order for the transformation to happen in upstream and downstream of a supply chain. There are a few points should be considered when identifying the expectations and constraints of the supply chain stakeholders:

- Enterprise as a participant in a business ecosystem and supply network
- Cluster of firms that gradually evolves as a group—the coevolution effects
- Gradual development of shared vision—centred around a product or product group
- Further, the role of clusters in competitiveness

The experts' experiences/communication: The last approach for the supply chain transformation is to adopt an expert opinion from a third party. A SCM project covers the areas of channel collaboration in material management, production planning, sales/distribution, quality control, assets management, and cost controlling, and requires the knowledge of a business processes enabler, such as the adoption of information systems. Acquiring expert opinions is vital to the successfulness of any SCM project, not only because of the need for the above expertise, but also in the pre-selection adoption methods, business processes design, training, and customised IT systems. That means, most likely, that firms have to get the help of consulting companies to enact the proper adoption methods and learn from others' successful experiences. Nevertheless, the SCM project owners have to interact with outside consultants who are not always familiar with the "know-how" of a particular industrial context.

Quanta Computer Inc., one of the major players in the IT industry of global market, has a sales volume of USD 10 billion in 2004. Its implementation of SCM has become a legendary story in the Taiwanese IT industry, as Quanta Computer Inc. accomplished the supply chain processes redesign with its trading partners and established its ERP systems (a modified version of SAP) in only half a year. It is a monumental SCM implementation project, not only because of such a short period of time, but also because of the success of building up the global supply network to dramatically achieve the target of cost cutting through low-level inventories. An interesting thing was, although the consultants for the SCM project of Quanta Computer Inc. had a strong background in SAP systems, only the project manager was initially conversant with the production line of IT products. Communication and exchange of ideas thus played a significant role before the commencement of SCM adoption. In addition, Quanta Computer Inc. and its trading partners have cooperated with consultants from various global regions throughout the adoption period.

In short, the transformation of existing supply chain processes and structure relies on identifying the gaps and opportunities for improvement. Both "top-down" and "bottom-up" approaches are keys to the success of supply chain configuration now and in the future. Moreover, it is necessary to discreetly survey the stakeholders' expectations from the standpoint of various supply chain entities in order to ensure substantial benefits and learn from the anatomy of successful/failed cases via the experiences of the experts from the third party.

Combining the Performance Control into SCOR Analysis

The important leverage gained from the supply chain integration is the mitigation of risk by certain control (Min & Zhou, 2002). It is generally believed that the implementation of an SCM project consumes considerable resources of human labour, materials, and time. It will definitely have an impact on the enterprise and its trading partners. Therefore, a part of reasonable performance control is to ensure that the supply chain operates right on track.

For such consideration, there are hundreds of KPI (metrics) mapping the levels of business processes defined in the SCOR model. Whether the KPI information of the supply chain entities is available for calculation or not, it is possible to find out the existing problems and difficulties of supply chain configuration, as suggested in previous section. The recorded "As-Is" process, as illustrated in Figure 5, can be labelled in the format of normal flowchart.

Then, each of the codified processes should be analysed by a set of SIPOC diagrams (Pyzdek, 2003), which were originally used as quality control tools and can detail the information deliver (supplier), data sent (input), data generated (output), and information receiver (customer) for the purpose of systems development. This instrument allows us to see the opportunities for improving current communication interfaces among departments and trading partners. The previously identified "gaps" should be then codified, grouped, and prioritised, since some of them may cause similar problems, affect related business processes and supply chain entities, or be overcome by integrated solutions. The grouped and prioritised "gaps" thus

Figure 5. Example of current processses coding in the flowchart

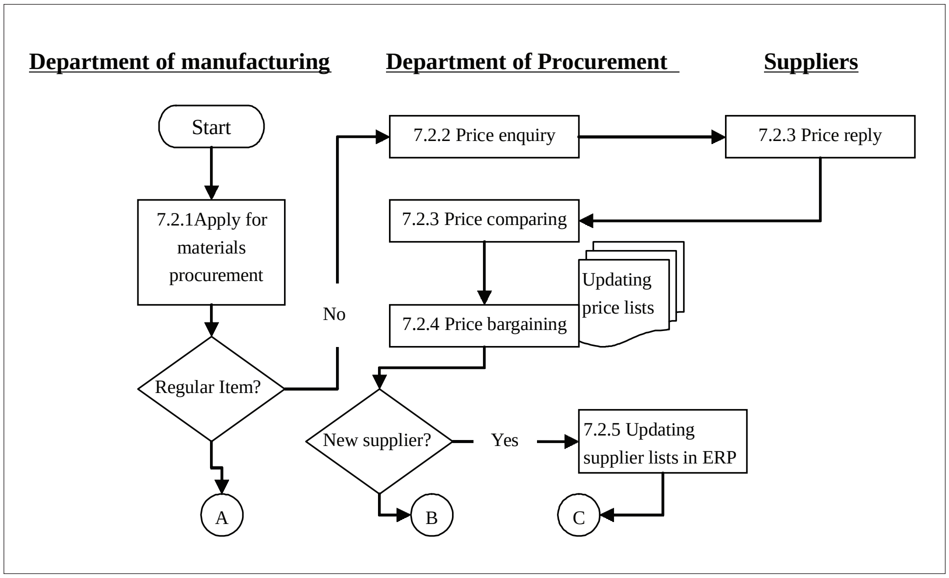
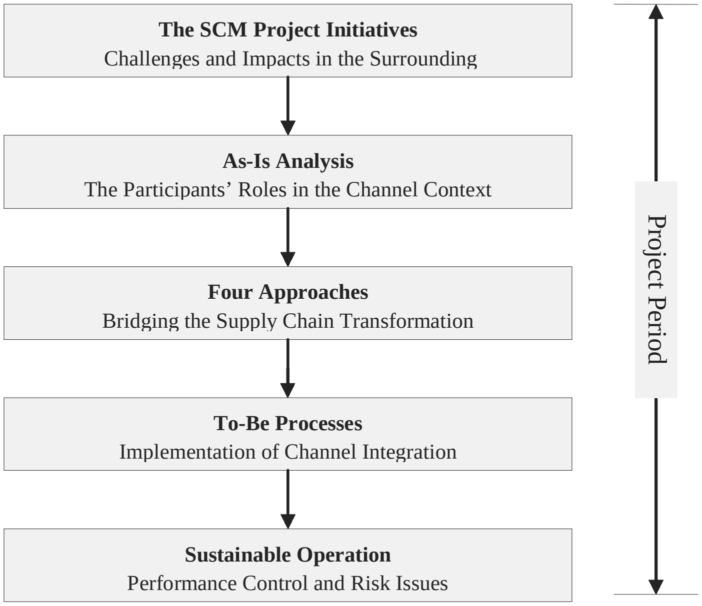


Figure 5. The sequence of SCM implementation



become the basis for creating "To-Be" scenarios that are associated with the adjustment of corporate policies, organisation structures, business flows, and information systems.

As previously discussed, most of the KPI items are naturally related to existing business processes because of their formulas for calculation. For instance, the KPI "day sales receivable outstanding" in the D element of SCOR Level 2 is related to the processes performance of sales department. As most of the SCOR metrics are related to the business processes of a single organisation, we recommend an extended table to map the cross-functional channel activities for performance monitoring encompassing the supply chain entities within the scope of an SCM project.

Formulated in another way, the business processes can be divided into two types—the planing and coordinating activities owned by the supply chain group and the operational activities of individual firms. Staff in the department of procurement in one firm might often play the role of directly and indirectly taking care of the purchasing decisions of other collaborative participants in the supply chain structure. The supply chain coordinating team may also negotiate with the customers' team to manage the suppliers' inventory level (Lambert & Pohlen, 2001). Ideally, it means that they should be evaluated both by the KPI of their original firms and the KPI of the suppliers and customers, based on certain percentages in order to monitor the two types of business processes. A control panel is thus generated in Table 2 for designing the KPI measurement and monitoring the supply chain performance.

Table 2 is an example of the control panel for planning and decision-making activities that maps the existing processes and "To-Be" processes in a project with four companies. It entails the information of how to control the supply chain functions across the boundaries of firms based on the selected KPI that are predefined by the SCOR standard. More importantly, this table contains the implications that the "gaps" between the current and future infrastructures of information exchange might be overcome by combining the current business processes codes that are embedded with SIPOC analyses and

Table 2. The control panel of planning and decision-making activities

Collaborative activities I			**ndividual Supply Chain Entities**				
Business Processes	SCOR Code	'To-Be' SCOR KPI	Core firm (SCM initiator)	Distributor	Supplier 1	Supplier 2	Current Business Processes Code
Supply Chain Planing	P1	Provided by SCOR documents (should be further selected based on the top managers' opinion).	V				Recorded in 'As-Is' analysis and should be mapped into the planning processes.
Plan Sourcing	P2		V	V			
Plan Making	P3		V		V V		
Plan Delivering	P4		V	V			

Notes: The level 3 SCOR code and the related departments of each supply chain entities should be shown on a real control panel. They are omitted in this table because of consideration of simplicity.

the responsible supply chain entities. One of the benefits is, for example, this joint process-metrics analysis of customer, supplier, and distributor will capture how the repositioning of inventory control improves total supply chain performance, whereas the information of inventory turns does not reflect any of the trade-offs that occurred in the channel links (Lambert & Pohlen, 2001). Consequently, it amends the insufficiency of using current SCOR metrics in the dyad and network supply chain structure.

CONCLUSION

We have stated in the foregoing sections that SCM plays a role in influencing the economic behaviour by the way business processes are managed. This, in itself, is certainly a very significant point, as it influences the costs of inventory holding, goods delivery, and manufacturing processes. In particular, it affects performance in customer fulfillment and cash-to-cash cycling, which are vital to enterprise survival (Garrison & Noreen, 2003). Achieving effectiveness of SCM does not only rely on process tuning, but also just-in-time communication and decision making through the enablers as performance measurement and information systems. Despite its importance, however, there is not much literature on the implementing framework, and most of the existing reports are individual case studies (Croom et al., 2000).

The SCOR model has been the most widely adopted standard and may be the only one for the analysis of SCM implementation. It has been modified several times since its first announcement by the Supply Chain Council in 1996. There is yet another point deserving the attention of academia and practitioners, namely, it is not a complete framework for implementation of an SCM project, but merely a referential tool for assigning business processes and associated factors of performance measures. It may actually be dysfunctional without considering the stakeholders' value/expectation and embedding the mutually owned processes into performance measurement. Therefore, we have amended its weakness by discussing the supply chain configuration and transformation and the implementation procedures.

Future research is required to test the proposed framework in actual business settings, including different industries and regions. Other barriers and limitations to SCM implementation and how they shall be overcome need to be further identified. These may consist of the demand up-size and down-size from order changes, for example, emergent orders or order cancelling, and the calculation of KPI for nonfinancial figures from the operation activities. To the extent that similar difficulties and solutions are identified in various supply chain context, it is possible that a refined framework can be developed for practitioners. Finally, progress should be tracked over time to prove the long-term benefits derived from implementing SCM based on such a framework.

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ENDNOTE

[1] Addition to the processes introduced in this chapter, the Supply Chain Council has recently announced DCOR and CCOR models to define the design and customer service activities to amend SCOR model. Some professionals have considered them to be part of the enablers of existing SCOR processors.

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Chapter 1.23

Information Systems, Software Engineering, and Systems Thinking:

Challenges and Opportunities

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ABSTRACT

This article traces past research on the application of the systems approach to information systems development within the disciplines of information systems and software engineering. Their origins historically are related to a number of areas, including general systems theory. While potential improvement of software development practices is linked by some leading experts to the application of more systemic methods, the current state of the practice in software engineering and information systems development shows this is some way from being achieved. The authors propose possible directions for future research and practical work on bringing together both fields with systems thinking.

INTRODUCTION

Information technology (IT) articles often include statements along these lines: "systems development continues to be challenging. Problems regarding the cost, timeliness, and quality of software products still exist" (Iivari & Huisman, 2007, p. 35). This recognition justifies the continuous search for improvement of Information Systems Development (ISD).

Glass, Ramesh, and Vessey (2004) provide an analysis of the topics covered by the three computing disciplines—information systems (IS), software engineering (SE), and computer science (CS)—and show overlaps between them all in the area of systems/software concepts. They also demonstrate that CS has only minor regard of the issues and concerns of systems/software management. Sommerville (2007) states that CS is concerned with the theories and methods that underlie computers and software systems rather than the engineering and management activities associated with producing software. Whilst acknowledging that CS, SE, and IS do have a considerable overlap, the practices of both IS and SE have to deal with common matters such as the management of huge development projects, human factors (both software developers and software end users), organisational issues, and economic aspects of software systems development and deployment (Van Vilet, 2000).

For the reasons stated above, we will concentrate here only on SE and IS and their links to systems thinking. We will consider as a starting point the reality that the whole computing field has evolved historically as several "stovepipes of knowledge": CS, SE, and IS (Glass et al., 2004). Whether the separation or integration of computing disciplines will prevail is a complex issue. Integration has yet to be achieved as a consequence of the sets of values central to each area. We believe, along with others, that a systems approach may lead to improvement of the development and management of software systems and to a greater integration of computing. One might expect that the use of the word "system" in various contexts today leads to more "systems thinking," but is this true?

A reflective history of the IS field is presented in Hirschheim and Klein (2003, pp. 244-249). According to them, because of its roots in multiple disciplines, "such as computer science, management, and systems theory, it is hardly surprising that the field of IS cast a wide net when defining its boundaries, sweeping in many themes and boundaries" (Hirschheim & Klein, 2003, p. 245). In that light, it is somehow striking to note the conclusion about a lack of a systems approach in IS research according to Lee (2004, p. 16). Alter (2004) is even more specific, claiming that "the information systems discipline is ostensibly about systems, but many of our fundamental ideas and viewpoints are about tools, not systems" (p. 757).

The systems approach has been acknowledged in the SE literature as providing an insight into the factors that influence the success or failure of computer technologies (Mathieu, 2002, p. 138). It is symbolic that the 2006 special issue of the *IEEE Computer* magazine on the 60th anniversary of the IEEE Computer Society is dedicated to the past and future of software engineering. A brief examination of the papers in that issue shows that four of them are dealing with some systems features and the other three give examples of tool thinking. None of the seven papers in the issue had a reference to any source from the field of systems thinking and only one paper (Baresi, Di Nitto, & Ghezzi, 2006) had references to several classic SE sources dealing with fundamental systems ideas. This does not advance the ideas suggested by Boehm (2006a) and Sommerville (2007) that there is a need to integrate SE with systems engineering, a branch of systems thinking (see Jackson, 2003).

The contribution of this research is in the identification of areas where a systems approach would lead to improvements in ISD within a point of view that favors implicitly the integration of the IS and SE disciplines. The article will proceed with an analysis of how links between software development and systems thinking were perceived in the fields of IS and SE. This is done predominantly with the intention of exploring the application of systems ideas to software development separately in the two fields, outlining the success stories and the open problems. At the end, we will propose possible directions for future research in software development within SE and IS associated with the systems approach.

ON INFORMATION SYSTEMS DEVELOPMENT AND SYSTEMS THINKING

A review of the history of various IS development methods is presented in Avison and Fitzgerald (2003). Iivari and Huisman (2007) point out, however, that the research literature on IS development has been scarce. This is most evident for the period after 1990. Prior to that point, the origins of IS research were associated more strongly with issues on building information systems. However, one sub-area of IS development grew significantly in the U.K. and elsewhere over the last 20 years: incorporation of Soft Systems Thinking (SST) into IS.

Soft Systems Thinking, Social Science, and Their Influence on IS

Stowell and West (1996) argued in the mid-1990s that practices of IS design had not appeared to have progressed since 1979; despite attempts in several proposals to embrace the social aspects of an information system, most seem to be based upon a functionalist view. Stowell and West (1996) explored the shift towards antipositivism in the mid-1980s, which resulted in a number of suggested methodologies that focused upon the social implications of computer systems design. As examples, they point out Soft Systems Methodology (SSM) (Checkland, 1999), the MULTIVIEW approach (Avison, 2000), participative systems design, and others (see also Avison & Fitgerald, 2003).

SSM evolved originally from experience within interventions in various management problems in public administration and industrial companies. However, subsequently it evolved more towards the field of IS (see Checkland & Holwell, 1998). Stowell (1995) presents a collection of papers analysing various aspects of the contribution of SSM to IS. SSM seems to be the most well researched interpretive systems approach used in the field of IS (see Holwell, 2000, for a detailed account of the literature on SSM, and Checkland & Poulter, 2006, for a contemporary presentation of SSM ideas).

The relevance of SSM to the field of IS has been explored in two directions. One way is to apply SSM on its own in some IT related aspect, for example, extend the standard SSM method to specify the information requirements of the system (see Wilson, 1990). The use of SSM in data modeling is explored by Lewis (1995). A further application of SSM for improvement of software quality is presented in Sweeney and Bustard (1997). A second direction of using SSM in information systems is through the linking of SSM to existing design methods. An overview and detailed analysis of using SSM with structured analysis and design is provided by Mingers (1995). Several authors have covered aspects of combining the Unified Modeling Language (UML) with SSM. A recent paper by Sewchuran and Petkov (2007) analyses the related theoretical issues and shows a practical implementation of a combination of UML and SSM within a Critical Systems Thinking (CST) (see Jackson, 2003) framework justified by Multimethodology (see Mingers, 2001).

On Critical Systems Thinking, Multimethodology, and IS

Multimethodology is a metatheory for mixing methods from different methodologies and paradigms in the same intervention (Mingers, 2001). It seems to be an attractive vehicle for further research in systems thinking and IS research.

Further refinement of the ideas on pluralist interventions can be found in a recent paper on Creative Holism (Jackson, 2006). Details on three cases, illustrating how Multimethodology and CST were practiced in separate systemic interventions in the Information and Communications Technologies sector, can be found in Petkov, Petkova, Andrew, and Nepal (2007).

In his paper on the links between CST and IS research, Jackson (1992) demonstrates the power of an integrated critical approach in the IS field. However, there have been relatively few subsequent publications on the practical application of CST in IS. Some of them are surveyed in Ngwenyama and Lee (1997), a paper demonstrating the significant relevance of CST to IS. Another interesting example, exploring how Triple Loop Learning (Flood & Romm, 1996) can be applied to the complexities during systems development is given in Finnegan, Galliers, and Powell's (2002) work. Further papers on systems thinking and IS can be found in proceedings of several meetings on the philosophical assumptions of IS research that took place after 1997, including the U.K. Annual Systems Conference, the European Conference on Information Systems, the Australasian Conference on IS, and Americas Conference on Information Systems (AMCIS).

CST provides both theoretical sophistication and practical directions for future research that are applicable to IS. Jackson (2003) cautions that whatever argument is made in favour of pluralism, it is bound to run up against objections from those who believe in the incommensurability of paradigms. The latter notion is linked to the assumption that if paradigms have distinct and opposing philosophical foundations, applying them together is impossible. This issue has been addressed by several authors in the past (see Jackson, 2003). Zhu (2006), however, questioned recently the relevance of concerns about paradigm incommensurability from a practical point of view, another issue for possible further research. His view on paradigm incommensurability is similar to that of the pragmatic pluralism approach. This is based on the assumption that we are witnessing the end of a particular reading of theory and that there is no single truth and no single rationality (White & Taket, 1996, p. 54).

Both pragmatism and functionalism are often criticised in systems thinking (see Jackson, 2003). However, an interesting and relevant new systems approach in IS, the work system method (Alter, 2007), has emerged recently that may be linked to the pragmatic school of thought.

The Work System Method and IS

Alter (2006) stresses that past dominance of single ideas like Total Quality Management and Business Process Re-engineering are not sufficient to influence the IS field profoundly. The work system method provides a rigorous but nontechnical approach to any manager or business professional to visualise and analyse systems related problems and opportunities (Alter, 2006). This method is more broadly applicable than techniques "designed to specify detailed software requirements and is designed to be more prescriptive and more powerful than domain-independent systems analysis methods such as soft system methodology" (Alter, 2002). We may note that making comparisons between the work system method and soft systems methodology requires a broader investigation of their philosophical assumptions and scope. A possible starting point for comparing their areas of applicability could be the classification of strategies for doing systems analysis provided by Bustard and Keenan (2005). SSM has been attributed by them to the situation when the focus is on development of a long term vision of the environment in which a computer system is to be used with identification of appropriate organisational changes (see Bustard & Keenan, 2005). Where Alter's approach stands in the Bustard and Keenan (2005) classification is an open question for research requiring both theoretical work and field experimentation. We consider the systemic nature of the work system method and its applicability to understanding business and IS problems to be its most distinctive and important characteristics. Though the work system method has a relatively short history and a small group of followers for now, the multifaceted scale of Alter's work, bringing together systems ideas with methods for deeper understanding of work systems and IS, has strong appeal.

On Sticking to a Single Research Tradition in IS

Bennetts, Wood-Harper, and Mills (2000) provide an in-depth review of combinations of SSM with other IS development methods supporting multiple perspectives along the ideas of Linstone (1984). Thus, they brought together two distinct traditions in IS research: the former practiced in U.K./Europe/Australia where SSM has found significant acceptance, and the latter was pursued predominantly in the U.S. Linstone's ideas are strongly related to the influence of Churchman whose analysis of Inquiring Systems was a starting point for some significant IS research that followed (e.g., Vo, Paradice, & Courtney, 2001).

It is interesting to note that Bennetts et al. (2000) have examined sources not only from IS but also from the CS and SE literature. This raises a question that is hard to answer in a simple way. We observe that often authors of SE articles belong to CS or IS departments, rather than engineering schools (Aurum & Wohlin, 2005; Dietrich, Floyd, & Klichewski, 2002). On the other hand, it seems that publications on IS development written by U.S. scholars often use references only from IS or from SE disciplines, depending on the field of the authors; a refreshing exception is a series of articles written over many years by R. Glass and I. Vessey with several collaborators (Glass et al., 2004). The reason could be the lack of communication between CS, SE, and IS (see Glass, 2005). Another possible reason is the growing concern within the separate computing fields for promoting and protecting their own paradigms (Bajaj, Batra, Hevner, Parsons, & Siau, 2005).

Maybe similar paradigmatic concerns have led Allen Lee to formulate his first idea from an advice to IS researchers: "practice paradigm, systems thinking and design science" (Lee, 2000). These are seen as a recipe to address the three dilemmas that are as relevant today as they were in 2000: the rigor vs. relevance debate in IS research; the "reference discipline" vs. "independent discipline" dilemma; and the technology vs. behaviour as a focus for IS research dilemma.

So far, we have considered the second of Lee's ideas and its relevance to IS development over the last 15 years and to a lesser degree some issues related to scientific paradigms in terms of Kuhn (1970). Further details on earlier contributions of Systems Science in the 1970s and 1980s can be found in comprehensive reviews related to the fields of IS research (see Xu, 2000), Decision Support Systems (see Eom, 2000), and Information Resources Management (see McLeod, 1995). Mora, Gelman, Forgionne, Petkov, and Cano (2007) presented a critique and integration of the main IS research paradigms and frameworks reported in the IS literature using a systems approach. We briefly comment below on design science, a more recent trend in IS research.

On Design Science As One of the Directions to Resolve the Three Dilemmas in IS

According to Hevner, March, Park, and Ram (2004), IS related knowledge is acquired through work in behavioural science and design science paradigms. They point out that "behavioral science addresses research through the development and justification of theories that explain phenomena related to the identified business need, while design science addresses research through the building and evaluation of artifacts designed to meet the particular need." Another relevant detail is the differentiation that Hevner et al. (2004) make between routine design and system building from design science. The former is associated with application of existing knowledge to organisational problems, while the latter is associated with unique (often wicked or unresolved) problems that are associated with the generation of new knowledge. The latter idea is similar to the main thesis in Hughes and Wood-Harper (1999). Hevner et al. (2004) laid the foundation for a significant boost in IS research on issues related to IS development, including systems analysis and design science. The journal *Communications of AIS* started a series of articles in 2005 on this topic; the first of which was Bajaj et al. (2005). We may note that in spite of progress in applying action research in IS in theory (see Baskerville & Wood-Harper, 1998) and in practice (see the IbisSoft, n.d., position statement on environment that promotes IS research) the dominant IS research trend has been of a positivist behavioural science type which is another challenge for the proponents of a systems approach.

A substantial attempt to provide suggestions towards resolving the three dilemmas in IS research mentioned by Lee (2000) is discussed in Hirschheim and Klein (2003). They identify a number of disconnects between various aspects of IS research and outline a new body of knowledge in IS development (Iivari, Hirschheim, & Klein, 2004). They suggest there are five knowledge areas in ISD: technical knowledge, application domain (i.e., business function) knowledge, organisational knowledge, application knowledge, and ISD process knowledge. Further, according to Hirschheim and Klein (2003):

> *ISD process knowledge is broken down into four distinctive competencies that IS experts are suggested to possess: (1) aligning IT artefacts (IS applications and other software products) with the organizational and social context in which the artefacts are to be used, and with the needs of the people who are to use the system as identified through the process of (2) user requirements construction…(3) organizational implementation from which (4) the evaluation/assessment of these artefacts and related changes is factored out …. These competencies are … at best weakly taken into account in the ten knowledge areas of SWEBOK.* (see for comparison SWEBOK, 2004)

Hirschheim and Klein (2003) present comprehensive proposals for strengthening the IS field. Their work was partly motivated by a widely discussed paper by Benbasat and Zmud (2003) on the identity crisis in the IS discipline. Both papers provide important background details about the IS research environment in which one may pursue the main ideas of this article. The next section will explore the relevance of systems thinking to SE.

ON SOFTWARE ENGINEERING AND SYSTEMS THINKING

Software engineering has a primary focus on the production of a high quality technological product, rather than on achieving an organisational effect, however increasing emphasis in SE is being given to managerial and organisational issues associated with software development projects. Cornford and Smithson (1996) observe that SE "can never encompass the whole range of issues that need to be addressed when information systems are studies in the full richness of their operational and organisational setting".

Weinberg (1992) writes about systems thinking applied to SE. It is an excellent introduction to systems thinking and quality software management dealing with feedback control. It has a close kinship with the concepts of systems thinking and system dynamics in Madachy (2007), even though it is almost exclusively qualitative and heuristic. Weinberg's main ideas focus around management thinking about developing complex software systems, having the right "system model" about the project and its personnel.

Systems thinking in the context of SE, as described in Madachy (2007), is a conceptual framework with a body of knowledge and tools to identify wide-perspective interactions, feedback, and recurring structures. Instead of focusing on open-loop event-level explanations and assuming cause and effect are closely related in space and time, it recognises the world really consists of multiple closed-loop feedbacks, delays, and nonlinear effects.

Lee and Miller (2004), in their work on multi-project software engineering, advocate a systems thinking approach as “in general, we are able to make better, more robust, and wiser decisions with systems thinking, since we are considering the problem by understanding the full consequences of each feasible solution”.

Other details on systems thinking with links to other books and articles can be found through practitioner’s Web sites such Weinberg (2007), Developer (2007), or Yourdon (2007). The interest of software practitioners in systems ideas is a significant fact, in light of the previously mentioned debate about relevance in the IS literature. However, systems thinking is not mentioned by Reifer (2003) in his taxonomies of the SE theory state-of-the-art and SE state of practice. In relation to that, we will discuss below whether systems ideas are promoted in SE education.

Software Engineering Education and Systems Thinking

The coverage of systems concepts in leading SE textbooks is possibly another indicator about the way the systems approach is perceived within the SE community. We considered books by several well established authors: Sommerville (2007), Pressman (2001), and Pfleeger (2001), amongst many. Table 1 shows a summary of findings related to the treatment of several typical systems notions in those books.

Table 1 shows that the systems concepts covered in the three widely used textbooks are mostly related to introductory notions from systems thinking. There is nothing about open

Table 1. Systems features covered in popular software engineering textbooks

Notions covered	**Author**		
	Sommerville	Pressman	Pfleeger
System definition	Yes	Yes	Yes
Boundary	Implied	Yes	Yes
Open vs Closed systems	No	No	No
Relationships	Implied	Implied	Yes
Inter-related systems	Implied	Implied	Yes
Emergent property	Yes	No	No
Decomposition	Yes	Yes	Yes
Coupling	No	Yes	Yes
Cohesion	No	No	Yes
Hierarchy	Yes	Yes	Yes
System behaviour	Yes	Yes	Yes
Law of requisite variety	No	No	No
Sociotechnical systems	Yes	No	No
Systems engineering	Yes	To some extent	To some extent

and closed systems, about the law of requisite variety or any other aspect of cybernetics, very little about sociotechnical systems, and nothing about soft systems methodology or CST. In our opinion, these are unexploited notions that have some potential to introduce fresh ideas in SE after further research.

Crnkovic, Land, and Sjogren (2003) question whether the current SE training is enough for software engineers. They call for making system thinking more explicit in SE courses. They claim that "the focus on modifiability (and on other non-functional properties) requires more of a holistic and system perspective" (Crnkovic et al., 2003). Similar thoughts are shared more recently by others in engineering like Laware, Davis, and Perusich (2006).

The narrow interpretation of computing disciplines is seen as a contributory factor to the drop in student enrolments in the last five years. Denning (2005) hopes that students will be attracted by a new educational approach promoted by the ACM Education Board that relies on four core practices: programming, systems thinking, modeling, and innovating. It has now been four years since those ideas were stressed by ACM, but there is little evidence that systems thinking has become a core practice emphasised in teaching in any of the three computing disciplines.

In the U.K., the Quality Assurance Agency (which monitors and quality assures all U.K. university programmes) recently published the updated version of the computing benchmark statement (encompassing IS, SE, and CS) on the content and form of undergraduate courses (QAA, 2007). Although not intended to be an exhaustive list but "provided as a set of knowledge areas indicative of the technical areas within computing," it fails to make explicit reference to systems thinking or systems approaches and makes only one reference to "systems theory" under a more general heading of "systems analysis and design". Perhaps the answer is to explore how to introduce these concepts earlier in pre-university education or to continue to try to convince the broader academic community of the importance of systems thinking.

One promising systems approach used for education of software engineers is the Model-Based System Architecting and Software Engineering (MBASE) framework being used at USC, and also adapted by some of their industrial affiliates. According to Boehm (2006c), MBASE integrates the systems engineering and SE disciplines, and considers stakeholder value in the system development. The MBASE framework embodies elements of agile processes and teaches students to "learn how to learn" as software development will continue to change. Valerdi and Madachy (2007) further describe the impact of MBASE in education.

On Software Engineering and Systems Engineering

Systems Engineering is concerned with all aspects of the development and evolution of complex systems where software plays a major role. Systems engineering is therefore concerned with hardware development, policy and process design, and system deployment, as well as software engineering. System engineers are involved in specifying a system, defining its overall architecture, and then integrating the different parts to create the finished system. Systems engineering as a discipline is older than SE, as people have been involved in specifying and assembling complex industrial systems such as aircraft and chemical plants for more than 100 years (Sommerville, 2007).

A thought provoking comparison of SE culture vs. systems engineering culture is presented by Gonzales (2005). This work points out to where we should strive to change the perceptions of the SE student entering the IT profession. We agree with Gonzales (2005) that we "must continue the dialogue and ensure that we are aware of strides to formalise standard systems engineering approaches and generalise software engineering approaches to capturing, specifying and managing requirements" (p. 1). We would also suggest that this dialogue should be supported by more work on the application of a systems approach to SE, stimulated by journals such as IJITSA.

Boehm (2006b) concludes that "The push to integrate application-domain models and software-domain models in Model Driven Development reflects the trend in the 2000's toward integration of software and systems engineering". Another reason he identifies is that other surveys have shown that the majority of software project failures stem from systems engineering shortfalls. A similar thought is expressed by Boehm and Turner (2005), who state that there is a need to move towards a common set of life-cycle definitions and processes that incorporate both disciplines' needs and capitalise on their strengths.

Boehm (2006a) points out that "recent process guidelines and standards such as the Capability Maturity Model Integration (CMMI), ISO/IEC 12207 for software engineering, and ISO/IEC 15288 for systems engineering emphasise the need to integrate systems and software engineering processes". He further proposes a new process framework for integrating software and systems engineering for 21st century systems and improving the contractual acquisition processes. Another issue is how to capitalise on the new developments in SE over the last decade which will be discussed in the next section.

The Evolution of Plan-driven and Agile Methods in SE and System Thinking

The traditional software development world, characterised by software engineering advocates, use plan-driven methods which rely heavily on explicit documented knowledge. Plan-driven methods use project planning documentation to provide broad-spectrum communications and rely on documented process plans and product plans to coordinate everyone (Boehm & Turner, 2004). The late 1990s saw something of a backlash against what was seen as the over-rigidity contained within plan-driven models and culminated in the arrival of agile methodologies, which rely heavily on communication through tacit, interpersonal knowledge for their success.

Boehm and Turner (2004) quote Philippe Kruchten (formerly with IBM Canada and now a professor at UBC in Vancouver) who has likened the Capability Maturity Model (CMM)—a plan-drive approach—to a dictionary:

> *'that is, one uses the words one needs to make the desired point; there is no need to use all the words available' (p. 23). They conclude that processes should have the right weight for the specific project, team, and environment. Boehm and Turner (2004) have produced the first multifaceted comparison of agile and plan-driven methods for software development. Their conclusions show that neither provides a 'silver bullet' (Brooks, 1987). Some balanced methods are emerging. We need both agility and discipline in software development.* (Boehm & Turner, 2004, p. 148)

Boehm (2006b) presents a deep analysis of the history of SE and of the trends that have emerged recently. These include the agile development methods: commercial off-the-shelf software and model driven development. The same author points out that the challenges are in capturing the evolving IT infrastructure and the domain restructuring that is going on in industry. In our opinion, it is necessary to investigate further if systems thinking may play a role in integrating agile and plan-driven methods (see Madachy, Boehm, & Lane, 2007, as an application of systems thinking to this problem). It has also been speculated that systems thinking could be relevant to Extreme Programming (XP) as it supports building relevant mental models (see Wendorff, 2002).

A recent paper by Kroes, Franssen, van de Poel, and Ottens (2006) deals with important issues in systems engineering such as how to separate a system from its environment or context. They conclude that the idea that a sociotechnical system can be designed, made, and controlled from some central view of the function of the system has to be given up, as many actors within the sociotechnical system are continuously changing (redesigning) the system. This is an important issue deserving further investigation in light of software systems and the methods implied by agile development frameworks.

Systems Dynamics and SE

A widely publicised idea is modeling software development processes through systems dynamics (see Abdel-Hamid & Madnick, 1991; Madachy, 2007; and others). The differences and relationships between systems dynamics and systems thinking are detailed in Richmond (1994) and others. Systems dynamics is a tool that can assist managers to deal with systemic and dynamic properties of the project environment and can be used to investigate virtually any aspect of the software process at a macro or micro level. It is useful for modeling sociotechnical factors and their feedback on software projects. The systems dynamics paradigm is based on continuous systems modeling, which has a strong cybernetic thread. Cybernetic principles are relevant to many types of systems including software development systems, as detailed in Madachy (2007).

The primary purposes of using systems dynamics or other process modeling methods in SE as summarised from Madachy (2007) are strategic management, planning, control and operational management, process improvement and technology adoption, and training and learning. Example recent work by Madachy (2006) focuses on the use of systems dynamics to model the interaction between business value and the parameters of a software process for the purpose of its optimisation. Another application of systems dynamics to assess a hybrid plan-driven and agile process that aims to cope with the requirements of a rapidly changing software environment while assuring high dependability in Software-Intensive-Systems-of-Systems (SISOS) is presented in Madachy, Boehm, and Lane (2007).

On Other Methods of Systems Thinking Applicable to SE

The development of understanding of a particular software project for making better judgments about the cost factors involved in cost and effort estimation is supported also by the work of Petkova and Roode (1999). They implemented a pluralist systemic framework for the evaluation of the factors affecting software development productivity within a particular organisational environment. It combines techniques from several paradigms: stakeholder identification and analysis (from SAST, see Mason & Mitroff, 1981), from SSM (Checkland, 1999), Critical Systems Heuristics (Ulrich, 1998), and the Analytic Hierarchy Process (Saaty, 1990).

While we could not find any specific earlier accounts of the use of SSM in the mainstream SE literature, it is significant that Boehm (2006a) has recognised its potential as he quotes its originator in a recent paper:

> Software people were recognising that their sequential, reductionist processes were not conducive to producing user-satisfactory software, and were developing alternative SE processes (evolutionary, spiral, agile) involving more and more systems engineering activities. Concurrently, systems engineering people were coming to similar conclusions about their sequential, reductionist processes, and developing alternative "soft systems engineering" processes (e.g., Checkland, 1999), emphasising the continuous learning aspects of developing successful user-intensive systems.

One does not need always to have a systems philosophy in mind to generate an idea that has a systemic nature or attempts to change the current thinking in SE. Thus, Kruchten (2005) presents, under the banner of postmodernist software design, an intriguing framework for software design borrowed from architecture. One may investigate how such an approach is different from a systemic methodology and what are their common features. Starting from a language-action philosophy point of view, Denning and Dunham (2006) develop a framework of innovation based on seven practices that are inter-related in their innovation model—every element is in a relationship with all others, thus fulfilling the criterion for "systemicity" by Mitroff and Linstone (1993). We need more analogical examples of systemic reasoning or even just of alternative thinking related to every aspect of the work of a software engineer and IS developer demonstrating the power of innovative interconnected thinking. The analysis so far allows us now to formulate some recommendations in the following section.

CONCLUDING RECOMMENDATIONS ON THE NEED FOR MORE RESEARCH LINKING SOFTWARE ENGINEERING, INFORMATION SYSTEMS DEVELOPMENT, AND SYSTEMS THINKING

We may derive a number of possible directions for future work from the analysis of research and practice in ISD and systems thinking within the fields of IS and SE. Alter (2004) has produced a set of recommendations for greater use of systems thinking in the IS discipline which incorporate various aspects of the work system method. We believe that Alter's proposals are viable and deserve the attention of IS and SE researchers.

Boehm and Turner's (2005) suggestions to address management challenges in integrating agile and plan-driven methods in software development will be used by us as an organising framework for formulating directions for research on integrating IS, SE, and the systems approach. The five main points below are as defined originally by Boehm and Turner (2005) for their purpose, while we have provided for each of them suggestions promoting such integration along the aims of this article:

1. **Understand how communication occurs within development teams:** There is a need to continue the work on *integrating systemic methods promoting organisational learning* (see Argyris & Schon, 1978) like systems dynamics, stakeholder analysis, soft systems methodology, critical systems thinking, and others to identify the advantages of using specific methods and their limitations when dealing with uncovering the microclimate within a software development team. Most of the previously mentioned applications of systems methods for this purpose have had limited use and little experimental evaluation. *More case studies need to be conducted in different software development organisations to validate the claims for the applicability of such methods and to distil from the accumulated knowledge best practices and critical success factors* relevant to flexible, high quality software development teams. We may *expand further the boundary of investigations with respect to what is happening at the level of systems-of-systems* (see Sage, 2005). An example of related relevant ideas on cost estimation for large and complex software projects can be found in Lane and Boehm (2007). Another direction is to *explore information systems development as a research act*, as suggested by Hughes and Wood-Harper (1999) and Hevner et al. (2004), as well as the philosophy of integrating practice with research in the field of software and management, promoted by IbisSoft (n.d.).

2. **Educate stakeholders:**This is probably the most difficult task of all. It needs to be addressed at several levels:

- *Implement changes in educational curricula*—it is essential to introduce the systems idea in relatively simple forms at the undergraduate level and in more sophisticated detail at the masters' level. There is *a need to create the intellectual infrastructure for more doctoral dissertation projects in IS or SE involving systems thinking*. Teaching could be supported by *creating an accessible repository for successful utilisation of systems ideas in IT education*. Amongst the many examples we may mention here the use of SSM in project-based education at a Japanese university (Chujo & Kijima, 2006), on integrating systems thinking into IS education (see Vo, Chae, & Olson, 2006), or the use of MBASE in student projects (see Boehm, 2006c; Valerdi & Madachy, 2007).
- *Broaden the systems knowledge of IS and software engineering educators*—the current situation in some of the computing disciplines can be compared to a similar one in Operations Research (OR) in the 1960s, which had evoked a sharp critique by Ackoff (1999) in his famous paper "The Future of Operational Research Is Past." published originally in 1979. Ackoff (1999, p. 316) points that survival, stability, and respectability took precedence over development and innovativeness in OR in the mid-1960s and its decline began. The *challenge however is not just to bring systems thinking to IS and SE education beyond several elementary concepts of general systems theory but to keep up to date with the latest body of knowledge in the systems field*. For a comprehensive overview, see Jackson (2003) and, for recent developments in systems science, see Barton, Emery, Flood, Selsky, and Wolstenholm (2004).
- *Empower IT developers to practice systemic thinking*—a significant role here needs to be played by research on the most *suitable forms for continuing professional education on IT and the systems approach*, *supported by professional meetings and journals for mixed audiences* like this one, that are oriented to academia and industry practice. Ackoff (2006) underlines that one of the reasons why systems ideas are adopted by few organisations is that "very little of the systems literature and lectures are addressed to potential users" (p. 707). Further, he stresses the need to analyse management failures systemically, pointing out that there are two types of failures: errors of commission and errors of omission. In spite of publications analysing software failures like Glass (2001), *there is still room for systemic analysis of IT failures and there are very few accounts of errors of omission* in software projects.
- *Change the attitudes of clients in managerial and operational user roles*—viable research and practical activities in this direction could *use the work system method* (Alter, 2006) and other relevant methods to develop better understanding of organisational problems and to improve their communication with software developers.

3. **Translate agile and software issues into management and customer language:** We may suggest several possible directions here:
    - *Investigate in a systemic way the existing agile and plan-driven models* for software development and continue with the work started in Boehm (2006a) on creating new process models integrating not just SE and systems engineering ideas but other applicable systems concepts as well.

- *Explore the applicability of "Sysperanto"* (see Alter, 2007) to foster a common language for all stakeholders in software development.
- *Build methods and tools to facilitate the communication process between software developers, customers, and supporting multiple perspective* representations of problem situations as proposed by Linstone (1984).

4. **Emphasise value for every stakeholder:** Design science research and agile methods place high emphasis on this idea. There is a *need for more research on systemic identification of stakeholder values.* Further, there is a need for research on methods to model and help the effective analysis and *better systemic understanding of all aspects of software development*, related to the technical product attributes, the project organisational attributes, the developers attributes, and the client features in a particular project or system-of-projects.
5. **Pick good people, reward the results, and reorient the reward system to recognise both individual and team contribution:** These suggestions can be categorised as human resource management issues and hence are also suitable for *investigation through suitable systemic approaches and problem structuring methods, including multicriteria decision analysis, promoting evaluation, and decision making.*

One of the limitations of the scope of our proposals is that we have provided suggestions reflecting only on the above five ideas by Boehm and Turner (2005). A systemic investigation of all aspects of ISD could lead to a much broader set of considerations integrating SE, IS, and systems thinking. We believe, however, that the examples we have provided here can lead to easier adaptation and development of other relevant ideas serving a similar purpose. Another possible limitation is that we have produced our suggestions for future research on integrating SE, IS, and the systems approach by assuming that the current state of the art and practice in SE and IS are known and we have focused rather only on identifying examples of the use of a systems approach in IS or SE. As we have pointed out earlier, we have relied on the comprehensive analysis of the state-of-the-art of the IS discipline provided by Hirschheim and Klein (2003). We have also reflected on trends in SE (see Reifer, 2003; Boehm, 2006a, b; Boehm & Turner, 2004) and on the comparative analysis of research in the three computing disciplines by Glass et al. (2004). It would be interesting to conduct a further investigation of IS implementation as a whole that goes beyond the existing disciplinary boundaries and takes a systems approach as an organising viewpoint.

Most of our recommendations on integrating IS, SE, and systems thinking relate to issues of organisational learning where contemporary systems methods have a significant history of achieving improvement. The challenge for IS and SE practitioners, researchers, and educators is not just to investigate the issues we discussed in this article but also to practice what was learned for improved ISD.

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Chapter 1.24

Software Engineering and the Systems Approach:

A Conversation with Barry Boehm

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INTRODUCTION

IJITSA is honored by the fact that this issue presents an interview with probably the most significant figure in the field of software engineering since its inception and one of its founders, Professor Barry W. Boehm. He has published many seminal books and papers that have shaped the foundations of software engineering. We have included in the references just a small sample of his numerous publications addressing some of the fundamental issues in this field in recent years. They cover diverse topics ranging from a comparison of agile development methods and software engineering (Boehm & Turner, 2004) to reflections on enhancing software engineering education (Boehm, 2006c). A thought-provoking review of the evolution of software engineering and its current challenges is presented in Boehm (2006b), while his thoughts on the need to integrate more closely software and systems engineering are reflected in Boehm (2006a) and Boehm and Lane (2006). The questions we asked Professor Boehm relate to his significant contributions to software engineering and enhancing its links to the systems approach.

Dr. Barry Boehm is the TRW Professor of Software Engineering and Director, Center for Software Engineering, University of Southern California. He received his B.A. degree from Harvard in 1957 and his M.S. and Ph.D. degrees from UCLA in 1961 and 1964, all in mathematics.

He also received an honorary Sc.D. in computer science from the University of Massachusetts in 2000. He served within the U.S. Department of Defense (DoD) as Director of the DARPA Information Science and Technology Office, and as Director of the DDR&E Software and Computer Technology Office. He worked at TRW from 1973 to 1989, culminating as Chief Scientist of the Defense Systems Group, and at the Rand Corporation from 1959 to 1973, culminating as Head of the Information Sciences Department. He was a Programmer-Analyst at General Dynamics between 1955 and 1959.

Professor Boehm's current research interests focus on value-based software engineering, including a method for integrating a software system's process models, product models, property models, and success models called Model-Based (System) Architecting and Software Engineering (MBASE). His contributions to the field include the Constructive Cost Model (COCOMO), the Spiral Model of the software process, the Theory W (win-win) approach to software management and requirements determination, the foundations for the areas of software risk management and software quality factor analysis, and two advanced software engineering environments: the TRW Software Productivity System and Quantum Leap Environment. He has served on the boards of several scientific journals, including the *IEEE Transactions on Software Engineering*, *IEEE Computer*, *IEEE Software*, *ACM Computing Reviews*, *Automated Software Engineering*, *Software Process*, and *Information and Software Technology*. He has served as Chair of the AIAA Technical Committee on Computer Systems, Chair of the IEEE Technical Committee on Software Engineering, and as a member of the Governing Board of the IEEE Computer Society. He has also served as Chair of the Air Force Scientific Advisory Board's Information Technology Panel, Chair of the NASA Research and Technology Advisory Committee for Guidance, Control, and Information Processing, and Chair of the Board of Visitors for the CMU Software Engineering Institute.

Professor Boehm was the recipient of numerous honors and awards, which include among others the ACM Distinguished Research Award in Software Engineering (1997) and the IEEE Harlan D. Mills Award (2000). He is a Fellow of the primary professional societies in computing (ACM), aerospace (AIAA), electronics (IEEE), and systems engineering (INCOSE), and a member of the National Academy of Engineering.

THE CONVERSATION

IJITSA: Professor Boehm, thank you for agreeing to this interview for IJITSA. You have noted in your previous writings the need for integration of systems engineering and software engineering. Please could you provide your opinion on why the systems approach is useful to software engineering?

Professor Boehm: I think the most convincing reason for that is most of the analyses of the root causes of failed software projects. They tend not to be whether you got your algorithms and data structures correct. They tend to be failures in doing the systems engineering. Getting the wrong requirements, or getting incomplete requirements, or getting the wrong stakeholders to give you requirements, or not understanding the feasibility of the requests, or being able to estimate cost or schedule, or tradeoffs in performance and reliability. So, most of the projects that fail seem to be failing because of failures in doing a good job of systems engineering. As we've tried to teach software engineers here at USC, we find that what we end up doing in the whole first semester of a two-semester course is getting them to learn how to systems engineer the operational concepts, the prototypes, the requirements, the architecture, the plans and get those right before they start doing a lot of detailed programming.

IJITSA: How would you assess the current level of information technology professionals practicing a systems approach? Would you say that the IT community faces a challenge to include more systems thinking in the state of the practice and state of theory in software engineering, information systems or systems engineering?

Professor Boehm: I think there is a bit of a gap in that there are some information technology professionals who are good at business workflows and things like that, but do not have a really deep computer science background as far as knowing whether the COTS products that they rely on are scalable or able to be tailored in ways that are necessary for the application. And on the other hand, there is a bunch of people who major in computer science who know all of that stuff, but don't know much about the business workflows. I think what's really valuable is when you get information technology professionals who have enough depth to do both of those things. And so, with the business-intensive people that do IT in the business school, we have just set up a joint Master's Program where you can get a master's in the management of software engineering that says that you need to know what the Business School people know about management and business applications, but you will also need to know what software engineers do about the algorithms, data structures, object-oriented methods, architectures, and those kinds of things.

IJITSA: What would be your recommendations for a better introduction of systems ideas in the software engineering and information systems curriculum at undergraduate and postgraduate levels?

Professor Boehm: This is easier to do for the post-graduate level. At the undergraduate level, it is hard to get people up to speed in both these things that are needed to understand information systems and computer science. So at USC, we find you can teach them a principles course in the junior year and they sort of get it and a small project course in the senior year and they get it a bit more. But where it all seems to come together best is really at the master's degree level. If they are well-enough grounded in one or the other, they can learn what they need to learn about the counterpart things: systems engineering if they are more in software engineering, software engineering if they are more systems oriented.

Actually, this is the direction that the current software engineering body of knowledge group is going. The previous body of knowledge was fairly heavy on computer science aspects. The more recent one is more appreciative and reflective of systems analysis, economics, business cases analyses, and things like that. Also, there is a similar activity to define a body of knowledge that is not just driven by academics, but really driven by a balance of academic and industry people that I think will have even more emphasis on the systems engineering and the management aspects.

IJITSA: You have pioneered and inspired significant research in software cost and effort estimation over many years. How would you characterize the role of the systems approach for the more recent evolution of the body of knowledge in that area?

Professor Boehm: Well again, as we saw with software engineering, it really needed to adapt more to the practices that are involved in systems engineering and software engineers needed to know more about the aspects of the rest of the system like the hardware, the facilities, and things like that. So what that means is that where our previous cost models really focused on defining and designing and developing the software, we've gone more into looking at models that estimate the cost of doing systems engineering, integrating systems of systems, integrating commercial-off-the-shelf (COTS) products, or things like that. A lot of the systems approach has been valuable in providing things like system engineering standards such as ISO 15288 and EIA 632 that give you representative work breakdown structures that you can relate to in doing these estimation models.

IJITSA: You indicate in some 2006 papers (Boehm, 2006a; Boehm & Lane, 2006d) that there is a need for considering alternative soft approaches such as those embodied in the ideas of Peter Checkland. Why do you think that a variety of systems approaches from different paradigms would improve our understanding of important software engineering activities?

Professor Boehm: Let me turn the question around a little bit. I think the software people really had to understand the role of people in systems more rapidly than some of the traditional system engineers who were engineering bridges and buildings and various kinds of physical artifacts. So, a lot of the soft systems engineering was necessary for software engineers to adapt as far as what they did with the front end of the life cycle. As I got more involved in doing this, I started seeing a lot of this really good work that John Warfield, Peter Checkland, and Eberhart Rechtin were doing in trying to take a more holistic approach to "what is a system?" There are still definitions of systems in the systems engineering field that say they do not include the people. But it's hard these days to exclude the people from being part of the problem and part of the solution when you are trying to engineer a system that has software in it.

IJITSA: What do you think of the potential of the systems approach to address some unresolved research challenges in the disciplines of information systems, software engineering or systems engineering?

Professor Boehm: I think that it's really been extremely valuable. As we have tried to do this in what we do in teaching computer science people how to do a systems approach, it has been very valuable. I was recently on a National Research Council study that was trying to come up with better ways in integrating human factors into the system development process, and again, the system approach had an appropriate framework for doing this, particularly if you included people as part of the system. I think it has been good to see that the "systems approach" has broadened enough to so that it does account for all of those kinds of things. There are still a lot of devils in the details about how do you come up with systems approaches that fit all of the different possible configurations of systems that need to be built these days. But I think the framework is going to be strong enough to help address those.

IJITSA: Could you give us, please, a final message related to the systems approach movement in IT in general and in software engineering more specifically?

Professor Boehm: Well, I think we were approaching that in the previous question which is that the systems that we are trying to engineer these days are getting a lot more complicated than the ones that were done before in that they are trying to pull together existing systems that have different owners and are operating on different timescales, different objectives, and different management chains. And somehow we need to make these things come together and operate as some kind of unified whole. At the same time these things are becoming more software intensive, so the software needs to be brought more up front. The pace of change in the system means that you have to do the systems engineering very rapidly or the system will be obsolete by the time you build it. And these things need to be much more resilient than they used to be because they are now driving the whole world's financial systems, the whole world's emergency services, and all the things we rely on in preserving and having a good quality of life.

IJITSA: Thanks very much for sharing your knowledge and wisdom with the IJITSA readers and us.

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Chapter 1.25

Information and Knowledge Perspectives in Systems Engineering and Management for Innovation and Productivity Through Enterprise Resource Planning

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ABSTRACT

This article provides an overview of perspectives associated with information and knowledge resource management in systems engineering and systems management in accomplishing enterprise resource planning for enhanced innovation and productivity. Accordingly, we discuss economic concepts involving information and knowledge, and the important role of network effects and path dependencies in influencing enterprise transformation through enterprise resource planning.

INTRODUCTION

Many have been concerned with the role of information and knowledge and the role of this in enhancing systems engineering and management (Sage, 1995; Sage & Rouse, 1999) principles, practices, and perspectives. Major contemporary attention is being paid to enterprise transformation (Rouse, 2005, 2006) through these efforts. The purpose of this work is to discuss many of these efforts and their role in supporting the definition, development, and deployment of an enterprise resource plan (ERP) that will enhance transformation of existing enterprises and development of new and innovative enterprises.

Economic Concepts Involving Information and Knowledge

Much recent research has been conducted in the general area of information networks and the new economy. Professors Hal R. Varian and Carl Shapiro have published many papers and a seminal text, addressing new economic concepts as they apply to contemporary information networks. These efforts generally illustrate how new economic concepts challenge the traditional model, prevalent during the Industrial Revolution and taught throughout industry and academia over the years. In particular, the book *Information Rules* (Shapiro & Varian, 1999) provides a comprehensive overview of the new economic principles as they relate to today's information and network economy. The book addresses the following key principles:

- Recognizing and exploiting the dynamics of positive feedback
- Understanding the strategic implications of lock-in and switching costs
- Evaluating compatibility choices and standardization efforts
- Developing value-maximizing pricing strategies
- Planning product lines of information goods
- Managing intellectual property rights
- Factoring government policy and regulation into strategy

These concepts have proven their effectiveness in the new information economy and have been fundamental to the success of many information technology enterprises introducing new ideas and innovations into the marketplace. Paramount to an enterprise's success in reaching critical mass for its new product offering is the understanding and implementation of these new economic concepts.

Economides (1996) has also been much concerned with the economics of networks. He and Himmelberg (1994) describe conditions under which a critical mass point exists for a network good. They characterize the existence of critical mass points under various market structures for both durable and non-durable goods. They illustrate how, in the presence of network externalities and high marginal costs, the size of the network is zero until costs eventually decrease sufficiently, thereby causing the network size to increase abruptly. Initially, the network increases to a positive and significant size, and thereafter it continues to increase gradually as costs continue to decline. Odlyzko (2001) expands on the concept of critical mass and describes both the current and future growth rate of the Internet and how proper planning, network budgeting, and engineering are each required. He emphasizes the need for accurate forecasting, since poor planning can lead to poor choices in technology and unnecessary costs.

Economides and White (1996) introduce important concepts with respect to networks and compatibility. They distinguish between direct and indirect externalities, and explore the implications of networks and compatibility for antitrust and regulatory policy in three areas: mergers, joint ventures, and vertical restraints. They also discuss how compatibility and complementarity are linked to provide a framework for analyzing antitrust issues. Strong arguments are made for the beneficial nature of most compatibility and network arrangements, with respect to vertical relationships, and policies are set forth to curb anti-competitive practices and arrangement. Farrell and Katz (2001) introduce concepts of policy formulation in preventing anti-competitive practices and, in addition, explore the logic of predation and rules designed to prevent this in markets that are subject to network effects. This work discusses how the imposition of the leading proposals for rules against predatory pricing may lower or raise consumer welfare, depending on conditions that may be difficult to identify in practice.

Research conducted on these economic concepts establishes a solid foundation and baseline for further research in the area of enterprise resource planning and new technology innovations (Langenwalter, 2000). In this work, he extends the traditional enterprise resource planning (ERP) model to incorporate a total enterprise integration (TEI) framework. He describes TEI as a superset of ERP and also describes how it establishes the communications foundation between customer, manufacturer, and supplier. Each entity is linked internally and externally, allowing the TEI system to enhance performance and to provide process efficiencies that reduce lead times and waste throughout the supply chain. This work illustrates how ERP is uniquely integrated with customers and suppliers into the supply chain using TEI and how it significantly improves customer-driven performance. The model for this includes five major components: executive support, customer integration, engineering integration, manufacturing integration, and support services integration. These components are essential for integrating all information and actions required to fully support a manufacturing company and its supply chain. TEI presents a strategic advantage to an enterprise, rather than just improving operating efficiencies. The TEI framework provides the enterprise a competitive edge by:

- Maximizing speed and throughput of information and materials
- Minimizing response time to customers, suppliers, and decision makers
- Pushing decisions to the appropriate levels of the organization
- Maximizing the information made available to the decision-makers
- Providing direct integration into the supply chain

In addition to the technology, TEI also incorporates stakeholders. People are empowered at all levels of the enterprise to improve the quality of their decision-making. One result of this is MRP II (Manufacturing Resources Planning) systems. MRP II evolved from MRP (Material Requirements Planning), which was a method for materials and capacity planning in a manufacturing environment. Manufacturing plants, to plan and procure the right materials in the right quantities at the right time, used this method. MRP became the core planning module for MRP II and ERP. MRP was later replaced by MRP II, which expanded the MRP component to include integrated material planning, accounting, purchasing of materials for production, and the shop floor. MRP II integrated other functional areas such as order entry, customer service, and cost control. Eventually, MRP II evolved into enterprise resource planning (ERP), integrating even more organizational entities and functions such as human resources, quality management, sales support, and field services. ERPs became richer in functionality and involved a higher degree of integration than their predecessors MRP and MRP II.

Another very well-known contributor to the field of enterprise resource planning is Thomas H. Davenport (2000). In *Mission Critical: Realizing the Promise of Enterprise Systems*, the need to take a customer or product focus when selecting an operational strategy is emphasized. To enable this, a direct connection should exist between the daily operations and the strategic objectives of the enterprise. This is made possible through the use of operational data, that is used to enhance the operational effectiveness of the enterprise. Operational data is defined by the organization seeking to measure the operational effectiveness of its environment. Operational data may be defined in terms of various parameters such as cycle time (CT), customer response time (CRT), or MTTR (mean time to repair). These are only a few of the parameters, and they are contingent on the operational strategy the organization is seeking to adopt. For example, an organization that seeks to reduce cycle time (CT) for processing orders in order to minimize cost may look to capture CT in its operational data. This data is captured over time as process efficiencies are instituted within the existing order process. Operational effectiveness is then determined by comparing the future CT state of the order process with that of its initial CT benchmark. For example, if cycle time to process an order was originally 15 minutes, and after the process efficiencies were instituted, CT was then 5 minutes, then operational effectiveness improved by 10 minutes. Now it takes fewer resources to process orders, thus reducing operational costs.

Davenport (2000) introduces a data-oriented culture and conveys the need for data analysis, data integrity, data synthesis, data completeness, and timely extracts of data. Data is used across organizational boundaries and shared between the various entities in an effort to enhance operational effectiveness. For example, transaction data must be integrated with data from other sources, such as third-party vendors, to support effective management decision-making. One's ability to interpret and analyze data can effect the decisions that are made and the confidence management has in pursuing particular ongoing decisions. Davenport believes that a combination of strategy, technology, data (data that is relevant to the organization), organization, culture, skills and knowledge assist with developing an organization's capabilities for data analysis. When performing data analysis, various organizations may have similar results, but with different meanings. He indicates that a typical corporation may have divisions that have a need to store customer data in different customer profile schemes. Therefore, a common shared master file between the divisions may not be feasible. This approach takes on more of a distributed approach versus a centralized approach to data management. The operational effectiveness of each of these divisions will vary based on the benchmarks and target improvements they have set for themselves.

Christopher Koch (2006) supports Davenport's data concept and elaborates on the value of an ERP and how it can improve the business performance of an enterprise. He demonstrates the value of an ERP by integrating the functions of each organization to serve the needs of all stakeholders. The associated framework attempts to integrate all organizational entities across an enterprise onto a single-systems ERP platform that will serve the needs of the various entities. This single platform replaces the standalone systems prevalent in most functional organizations such as human resources, finance, engineering, and manufacturing, thereby allowing people in the various organizations to access information not only in the most useful manner but also from their own perspectives. This information may be the same shared data used between the organizations or may vary, based on the need of each of the organizations. Each organization in the enterprise and its stakeholders will have their own set of requirements for accessing, viewing and manipulating their data. Data management may even take on a hybrid of a centralized and distributed approach. Some organizations may need a view of the same data, while others may have their own unique data requirements. Koch (2006) indicates that there are five major reasons why an enterprise adopts an ERP strategy:

1. Integrate financial information
2. Integrate customer order information
3. Standardize and speed up manufacturing processes
4. Reduce inventory
5. Standardize human resources (HR) information

Each organization within an enterprise has its own requirements for an ERP. They may share the same ERP solution; however, the ERP may be designed to support the specific business need of each organization. Some organizations may have a need to view the same data. For example, a sales and customer care-focused organization may need to view the same customer profile data to access customer contact information. In comparison, a human resources-focused organization may not need to be privy to this same information. They may be more interested in accessing internal employee personnel records for employee performance monitoring. The senior executive level of an enterprise will also have its own unique data requirements in order to make key strategic and tactical decisions. This executive level may need the capability to access data from each of the organizational units in order to effectively manage the operations of the business. The organizations, within an enterprise each have their own instances of an ERP with respect to accessing data and implementing processes. Some organizations may share a common process such as the order fulfillment process. For example, this process may be shared between organizational entities such as sales, operations, and revenue assurance. Sales would complete a service order, operations would deliver the service, and revenue assurance would bill the customer. However, there are processes that are only unique to a particular organization. For example, the marketing organization may not be interested in the escalation process used by operations to resolve customer issues. This process is unique to operations and, as a result, the ERP would be designed for such uniqueness. The design of an ERP should, of course, take organizational data and process requirements into account and support management of the enterprise and its inter-workings in a transdisciplinary and transinstitutional fashion (Sage 2000, 2006).

William B. Rouse had produced very relevant and important popular work surrounding new technology innovation with respect to the enterprise. In *Strategies for Innovation*, Rouse (1992) addresses four central themes to introduce strategies for innovation in technology-based enterprises. Rouse discusses the importance of strategic thinking and how some enterprises fail to plan long term. This is based on the notion that "while people may want to think strategically, they actually do not know how(p. 3)." He emphasizes the need for stakeholders to understand the solutions offered as a result of new innovation, and how strategies are critical for ensuring successful products and systems. Most importantly, these strategies must also create a successful enterprise for developing, marketing, delivering, and servicing solutions, thus leading to the need for human-centered planning, organization, and control. These are among the approaches needed to stimulate innovation in products and services (Kaufman & Woodhead, 2006).

Rouse (1992) describes the need for applying a human-centered design methodology to the problem of enhancing people's abilities and overcoming their limitations. In the process of planning, organizing, and controlling an enterprise, he illustrates how technology-based enterprises differentiate themselves from each other based on their core product technologies. This strategic strength is based on the unique value that the core product can provide to the marketplace. He indicates that the enterprise should continuously analyze the market and measure core product value to determine the benefits that can be provided. Assessing and balancing the stakeholders' interests will be necessary to ensure success of the core product. Stakeholders consist of both producers and consumers. Each may have a stake in the conceptualization, development, marketing, sales, delivery, servicing, and use of the product. The three key processes highlighted in this work are: strategic planning, operational management, and the engineering/administration, vehicles used by the enterprise to assist stakeholders with pursuing the mission of the enterprise.

Rouse further addresses strategic approaches to innovation in another one of his books. In *Essential Challenges of Strategic Management* (Rouse, 2001), he illustrates the strategic management challenges faced by all enterprises and introduces best practices for addressing these challenges. He disaggregates the process of strategically managing an enterprise into seven fundamental challenges. The essential challenges he describes, which most enterprises are confronted with, are: growth, value, focus, change, future, knowledge, and time. Growth is critical to gaining share in saturated and declining markets and essential to the long-term well-being of an enterprise. A lack of growth results in declining revenues and profits, and, in the case of a new enterprise, there is the possibility of collapse. He describes value as the foundation for growth, the reason an enterprise exists. Matching stakeholders' needs and desires to the competencies of the enterprise, when identifying high-value offerings, will justify the investments needed to bring these offerings to market. While value enhances the relationships of processes to benefits and costs, focus will provide the path for an enterprise to provide value and growth. Focus involves pursuing opportunities and avoiding diversions, that is, making decisions to add value in particular ways and not in others are often involved. For example, allocating too few resources among many projects may lead to inadequate results or possible failure.

The focus path is followed by another path called change. An enterprise challenged with organizational re-engineering, downsizing, and rightsizing often takes this change path. The enterprise will continue to compete creatively while maintaining continuity in its evolution. As the nature of an organization changes rapidly during an enterprise's evolution, managing change becomes an art. According to Rouse (2001), investing in the future involves investing in inherently unpredictable outcomes. He describes the future as uncertain. The intriguing question is, "If we could buy an option on the future, how would we determine what this option is worth(p. 6)?" A new enterprise will be faced with this challange when coming into the marketplace.

The challenge of knowledge is transformation of information from value-driven insights to strategic programs of action. Determining what knowledge would make an impact, and in what ways, is required. This understanding should facilitate determining what information is essential and should provide further elaboration on how it is to be processed and how its use will be supported. The most significant challenge identified is that of time. A lack of time is the most significant challenge facing best use of human resources. Most people spend too much time being reactive and responding to emergencies, attending endless meetings, and addressing an overwhelming number of e-mails, all of which cannibalize time. As a result, there is little time for addressing strategic challenges. Carefully allocating the scarcest resource of an organization is vital to the future of an enterprise. Some of the best practices Rouse (2001) has presented in addressing the seven strategic challenges may be described as follows.

- **Growth:** Buying growth via strategic acquisitions and mergers; fostering growth from existing market offerings via enhanced productivity; and creating growth through innovative new products and brand extensions.
- **Value:** Addressing the nature of value in the market; using market forces in determining the most appropriate business process; and designing cost accounting system to align budgets and expenditures with value streams.
- **Focus:** Deciding what things to invest in and those things to be avoided or stopped; and linking decisions or choices to organizational goals, strategies, and plans.
- **Change:** Instituting cross-functional teams for planning and implementing significant changes; and redesigning incentive and reward systems in order to ensure that people align their behaviors with desired new directions.

- **Future:** Employing formal and quantitative investment decision processes; and creating mechanisms for recognizing and exploiting unpredictable outcomes.
- **Knowledge:** Ensuring that knowledge acquisition and sharing are driven by business issues in which knowledge has been determined to make a difference; using competitive intelligence and market/customer modeling to provide a valuable means for identifying and compiling knowledge.
- **Time:** Committing top management to devoting time to challenges; and improving time management, executive training, and development programs, in addition to providing increased strategic thinking opportunities.

Gardner (2000) takes a complementary approach to the enterprise and to innovation by focusing on the valuation of information technology. He addresses the difficulties of defining the value of new technologies for company shareholders using integrated analytical techniques in his book *The Valuation of Information Technology*. Gardner presents methodologies for new enterprise business development initiatives and presents techniques for improving investment decisions in new technologies. This 21st-century approach to valuation avoids making investment decisions on an emotional basis only, in favor of predicting shareholder value created by an information technology system before it is built. Determining the contribution an information technology system makes to a company's shareholder value is often challenging and requires a valuation model. Gardner suggests that the primary objective of information technology systems development in business is to increase the wealth of shareholders by adding to the growth premium of their stock. The objective of maximizing shareholder wealth consists of maximizing the value of cash flow generated by operations. This is accomplished by generating future investment in information technology systems. As an example, this could be a state-of-the-art enterprise resource planning system, which could easily maximize what we will call operational velocity and, as a result, maximize shareholder wealth. The process that Gardner suggests using would be to first identify the target opportunity, align the information technology system to provide the features the customer wants in a cost-effective manner, and then to accurately measure the economic value that can be captured through this.

Some of the techniques Gardner uses to compute economic value are net present value (NPV), rate of return (ROR), weighted average cost of capital (WACC), cost of equity, and intrinsic value to shareholders of a system. Each of these techniques may be used to determine aspects of the shareholder value of an information technology system. The results from computing these values will assist an enterprise with making the right decisions with respect to its operations. For example, if the rate of return on capital is high, then time schedule delays in deploying an information technology system can destroy enormous value. Time to market becomes critical in this scenario. Gardner suggests that it may be in the best interest of the company to deploy the system early by mitigating the potential risk and capitalizing on the high rate of return. A risk assessment must be performed to ensure that the customer relationship is not compromised at the expense of implementing the system early. If the primary functionality of the system is ready, then the risk would be minimal, and the other functional capabilities of the system may be phased in at a later time.

If the rate of return is low, however, schedule delays will have a lesser effect on value and deployment of a system does not immediately become crucial to the success of the enterprise. This approach to predicting value takes a rational approach to decision making by weighing the rewards and risks involved with an information technology system investment. The author suggests moving away from the more intuitive approach of valuation often practiced in the high-tech industry, which is said to be very optimistic, spotty, and driven by unreasonable expectations from management. Gardner describes this intuitive practice as a non-analytical approach to assessing the economic viability of an information technology system. This practice primarily ignores the bare essentials that management must consider in assessing whether the economics of an information technology system are attractive. Gardner has established an analytical framework for analyzing the economics of information technology systems. His process is comprised of the three following steps:

1. Identify the target customer opportunity.
2. Align the information technology system to cost-effectively provide the features the customer wants.
3. Measure the economic value that can be captured.

The result of utilizing the framework is the quantification of the shareholder value created by an information technology system.

Boer (1999) also has much discussion on the subject of valuation in his work on *The Valuation of Technology*. He illustrates links between research and development (R&D) activity and shareholder value. In addition, he identifies the languages and tools used between business executives, scientists, and engineers. The business and scientific/engineering communities are very different environments and are divided by diverse knowledge and interest levels. Bridging the gap between these communities is made possible through the process of valuation, which fosters collaboration and communication between both communities. Boer identifies the link between strategy and value and addresses the mutual relationship between corporate strategy and technology strategy. He introduces tools and approaches used to quantify the link between technological research and commercial payoff within the value model of an enterprise.

This value model is comprised of four elements: operations, financial structure, management, and opportunities. The opportunity element is most critical to the future growth of an enterprise. The options value of an enterprise and how it is addressed strategically will determine the fate of an emerging enterprise. Boer illustrates how productive research and development creates options for the enterprise to grow in profitability and size. He views R&D as a component of operations, since this is the point at which new technology is translated into commercial production. In the competitive marketplace, the enterprise evolves in order to generate opportunity and growth. R&D serves as the vehicle for converting cash into value options for the enterprise. Boer introduces R&D stages (conceptual research, feasibility, development, early commercialization), where the level of risk, spending, and personnel skills vary. Each stage of the R&D process allows management to make effective decisions regarding the technology opportunity and perform levels of risk mitigation. R&D can be instrumental in decreasing capital requirements with results of a very high rate of return on the R&D investment. The art of minimizing capital requirements requires good and effective communication between the scientific/engineering and business communities. This will allow both communities to share their views and foster the need for driving this essential objective.

Some of the methods Boer uses for asset valuation are similar to Rouse's methods. Boer uses discounted cash flow (DCF), NPV, cost of money, weighted average cost of capital, cost of equity, risk-weighted hurdle rates for R&D, and terminal value methods for assessing valuation. In accelerated growth situations, as in the case of an emerging enterprise, Boer emphasizes that the economic value is likely to be derived from the terminal value of the project, not from short-term cash flows. A lack of understanding of terminal value can compromise the analysis of an R&D project. R&D can be a cash drain, and the outcomes are difficult to predict. Boer's techniques provide a vehicle for converting cash into opportunity and creating options for the enterprise.

Another work that addresses valuation is entitled *The Real Options Solution: Finding Total Value in a High-Risk World* (Boer, 2002). Here, the author presents a new approach to the valuation of business and technologies based on options theory. This innovative approach, known as the total value model, applies real options analysis to assessing the validity of a business plan. All business plans are viewed as options. These plans are subject to both unique and market risks. While business plans seem to create no value on a cash flow basis, they do become more appealing once the full merit of all management options is recognized. Since management has much flexibility in execution, the model offers a quantifiable approach to the challenge of determining the strategic premium of a particular business plan. Boer defines total value as "the sum of economic value and the strategic premium created by real options (p. vii)." He presents a six-step method for applying this model in a high-risk environment for evaluating enterprises, R&D-intensive companies, bellwether companies, capital investments, and hypothetical business problems. His method reveals how changes in total value are driven by three major factors: risk, diminishing returns, and innovation.

Boer's option theory efforts provide the enterprise with a vehicle for computing the strategic premium to obtain total value. This six-step method to calculate total value is comprised of:

1. Calculation of the economic value of the enterprise,
2. Framing the basic business option,
3. Determining the option premium,
4. Determining the value of the pro forma business plan,
5. Calculating the option value, and
6. Calculating total value.

Options theory approached to valuation leverage on elements of uncertainty such as these afford enterprise managers major investment opportunities. This was not common using more traditional valuation methods such as NPV- and internal rate of return (IRR)-based calculations. As Boer (2002) illustrates, the new options theory emphasizes the link between options, time, and information. Boer states: "Options buy time. Time produces information. Information will eventually validate or invalidate the plan. And information is virtual (p. 106)." This theory and its extensions (Boer, 2004) may well pave the way for a new generation of enterprise evolution and enterprise innovation.

Rouse (2005, 2006) is concerned with the majority of these issues in his development of systems engineering and management approaches to enterprise transformation. According to Rouse, enterprise transformation concerns change, not just routine change but fundamental change that substantially alters an organization's relationships with one or more of its key constituencies: customers, employees, suppliers, and investors. Enterprise transformation can take many forms. It can involve new value propositions in terms of products and services and how the enterprise should be organized to provide these offerings and to support them. Generally, existing or anticipated value deficiencies drive these initiatives. Enterprise transformation initiatives involve addressing the work undertaken by an enterprise and how the work is accomplished. Other important elements of the enterprise that influence this may include market advantage, brand image, employee and customer satisfaction, and many others.

Rouse suggests that enterprise transformation is driven by perceived value deficiencies due to existing or expected downside losses of value; existing or expected failures to meet promised or anticipated gains in value; or desire to achieve new, improved value levels through marketing and/or technological initiatives. He suggests three ways to approach value deficiencies: improve how work is currently performed; perform current work differently; and/or perform different types of work. Central to this work is the notion that enterprise transformation is driven by value deficiencies and is fundamentally associated with investigation and change of current work processes such as to improve the future states of the enterprise. Potential impacts on enterprise states are assessed in terms of value consequences.

Many of the well-known contributors in the field of enterprise resource planning presented had developed their own unique model. Each had established a strategy to address the evolution and growth of the enterprise. Differences between the models varied based on the challenge presented and the final objective to be achieved by the enterprise. A comparison of the ERP models presented is illustrated in Table 1.

Fundamentally, system engineering and system management are inherently transdisciplinary in attempting to find integrated solutions to problems that are of a large scale and scope (Sage, 2000). Enterprise transformation involves fundamental change in terms of reengineering of organizational processes and is also clearly transdisciplinary as that success necessarily requires involvement of management, computing, and engineering, as well as behavioral and social sciences. Enterprises and

Table 1. Comparison of ERP models

ERP Models				
Contributor	**Model**	**Strategy**	**Challenge**	**Objective**
Gary A. Langenwalter	Total enterprise integration (TEI) framework	• Integrates customer, manufacturer, and supplier • Provides competitive edge by: maximizing speed of information, minimizing response time, pushing decisions to the correct organizational level, maximizing information available to decision-makers, and direct integration of supply chains	• Establishing seamless communication • Multi-functional integration	• Incorporate all stakeholders • Empower people at all levels of the organization • Improve quality of decision-making
Thomas H. Davenport	Operational data model	• Introduces data-oriented culture • Supports a customer and product focus • Uses operational data to measure operational effectiveness	• Defining organizational boundaries • Enhancing operational effectiveness	• Define operational performance parameters • Measure operational effectiveness • Support effective decision-making
Christopher Koch	Business performance framework	• Supports data sharing • Integrates financial information • Integrates customer order information • Standardizes manufacturing process • Reduces inventory • Standardizes HR information	• Centralized and distributed approach to data management • Establishing requirements for accessing, viewing, and manipulating data	• Integrate all organizational entities across a single systems platform • Manage enterprise in transdisciplinary and transinstitutional fashions

continued on following page

Table 1. continued

William B. Rouse	Strategic innovation model	• Introduces a strategic approach to innovation • Focuses on the need for human-centered planning, organization, and control • Differentiating from the competition based on core product technologies	• Enhancing people's abilities and overcoming their limitations • Essential challenges: growth, value, focus, change, future, knowledge, and time	• Support strategic planning, operational management, and engineering • Ensure the successful innovation of products and systems
Christopher Gardner	Valuation model	• Presents methodologies for new enterprise business development initiatives • Determines the contribution an enterprise system makes to a company's shareholder value	• Defining the value of new technologies • Mitigating the potential risk and capitalizing on the high rate of return	• Increase shareholder wealth • Maximize the value of cash flow generated by operations
Peter F. Boer	Options model	• Bridges the gap between the business and scientific/engineering communities • Introduces research and development that creates options for the enterprise to grow in profitability and size	• Identifying the link between corporate strategy and technology strategy • Minimizing capital requirements • Understanding terminal value of a project	• Introduce research and development stages for assessing technology opportunities • Determine strategic premium created by real options

associated transformation are among the complex systems addressed by systems engineering and management. Rouse's efforts (2005, 2006) provide a foundation for addressing these issues and the transdisciplinary perspective of systems engineering and management provide many potentially competitive advantages to deal with these complex problems and systems.

Network Effects and Their Role in Enterprise Resource Planning

In today's information economy, introducing new technologies into the marketplace has become a significant challenge. The information economy is not driven by the traditional economies of scale and diminishing returns to scale that are prevalent among large traditional production companies. It has been replaced by the existence of network effects (also known as network externalities), increasing returns to scale and path dependence. This is the core economic reality, and not at all a philosophy, which has revolutionized traditional economic theories and practices, resulting in a new approach to economic theory as it pertains to the information economy.

There are a number of market dynamics or external variables that impact the success of any new technology entering the market. The most common variable is the element of network effects. A product exhibits network effects when its value to one user depends on the number of other users. Liebowitz and Margolis (1994) define network effects as the existence of many products for which the utility that a user of them derives from their consumption increases with the number of other agents that are also utilizing the product, and where the utility that a user derives from a product depends upon the number of other users of the product who are in the same network. Network effects are separated into two distinct parts, relative to the value received by the consumer. Liebowitz and Margolis (1994) denote the first component as the autarky value of a technology product, the value generated by the product minus the other users of the network. The second component is the synchronization value, the value associated when interacting with other users of the product. The social value derived from synchronization is far greater than the private value from autarky. This social value leads the way to increasing returns to scale, by creating path dependence (also known as positive feedback) and influencing the outcome for network goods. These efforts and others are nicely summarized in Liebowitz (2002) and Liebowitz and Margolis (2002).

Path dependence is essential for a company to reach critical mass when introducing new technologies into the market. As the installed customer base grows, more customers find adoption of a new product or technology of value, resulting in an increase in the number of consumers or users. Consumer choices exhibit path dependence for new products as others realize their value, eventually leading to critical mass. Path dependence is simply an effect whereby the present position is a result of what has happened in the past. The path dependence theory demonstrates that there are a number of stable alternatives, one of which will arise based on the particular initial conditions. Path dependence is evident when there is at least persistence or durability in consumer decision-making. Decisions made by early adopters can exhibit a controlling influence over future decisions or allocations made by late adopters. These product decisions are often based on the individual arbitrary choices of consumers, persistence of certain choices, preferences, states of knowledge, endowments, and compatibility. The outcome may depend on the order in which certain actions occur based on these behavioral determinants.

Network effects, increasing returns, and path dependence can be better illustrated when applied to the concept of a virtual network. The virtual network has similar properties to a physical or real network, such as a communications network. In such networks, there are nodes and links that connect the nodes to each other. In a physical network, such as a hard-wire communications network, the nodes are switching platforms and the links are circuits or telephone wires. Conversely, the virtual network nodes may represent consumers and transparent links represent paths, as driven by network effects and path dependence, that impact consumer behavior. The value of connecting to the network of Microsoft Office users is predicated on the number of people already connected to this virtual network. The strength of the linkages to the virtual network and its future expansion is based on the number of users who will use the same office applications and share files.

Path dependence can easily generate market dominance by a single firm introducing a new technology. This occurs when late adopters latch onto a particular virtual network, because the majority of users already reside on this infrastructure and have accepted the new technology. As more consumers connect to the virtual network, it becomes more valuable to each individual consumer. Consumers benefit from each other as they connect to the infrastructure. The larger network becomes more attractive to the other consumers who eventually become integrated. A communications network can best illustrate this concept. For example, additional users who purchase telephones and connect to a communications infrastructure bring value to the other users on the network, who can now communicate with the newly integrated users. This same concept applies to the virtual network and has the same impact. Real and virtual networks share many of the same properties and, over time, are destined to reach a critical mass of users.

New and emerging startup enterprises seeking to take advantage of network effects and path dependence when launching a new technology or innovation in the marketplace must have a reliable and operationally efficient enterprise resource planning (ERP) solution in place. The ERP solution must be capable of attaining operational velocity to address market demands. Miller and Morris (1999) indicate that traditional methods of managing innovation are no longer adequate. They suggest that as we make the transition to fourth generation R&D, appropriate complex timing for innovations remains a significant challenge. These authors assert that as new technologies and new markets emerge, management must deal with complexity, enormous discontinuities, increasing volatility, and the rapid evolution of industries. The challenge becomes that of linking emerging technologies with emerging markets through methods such as an ERP solution to bridge this link and to allow new emerging enterprises, or established mature enterprises seeking to transform themselves, to adapt quickly to the dynamics of the marketplace. The solution supports both continuous and discontinuous innovation as defined by Miller and Morris (1999). This form of innovation works well when customer needs in a competitive environment can be met within existing organizational structures.

In contrast to this, discontinuous innovation may bring forth conditions emanating from fundamentally different new knowledge in one or more dimensions of a product or service, and offer significantly different performance attributes. Discontinuous change potentially brings about change in a deep and systematic way. It offers a potential lifestyle change to customers that can be dramatic. Miller and Morris (1999) note, for example, the transition from typewriters to personal computers for producing written documents. In part, this occurred because customers no longer were satisfied with the existing framework of capability offered by the typewriter. New knowledge, organizational capabilities, tools, technology, and processes changed the behavior and desires of the customer. In addition to this change was also the change resulting in supporting infrastructure. Miller and Morris (1999) emphasize that discontinuous innovation affects not only products and services but also the infrastructures integral to their use, as well as extensive chains of distribution that may involve a plethora of affiliated and competing organizations.

As the threat of unexpected competition surrounds any new enterprise entering the market, the risk associated with technology shifts and the compression of the sales cycle make successfully managing discontinuous innovation a necessary challenge for success. We must be able to gauge how the market is evolving and what organizational capabilities must exist to sustain competitiveness as a result of this evolution. Because innovation usually requires large capital infusions, decreasing the time for appearance of a positive revenue stream is critical to the success of the enterprise. This decrease in time is made possible through operational velocity attainment, which requires changes in existing implementation strategies and organizational capabilities. This requires a collaborative effort between the various involved organizations to understand what is needed to support new innovations. Responsibility for supporting new innovation is not only supported by internal organizations but by such external organizations as suppliers, customers, and partners. Organizational structure, capabilities, and processes are fundamental to an evolutionary ERP model and serve as the framework for supporting new technology adoption in the marketplace.

The information economy is driven by network effects (also termed demand-side economies of scale or network externalities). Network effects support path dependence and are predicated on Metcalfe's Law, which suggests that the value of a network goes up as the square of the number of users (Shapiro & Varian, 1999), or on recent suggested modifications to this (Briscoe, Odlyzko, & Tilly, 2006). Positive effects occur when the value of one unit increases with an increase in the number of the same unit shared by others. Based on this premise, it is possible to create an enterprise resource planning model that influences positive feedback from human behavior in adopting new technologies and accelerates critical mass early in the deployment phase of the product development lifecycle, by attaining operational velocity. Operational velocity is defined in terms of speed in delivering products or services to market, meeting all customer expectations in a timely manner, and decreasing the time for appearance of a positive revenue stream as much as possible. This ERP model would support the integration of data, standardization of processes, order fulfillment, inventory control, supply-chain management, and customer relationship management (CRM) as critical drivers to result in enterprise transformation.

William B. Rouse, in his work *Strategies for Innovation* (Rouse, 1992), states "A prerequisite for innovation is strategies for making stakeholders aware of enabling technology solutions, delivery of theses solutions in a timely fashion, and providing services that assure the solutions will be successful. These strategies must not only result in successful products or systems, they must also create a successful organization—an enterprise—for developing, marketing, delivering, and serving solutions" (p. 2). His philosophy encompasses the human-centered design approach that takes into account the concerns, values, and perceptions of all stakeholders during a design initiative. This approach entertains the views of all the stakeholders, balancing all human considerations during the design effort.

Traditionally, when designing an enterprise resource planning solution, very few enterprises are easily able to think strategically. Most are only concerned with today's products and services and the financial profits and revenue growth realized in the short term. They often fail to properly forecast future growth and to properly scale their ERP in order to meet the potential consumer demands of the future. An enterprise must be able to plan for and respond to future demands by analyzing the market and evaluating the impact that their core product technologies will have in the marketplace. Market demand will drive consumer needs and desire for these core product technologies, as well as the type of ERP that will be used to support these products. An effective ERP must be capable of assessing and balancing all stakeholders' interests consciously and carefully. The market share that an enterprise is able to acquire for its core product technologies can be tied to how well an ERP is developed, deployed, and implemented in order to provide the operational support infrastructure needed. Many of the traditional success factors for an enterprise have been their position in the marketplace, achievements as innovators, productivity, liquidity and cash flow, and profitability. In order for an enterprise to grow and mature, it must be able to respond to market demand in a timely manner. Responding to market demand includes timely delivery of products and services, immediate attention to customer problem/resolution, and continuous process improvements. Operational velocity attainment becomes the focus and the critical success factor in the execution of an evolutionary ERP strategy, thus supporting the long-term vision of the enterprise by ensuring a strategic advantage for the enterprise.

A well-thought-out ERP strategy will require advanced planning to determine how each of the organizations will be integrated in supporting the long-term objective. Critical to the success of an enterprise is how well its associated organizations can adapt to organizational change, as the company begins to mature and demand increases for the new innovative products and services. Change may include the type of culture that is fostered, tools used, and level of knowledgeable resources required to make the organizational transitions. Most importantly, customer experiences becomes the focus. How fast an enterprise can service customers to meet their expectations may determine how soon it meets revenue expectations. The quality of on-time customer service could impact the number of future sales. A good product or service, combined with excellent customer service, may drive more business to the enterprise, decreasing the time taken to meet revenue forecasts. The mechanism used to drive customer on-time service becomes what we call an evolutionary ERP model. In order for new core technology products to become acceptable to a newly installed base of customers, service delivery and customer response times must be minimized as much as possible. True enterprise growth and profitability can be made possible through this model for emerging enterprises delivering new innovations to the marketplace. The model takes into account the long-term vision of the enterprise, which is a key to its consistent success. Rouse (1992) states this well when he says that many technology-based startup companies are very attracted to learning about new technologies, using these to creating new products, and hiring appropriate staff to accomplish these. Such activities may get the product, resulting from the enterprise vision, into the marketplace. Initial sales and profit goals may be achieved. He appropriately notes that without a long-term vision, plans for getting there, and an appropriate culture; no amount of short-term oriented activity will yield consistent long-term success.

The strategic advantages that a well-defined, developed, and deployed ERP brings to the enterprise are: integration across the enterprise, communication, operating efficiencies, modeling, and supply chain management. These effective strategies assist with bridging the overall corporate strategies with the organizational objectives. Integration across the enterprise supports the following organizational objectives:

- Maximization of speed and throughput of information,
- Minimization of customer response times,
- Minimization of supplier and partner response times,
- Minimization of senior management response times,
- Decision-making authority pushed to the appropriate levels within the organization, using work flow management,
- Maximization of information to senior management,
- Direct integration of the supply chain,
- Reduction of inventories,
- Reduction in order-to-ship time,
- Reduction in customer lead times, and
- Total quality integration.

Communication links the enterprise to both the suppliers and the customers. Good communication between supplier and the enterprise can help reduce design errors, foster good supplier and enterprise relationships, reduce enormous costs, reduce the supplier's time to respond to the enterprise, and improve performance and market adoption of a new core technology product.

Langenwalter (2000) indicates in his work on enterprise resource planning that integrating the design process with customers can surface customer responses with respect to their true needs. He emphasizes the voice of the customer (VOC) as a proven methodology that addresses the true needs and expectations of the customer. VOC serves as basic input to the evolutionary ERP model. Key customer considerations in achieving operational velocity using this model are ranked customer expectations, performance metrics, and customer perceptions of performance.

In *The Valuation of Technology*, Boer (1999) is also concerned with these customer considerations by including the concept of the value proposition from the customer's viewpoint. He emphasizes that stakeholders must find useful ways to determine the value added in every step of the business process from the viewpoint of the customer. The enterprise must exist to deliver value to the extent that it improves operational performance and/or lower costs through new or enhanced products, processes and services. For example, the operations of an enterprise will focus on procuring equipment and materials from vendors and suppliers to produce products on time and within budget. The operations objective is to meet customer demand through scheduling, procurement, implementation, and support, to meet the ever-changing needs of the customer environment. These changes must be measured so that the operations of the enterprise may be able to meet the needs of the marketplace. Such flexibility of operations in the marketplace is essential in keeping up with the dynamic needs of the customer.

In the new technology age, markets are moving much faster than traditional predictive systems suggest. Flexibility therfore becomes an essential and necessary element in achieving operational velocity. To achieve this, Langenwalter (2000) introduces a new measurement system that recognizes the ever-changing dynamics of products, customers, workers, and processes. His approach is based on the assumption that all products have life cycles and should have four key metrics: profitability, time, quality, and company spirit. Encompassing this approach would be the execution of a continuous process improvement initiative, with respect to the operational component of the product lifecycle. He proposes that the enterprise measure each organizational contribution to profit for the entire lifecycle of the product. An ERP can effectively measure the contribution to margin that a sales organization may make on new product releases. Unprofitable products can be immediately identified and retired. In comparison, an ERP can also track the total lifecycle cost that a manufacturing organization incurs when producing a product. Total profit and loss (P&L) responsibilities can be tracked and material procurement and cost strategies can be evaluated to enhance profitability to the extent possible. Other organizational facets such as engineering and marketing can increase profits, by accessing customer profile information from an ERP and trending product demand for various new features and functionality. Incorporating new design considerations in future product releases may also increase potential profitability, as more high-end products are released.

The element of time is an important metric and is truly a measure of process, although process efficiencies can also translate into cost savings. Langenwalter (2000) describes three key time dimensions: time to market, time to customer, and velocity. Each is a component of operational velocity. In achieving operational velocity, time to market is critical for new technology adoption. It is crucial for new enterprises to launch their core technology product(s) on time, in order to sustain long-term product profitability. This is especially true if new technology is involved. Langenwalter (2000) indicates that a study performed by the McKinsey Consulting Group reflects that a six-month delay in entering a market results in a 33% reduction in after-tax profit over the life of the product. In addition, the six-month delay is five times more costly than a 50% development-cost overrun and approximately 30% more costly than having production costs 10% over budget.

An ERP should be capable of monitoring product development and manufacturing processes to ensure timely delivery of products to market. Such items as customer requirements, technical viability, manufacturing costs, production volumes, staffing levels, work order priorities, material requirements, and capacity requirements can be accessible via the ERP, and allow both the engineering and manufacturing components in an organization to respond to product demands quickly. The ERP supports time to market in that these two organizations are able to ensure efficient product development manufacturing processes and organizational communication in launching new products to market. The ERP, so enabled, becomes the common domain and communications intermediary between engineering and manufacturing.

Time to customer is the next most critical dimension, or aspect, of time as described by Langenwalter (2000). This time dimension is focused on reducing lead times to customers. For example, manufacturers look to reduce the lead-time it takes to produce a product, component, or assembly. Although it may have taken weeks to produce a particular component, improved manufacturing capabilities may now enable this process in only two days. This may have been accomplished through the use of an ERP, which made it possible to track performance metrics of the various manufacturing processes. As a result of isolating various inhibiting manufacturing processes and improving these processes, time to customer was reduced significantly, thus supporting the operational velocity objective of the enterprise.

Another good example is customer care, achieved by responding to a product fault scenario and providing technical support capability to the customer for fault resolution. Response to a customer call may have originally taken 72 hours to resolve the problem due to the lack of an effective scheduling tool for the timely dispatching of technical support field resources. With the integration of a resource-scheduling tool within ERP, customer care can now respond perhaps within four hours and provide timely customer support. Velocity, the final dimension that Langenwalter presents, is defined as the total elapsed time consumed by a process divided by the actual value-added time contributed by the same process.

The quality metric of the product life cycle, as described by Langenwalter, focuses on continuous improvement. Quality metrics are very much tied to what may be called an evolutionary enterprise resource planning architecture framework. Operational velocity is only as good as the product and the service that is delivered. Any compromise in quality may translate to potential customer attrition and/or the degradation of market share. A good ERP should be capable of tracking product component failure rates and product design flaws, so that immediate action may be exercised on the part of the enterprise. Speed without quality only becomes a formula for failure. Product failures are not the only inhibitors of quality. A lack of knowledgeable and skilled resources can compromise quality, and this describes Langenwalter's last critical metric – company spirit. He emphasizes the fact that people are the ones who develop relationships with customers and suppliers, eventually leading to new products and processes. This metric goes outside much traditional thinking. However, during the enterprise startup technology revolution, company spirit is generally the most important element of survival and success among enterprises. This leads to a greater sense of ownership and responsibility among the people involved. An enterprise without a healthy team spirit and aggressive workforce has little chance of success.

Rouse (1992) introduces yet another interesting growth strategy that further supports the concept of operational velocity for new technology adoption. He describes a strategy for growth via enhancing productivity through process improvement and information technology. This approach leads to higher quality and lower cost of products and services and, eventually, to greater market share and profits. Enterprise performance is not as visible as product performance, so the money and time saved on process refinements often go unnoticed. Each approach has its own value. Rouse describes product value as the foundation for growth and indicates that the challenge of value concerns matching stakeholders' needs and desires to the enterprise's competencies in the process of identifying high-value offerings that will justify investments needed to bring these to market. Value to the customer is dependent on the particular market domain. The most noticeable form of value comes in the form of new innovations that meet a customer's economics or needs. Customers quickly realize the benefits of a new technology product; however, the real value is determined at the enterprise level, where customer support becomes critical. Technology products are sophisticated and require a high level of customer support when potential problems arise. After the sale of the product, the relative performance of the enterprise becomes the focus of the customer. Lack of timely and quality support can erode consumer confidence and eventually erode market share for an enterprise.

After the launch of its first product, an enterprise is immediately under the scrutiny of the public. Often, early adopters of new technologies can either make or break an emerging enterprise. Early adopters will assess the enterprise on product quality, delivery, and customer support. If the product is reliable and performs well, then delivery and customer support become the two most critical criteria that a customer will evaluate. It is usually the shortfalls in these two areas that diminish consumer confidence and challenge the credibility of a new enterprise. An enterprise that has an ERP strategy to address these criteria is better positioned for success. If the ERP is designed well, it will allow the enterprise to ensure quality delivery and customer support to the end users. The true value to the customer is realized in enterprise performance as opposed to product performance. Historically, customers have been prone to pursue other vendors because of lack of customer support, moreso than with average product performance. The result of a well-executed ERP strategy enables the enterprise to react immediately and consistently, enabling the organizational components to focus their human and financial capital in the right areas.

Rouse describes the challenge of focus as deciding the path whereby the enterprise will provide value and grow. Rouse (2001) introduces some common challenges in and impediments to an organization's decision making, including:

- Assumptions made,
- Lack of information,
- Prolonged waiting for consensus,
- Lack of decision-making mechanisms,
- Key stakeholders not involved, and
- Decisions made but not implemented.

An enterprise is capable of addressing these challenges if it institutes an ERP solution during its evolution. The ERP solution will bridge many of the communication gaps common among enterprises that are often organizationally disconnected. A good ERP solution will support information sharing, track performance metrics, and archive information, thus providing methods and tools in supporting rapid decision making and furthering the concept of operational velocity. Many times, senior management is unable to focus on key areas due to lack of information and decision-making tools. This problem can be overcome by integrating these capabilities with the ERP. An ERP can scale easily to meet the business needs. The enterprise that plans for growth through its evolution can scale more easily and adapt to change.

Rouse (2001) states that "given a goal (growth), a foundation (value), and a path (focus), the next challenges concern designing an organization to follow this path, provide this value, and achieve this goal" (pp. 5-6). The climate of the enterprise changes rapidly and dramatically throughout its evolution. As new core technology products are launched, the environment is subject to change. Enterprises find ways to scale their infrastructures to meet growth, fend off competition, restructure, reengineer, and support virtual organizations. The objective of change is to improve quality, delivery, speed, and customer service. All of this is made possible through a well-integrated ERP. An ERP capable of facilitating change allows the enterprise to foster new opportunities for growth and reward. As an enterprise evolves over time into a major corporation, business practices change and a paradigm shift occurs over several phases of maturation. The ERP can assist an enterprise in transitioning new business philosophies and practices and to help pave the way for future growth. There is a major need to anticipate future opportunities and threats, plan for contingencies, and evolve the design of the enterprise so that the plans are successful.

The value of the future is difficult to estimate; this realization has lead to another interesting concept, the option value of an enterprise. As previously mentioned, Boer (2002) is a major proponent of options value as applied to the enterprise. This concept explores investment decisions based on buying an option on the future and determining what that option is worth. An enterprise must plan for future growth and weigh the various investment alternatives available. These include looking at the following:

- Strategic fit,
- Financial payoff,
- Project risk and probability of success,
- Market timing, and
- Technological capability of the enterprise.

The above factors weigh into the decisions made to invest in the future. It is through investments in education, training and organizational development that the enterprise is enabled to meet future objectives through resource allocation.

Other investments in research and development technology make decision-making much more complex. However, they may yield promising future results if planned well and integrated with other decisions taken. Investments in R&D require knowledgeable resources that can influence the abilities of an enterprise to provide value. Knowledge management becomes a key element in the overall ERP strategy. Rouse (2001) indicates that knowledge management and knowledge sharing (Small & Sage, 2006) will promote an integrated approach to identifying, capturing, retrieving, sharing, and evaluating an enterprise's information assets. This may be achieved by applying knowledge management concepts to the ERP strategy. A sound return on investment (ROI) model for an ERP should assess the dynamics of the enterprise, changes needed, and projected savings from these changes. The changes themselves should be measurable. An ERP must be planned carefully and, most importantly, well-executed with all resource considerations made during its evolution. The benefits derived from a well-executed ERP should reveal improvements in task management, automation, information sharing, and process workflow. Each of these components improves the most scarce resources that people face within the enterprise, that of time.

Time is a key ingredient for gaining organizational control. An ERP system with integrated tools and methods for communicating and modeling assists human resources with time management. Time management can be a critical problem and human resources can easily find themselves becoming reactive versus proactive in their day-to-day activities. Rouse (2001) emphasizes that it is important to increase the priority given to various long-term strategic tasks, especially since they too often suffer from demands for time from the many near-term operational tasks. A well-integrated ERP supports time management and allows human resources to gain control of their time and allocate it across the appropriate tasks. It further supports the need for long-term planning by supplying various tools and methods for enhancing strategic thinking. The tools and methods integrated within the ERP should improve both the efficiency and effectiveness of time allocation to tasks. An ERP that is incapable of handling the challenge of time diminishes the true value of the ERP. Time management is a crucial component in achieving operational velocity and must be controlled, in order for the enterprise to respond quickly to customer demands.

The seven challenges to strategic management of Rouse (2001) are all critical elements that need to be considered when designing an ERP. A well-designed ERP helps position the enterprise well in the market and gives it a strategic advantage. The true gauges of success of an enterprise, with a successfully executed ERP, will be reflected in how it is positioned in the marketplace. Rouse (1992) has identified five gauges of success:

1. Standings in your markets,
2. Achievements as an innovator,
3. Productivity,
4. Liquidity and cash flow, and
5. Profitability.

Each of these gauges of success is tied to shareholder value. Gardner (2000) also raises a major consideration about designing an ERP in his book *The Valuation of Information Technology*. He asks the questions:

> *What contributions will an information technology system make to a company's shareholder value? How can an information technology system be constructed to create shareholder value? In other words, not just determine the effect of a system on shareholder value but guide the activities involved in its construction in the first place.* (p. 63)

He emphasizes the need to predict the shareholder value that will be created by an information system before it is actually built. In the context of an ERP, the objective is to increase the wealth of shareholders by adding premium growth to their stock. An ERP can improve the asset utilization of an enterprise by allowing shareholders to increase their returns on invested capital. The traditional approach to increasing shareholder wealth consists of maximizing the value of the cash flow stream generated by an operational ERP. The cash flow generated from the ERP is allocated among the shareholders and debt holders of the enterprise. Shareholder value is traditionally measured by using the DCF method, which is central to the valuation of assets and the return they generate in the future. Boer (1999) addresses the DCF method well in his book *The Valuation of Technology*. He defines the premise of the DCF method "as a dollar received tomorrow is worth less than one in hand today" (p. 63).The question that arises from this premise is how much should one invest today in order to earn a dollar tomorrow. To address this, Boer presents one of the common DCF methods known as net present value.

The NPV method can be used to compute the value of tomorrow's dollar. Boer properly defines NPV as "the present value of a stream of future cash flow less any initial investment (p. 98)." NPV addresses the time value of money, which is essential for developing an ERP strategy, with the objective of attaining operational velocity. Gardner (2000) illustrates how this has a significant effect on the management of ERP systems. If the rate of return is high, schedule delays in deploying an ERP can erode value, which makes time to market critical; and since short product life generates as much value as long product life, there should be little resistance in replacing legacy systems. In comparison, if the rate of return is low, delays have little effect on value, and a longer product lifecycle is feasible, thereby allowing for a more thorough systems development effort. Gardner extends the NPV method to an ERP system and illustrates how shareholder value is created by changes in the present value of the cash flow to shareholders due to the use of the ERP system.

The DCF method illustrated here focuses solely on the economic value of the enterprise. Boer (2002) introduces a concept known as the options value of the enterprise in his book *The Real Options Solution: Finding Total Value in a High-Risk World*. The options method is presented as a means to value the strategic capital of an enterprise. This method is known as the total value model and combines the economic value and strategic value of the enterprise, and also takes into account three major drivers that affect value: risk, diminishing returns, and innovation. Enterprises satisfactorily releasing new technologies into the marketplace normally increase their strategic value if consumers adopt these new technologies to meet their needs. New technology adoption in the marketplace can vary based on need, price, standards, and other related factors. Once the need is recognized, operational velocity becomes critical to answering the customer's needs. How fast customers can be served and cared for will drive the strategic value of the enterprise. A well-designed and executed ERP can assist with operational velocity attainment by improving efficiencies, speed, and time to market. Boer's total value model uses a six-step approach to computing the total value of an enterprise. His practical six-step approach encompasses the following:

Step 1. Calculate the economic value of the enterprise, where free cash flow (FCF) is defined as the actual cash flow minus the amount of cash that must be reinvested: *Economic Value = FCF / (Cost of Capital – Growth Rate).*

Step 2. Frame the basic business option and identify strategic options. For example, leasing space at another site and expanding the enterprise may yield additional future revenue. Here, investment in an ERP system may yield future revenue, as a result of enhancing operational velocity.

Step 3. Determine the option premium, which is the premium paid or expenditures incurred to make the plan actionable. For example, this may include the option cost of technology, people, partners, financing, systems, and R&D.

Step 4. Determine the value of the pro forma business plan, where NPV is computed to determine valuation of the enterprise

Step 5. Calculate the option value. Here, the Black-Scholes option formula is used using five key elements: value of the underlying security, strike price, time period of the option, volatility, and risk-free rate.

Step 6. Calculate total value according to *Total Value = Economic Value + Strategic Value*.

Boer's model computes the true value of the enterprise taking options thinking into consideration, thus reflecting real life and the strategic payoff that can result if an enterprise is successful. To clarify the concept, Boer makes an interesting analogy by illustrating the strategic value of a common family with a low standard of living. The family's principal economic activities concern the income produced. Costs such as mortgage, utilities, and gas are set against this revenue. Any savings are stored away as additional income. The income and expenses mentioned thus far only reflect the economic value of the family. The potential strategic value lies in the education of its children. Education could pay off in the long term and increase the family's standard of living. However, there are also significant market risks. Once the children are educated, the marketplace may not demand their skills, or they may not meet the various job requirements of their profession. In comparison, an enterprise may have potential strategic value in a new technology that it develops. The enterprise may have sufficient venture capital to cover R&D expenses for the next few years. Once the technology goes to marketplace for the first time, the enterprise has first mover advantage in the market if it attracts enough early adopters to build market momentum. Critical mass can be achieved as momentum for the product accelerates. However, there could be the risk of competitors with a similar technology that may go to market during the same time frame. In addition, the competitor may have a similar product with different performance standards, which adds to the competitive nature of the situation. This leads to a race for market share and ultimate establishment of the preferred technology standard between the products.

Strategic value is not always predictable, and the dynamics of the market change constantly. A negative impact on strategic value could result in zero return; this results in a loss of venture capital to cover the R&D expenses. There is evidence during the past five years that a number of startup technology enterprises never arrived at fruition in strategic value. The strategic value represents the potential revenue that could be realized if market conditions are ideal for the enterprise. Gardner (2000) estimates the revenue opportunity for an enterprise using *Annual Revenue = ;Annual Market Segment Size x Annual Likelihood of Purchase x Annual Price*. The terms in this relation are time dependent and are critical to new technology adoption in the marketplace. Forecasting potential annual revenue requires understanding the purchasing decisions and patterns customers will make. Decreasing the time for appearance of a positive revenue stream for an enterprise, a new technology into the marketplace is highly desirable. The mechanism for achieving this objective is the evolutionary enterprise resource planning architecture framework, which will accelerate critical mass early in the deployment phase of the product development lifecycle by achieving operational velocity. Thus , the work established by the early pioneers of ERP and technology valuation methods has laid the foundation for a new ERP paradigm to evolve and support operational velocity attainment.

Network Elements Influencing Path Dependence and Network Effects

Consumers who become completely satisfied with a new technology product or innovation realize the value proposition derived from this new creation. For example, the value of a digital subscriber line (DSL) at home brings value to the home PC user who now has high-speed access to the Internet. The home user is no longer confined to the limiting speed capability of a 56 Kbps dial-up modem. As more users adopt DSL, due to its broadband capabilities, increasing returns to scale and path dependence are achieved. The economy has shifted from the supply-side economies of scale, based on the traditional industrial era of mass production driven by unit costs, to increasing returns to scale (also known as demand-side economies of scale) driven by consumer attitudes and expectations. Strategic timing is vital with respect to demand-side economies of scale. First, introducing an immature technology into the marketplace may result in negative feedback from potential consumers. For example, potential design flaws, functional limitations and constrained feature sets may overshadow the true value of the technology, making it less attractive to potential consumers. In addition, moving too late in the market means not only missing the market entirely but also the opportunity to acquire any significant market share. Moving without an effective ERP strategy compromises new customer acquisition and customer retention.

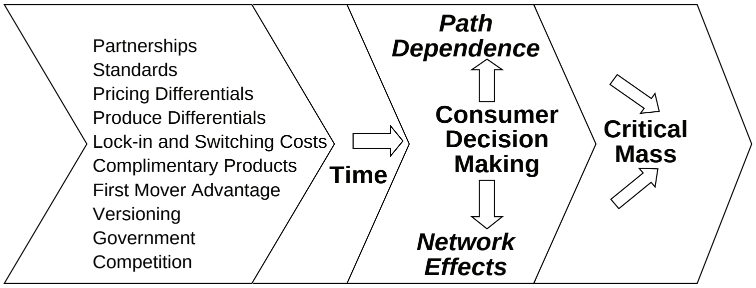
The marketplace is subject to various network elements that influence path dependence and network effects of new technology adoption. These network elements directly impact consumer decision-making and lead to the formulation of consumer perceptions and expectations of new technology. Network elements can be defined as economic, business, regulatory, market, and technological influences that impact consumer decision making relative to new technology adoption. Understanding what drives consumer behavior and how it can be controlled allows innovators and technologists to achieve better success in launching new products while gaining market acceptance.

In *Information Rules*, Shapiro and Varian (1999) identify 10 primary network elements that influence consumer decision-making. They describe how these network elements impact consumer decision making with respect to new technology adoption. The network elements described are: partnerships, standards, pricing differentials, product differentials, lock-in and switching costs, complementary products, first mover advantage, versioning, government, and competition. Figure 1 reflects these 10 primary network elements that influence consumer decision making over time. These network elements will shape consumer choice, based on the degree of consumer confidence, need, desire, satisfaction, and comfort with adopting a new technology. The degree that these human traits will vary among consumers will determine the speed with which a new technology will be adopted. Consumers will most likely fall into three categories of adoption: early, evolving, and late. As a technology becomes popular, consumer decision-making becomes positive with respect to new product acquisition. Early adopters of the technology will begin to generate demand for the product.

Based on the success of the initial product, more consumers will see and understand the value proposition realized by the early adopters. A large number of consumers begin to evolve connecting to the network of users. At this stage, consumer choice begins to exhibit path dependence and network effects. As the network of users begins to accelerate, critical mass is realized. Critical mass occurs when a large enough customer-installed base is established, as a result of positive feedback derived from the growing number of adopters. The network continues to expand until these late adopters eventually interconnect and the product reaches maturity in the marketplace. Network elements are also critical to consumer decision-making and can impact the destiny of a new technology if unrecognized. A good illustration of this was the competition between Beta and VHS in the 1970s. Beta was believed by most to be clearly superior to VHS in quality; however, VHS was the de-facto standard among consumers due to its compatibility. Operational velocity is one of the most fundamental critical success factors influencing adoption of new technology the presence of network elements. Operational velocity is a factor that needs the most attention and the one that can easily be controlled by implementing an effective ERP model. Since understanding the influence network elements have on achieving critical mass is essential, a narrative follows describing each one of the elements shown in Figure 1.

The first network element reflects partnerships, which provide a strategic advantage. New technology enterprises, possessing a leading-edge niche product in the marketplace, may find that one or more partnerships, with major players offering a complementary product suite, may be the answer to acquiring critical mass early in the game. An emerging enterprise would have the opportunity to immediately sell its new product to the existing installed customer base of its partner. This existing installed customer base may have taken the partner years to establish and grow, thus offering an advantage to a new enterprise, which has not yet established customer relationships or gained brand name recognition. An opportunity to sell into an existing installed base of customers, by gaining the visibility and credibility via a strong

Figure 1. Network elements



strategic partner, can shorten the sales cycle and accelerate critical mass. Alliances can even be established through suppliers and rivals as a means of accelerating critical mass attainment. It would also be advantageous for the enterprise to offer incentives when possible. Consumer confidence may be won, along with new customer acquisitions, by allowing customers who are undecided over a new technology to sample or test the new product.

The next element reflects standards. Standard setting is one of the major determinants when it comes to new customer acquisitions. Consumer expectations become extremely important when achieving critical mass, especially as each competitor claims they have the leading standard. Standards organizations try to dispel any notions or perceptions as to which company drives the predominant standard; however, most of these standards groups are comprised of industry players, each of whom attempts to market their own agendas. Most will try to influence the direction of standards setting for their own best interests. Standards are necessary for the average consumer, who wants to reduce potential product uncertainties and lock-in (defined as consumers forced to use a non-standard proprietary product). The product that consumers expect to be the standard will eventually become such, as standards organizations and large industry players begin to shape and mold consumer expectations. Standards increase the value of the virtual network and build credibility for new technologies introduced into the market.

One strategy often used among new and aggressive companies in order to gain market momentum is that of pricing differentials. This network element can ignite market momentum by under-pricing competitors and targeting various consumer profiles. Some enterprises may use various pricing strategies to offer incentives to new customers. As a result, this may be an effective strategy, since some customers may be more price sensitive and may not be as influenced by factors such as standards. A common pricing strategy is differential pricing; this may take the form of personalized or group pricing. Personalized pricing takes the form of selling to each consumer at a different price. The focus is in understanding what the consumer wants and tailoring a price to meet the consumer's needs. Group pricing will set targets for various consumer profiles and group them accordingly. This affords flexibility to potential consumers and takes into account various price sensitivities that may impact decision-making. Consumer lock-in may be achieved through pricing strategies by offering incentives such as discounts, promotions, and the absorption of consumer switching costs.

Making product differentials available is another strategy that is very common in the technology industry and that can effectively influence consumer decision-making. Product differentials offer consumers a choice across several product derivatives. By designing a new product from the top down, the company can easily engage any potential competition by introducing the high-end solution first. Once the high-end consumers have been acquired, a low-end solution can be made available to capture the low end of the market. The low-end product also may be used to position the high-end product, when using an up-selling strategy. When introducing a new technology to the market, the market should be segmented based on several factors such as user interface, delay, image resolution, speed, format, capability, flexibility, and features. These factors help target and span various consumer profiles.

As various pricing schemes, product features, and functionality are offered to the consumer, the fears of lock-in and excessive switching costs enter into the decision-making. This network element is one of the most common ones that can halt adoption of a new technology, especially if consumers only deal with one vendor. Most consumers want to deal with two or more vendors in order to maintain a level of integrity among the suppliers offering the product or service. This alleviates the possibility of lock-in with any one particular vendor, as long as they share the same standard. Consumers who deal with only one supplier may face the possibility of lock-in and high switching costs should they decide to select another vendor later. If the existing supplier has not kept up with standards and new technology trends, the consumer may be bound by old legacy infrastructure, which could result in complications if the consumers can no longer scale their environment to meet their own business needs. Some enterprises may absorb the switching costs of a consumer to win their business, if it is in their own best interest, and also if they need to increase their customer base and market share to gain critical mass. New enterprises gaining minimal market momentum with cutting-edge technology product introductions may be more willing to take this approach.

A common competitive strategy used by many high-technology organizations is the selling of complementary products to their installed base of customers. These complementary product offerings can arrive internally within a company by entering new product domains, or externally by offering a partner's complementary product and leveraging on its core competencies.

One of the most challenging network elements that an enterprise faces is having time to market a new innovation, better known as first-mover advantage. First-mover advantage is the best way to gain both market momentum and brand name recognition as the major provider of this new technology. Microsoft, Sun Microsystems, and Netscape serve as good examples of companies that have succeeded in gaining first mover advantage and that have become leaders in their industries (Economides, 2001). An early presence in the market place has allowed these companies to secure leadership positions throughout the years. We note, however, that Netscape has lost considerable market share to Microsoft's Internet Explorer for reasons that are also explainable by this theory.

Over the years, versioning has become a common practice among technology companies. The network element of versioning offers choices to consumers. Companies will offer information products in different versions for different market segments. The intent is to offer versions tailored to the needs of various consumers and to design them to accommodate the needs of different groups of consumers. This strategy allows the company to optimize profitability among the various market segments and to drive consumer requirements. The features and functions of information products can be adjusted to highlight differences and variations of what consumers demand. Companies can offer versions at various prices that appeal to different groups.

As observed with the Microsoft antitrust legislation proceedings, the government can impact the direction of new technology, whether it attempts to control a monopoly or fuel demand for new technologies (Economides, 2001). This network element can be the most restrictive in achieving critical mass. The government, in efforts intending to ensure that there are no illegal predatory practices that violate true competition, scrutinizes mergers and acquisitions involving direct competitors. There is every reason to believe that it will continue to focus on controlling genuine monopoly power and take action where necessary. All mergers and acquisitions are subject to review by the Department of Justice and the Federal Trade Commission. In addition, the government can serve as a large and influential buyer of new technologies. It can become a catalyst by financing, endorsing and adopting new technologies in order to accelerate their development, adoption, and use. Federal government IT spending on emerging technologies over the next several years can potentially aid those enterprises that are struggling for business and survival as a result of downturns in the economy.

Another network element that can restrict critical mass attainment is competition. Competition in the marketplace will continue as new enterprises are entering the market and presenting a challenge to some large established companies that are plagued by inflexibility and bureaucratic challenges. Companies will compete on new innovations, features, functionality, pricing, and, more importantly, standards. Information products are costly to produce but inexpensive to reproduce, pushing pricing toward zero. Companies that are challenged with a negative cash flow, and have limited venture capital, will need to devise creative strategies to keep themselves in the game. Margins begin to diminish as pricing reaches zero; a complementary set of products or services may be necessary or required to maintain a level of profitability. Knowing the customer, owning the customer relationship, and staying ahead of the competition are the major keys to survival.

Operational velocity is the critical success factor, making a much more profound impact on revenue and profit than the individual network elements described and illustrated in Figure 1. This critical mass determinant, which is the key to the success of an enterprise, is often given very little attention due to the organizational dynamics that take place. Operational velocity, as defined earlier, is speed in delivering products or services to market, meeting all customer expectations in a timely manner, and decreasing the time for appearance of a positive revenue stream as much as possible. This may appear to be a simple concept; however, it is very difficult to master. Without an evolutionary ERP approach, it will be quite challenging to scale a business to meet aggressive future customer demands. There exists a direct relationship between an effective evolutionary the ERP model and operational velocity attainment that allows an enterprise to scale its business accordingly while meeting customer demand in a timely manner. More importantly, there is a unique organizational process lifecycle and key behavioral influences that are essential to implementing an effective ERP model. Without these, the model becomes ineffective, in that ERP has not been implemented in an appropriate and effective manner.

Many enterprises lack any initial operations plan or back-office infrastructure to support new product launches in the marketplace. This is a major challenge in the commercial world, where time to market is critical and development of an effective ERP may be neglected in favor of seemingly more pressing and immediate needs. The primary focus of a new technology company is to amass customers immediately at minimal cost. Often a number of senior executives hired to manage a new enterprise come from sales backgrounds and have very little experience in running a company from a strategic IT, operations, and financial perspective. They sometimes lack the associated fundamental technical and nontechnical skill sets, which can easily compromise the future of the business. This often stems from senior executives who come from large corporations but who lack the entrepreneurial experience necessary to launch new businesses. For example, they may fail to see the value of hiring a chief operating officer (COO) who has the required operations background and who understands how to run a business in its operational entirety. The importance of the COO role is later recognized, but many times it is too late as much of the infrastructure damage has already occurred.

Many of the chief executive officers (CEO) hired to lead new enterprises are prior senior vice presidents of sales. It is believed that they can bring immediate new business to the enterprise and begin instant revenue-generating activity. The sole focus becomes revenue generation and new customer acquisitions. The common philosophy is that the company will resolve the back-office infrastructure later. This is usually a reactionary approach to developing a back-office versus a proactive approach. The lack of a sound evolutionary approach in developing an ERP from concept to market maturity for new products can result in missed customer opportunities, customer de-bookings, loss of market share, lack of credibility, competitive threats and, most importantly, bankruptcy of the business.

Other potential plaguing factors that can impact implementation of an effective ERP strategy are undefined, or at least under-defined, organizational requirements, sometimes termed business rules, and lack of business process improvement (BPI—also known as workflow management) initiatives and strategies. Organizational requirements and BPI for supporting new product launches should be addressed early in the development phase of the new technology. How a product is supported and the relationship and communication between the respective support organizations will be vital to the success of the product. Quite often, organizational requirements and BPI are lacking due to limited understanding and use of contemporary IT principles and practices. Many of the savvy technologists who have started the enterprise may lack knowledge in formal methods, modeling, systems development, and integration. They may be great internal design engineers who have come across a new innovation or idea; however, they lack infrastructure knowledge for commercializing the new technology. This had been a common problem among a number of new enterprises. Most new enterprises that have succeeded with these challenges have first mover advantage, a positive cash flow to continue hiring unlimited human resources, and, although reacting late in the process, have implemented an infrastructure that could support the business. The infrastructure was a splintered systems environment lending only to a semi-automated environment. The systems migration strategy occured too late in the product launch phase to allow for a seamless automated process.

Another factor that often plagues the enterprise is the lack of IT personnel who have business-specific skills. Personnel in the IT organization who lack business skills in the various vertical markets such as engineering, manufacturing, healthcare, financial, legal, and retail may have a difficult time eliciting internal customer requirements when developing and implementing an ERP. They may also lack the various business skills internally, if they are unfamiliar with the business and technical requirements of the other functional organizational elements such as sales, marketing, finance, operations, engineering, logistics, transportation, manufacturing, human resources, business development, alliances, product development, legal, along with any other relevant enterprise elements.

Finally, not all employees hired into an enterprise come with an entrepreneurial spirit. Some still have a corporate frame of mind and do not become as self-sufficient as is necessary to keep up the pace. They have a tendency to operate in closed groups and do not interact well with other business units. A team philosophy and aggressive work ethic is essential in order to succeed in an enterprise environment.

The approach, suggested here, to achieving operational velocity is to develop an ERP model that meets the following 15 performance criteria:

1. Reduces service delivery intervals;
2. Maintains reliable inventory control;
3. Reduces mean-time-to-repair (mttr);
4. Enhances customer response time;
5. Establishes timely and effective communications mechanism;
6. Automates processes;
7. Creates tracking mechanisms;
8. Maintains continuous business process improvement;
9. Supports fault management through problem detection, diagnosis, and correction;
10. Manages customer profiles;
11. Monitors business performance;
12. Establishes best practices;
13. Creates forecasting tools;
14. Supports supply chain management; and
15. Integrates all systems within the ERP model such as sales tools, order entry, CRM, billing, and fault management.

These performance attributes are ones that companies have adopted to monitor, manage, support, and measure success of their operational environment. Companies are also continuously challenged with developing and implementing an effective model to support these attributes. The challenges stem primarily from a lack of knowledge and limited use of contemporary IT principles and practices. Enterprises must realize the need for appropriate performance metrics in order to measure success criteria and to plan for future growth and expansion.

Of all the network elements impacting the adoption of new technology, operational velocity is the most compelling, since it will influence customer expectations based on how quickly customer needs can be serviced. These needs may consist of rapid customer service response time, product delivery, problem resolution, and maintenance. Operational velocity, like the network elements, will influence consumer decision making on new technology adoption. If a new technology product has long delays in service delivery or lacks customer support, new customer acquisition and retention eventually become compromised. Under these circumstances, it is possible to lose business to the competition, which may be introducing a similar product into the marketplace. Consumers become disappointed, less patient and quickly begin to look for alternatives. The lack of a reliable operational infrastructure would have been the result of a poorly executed ERP. An effective ERP must be automated, capable of tracking, serve as a communications mechanism, and support various tools. If these criteria are recognized and controlled by the core team of an enterprise, the ERP can provide many benefits as the business begins to scale and the product begins to meet customer expectations. Network elements can influence the outcome of a new technology or the destiny of the product. Understanding the impact that the various network elements have on the enterprise can help position the business in taking on the challenges that prevail. The market timing of the product and the influence on customer decision making will determine the end result of critical mass attainment. An enterprise that prepares and develops strategies, and which takes into account the large number of potential network influences, will accordingly realize this end result. There are a number of complex adaptive system challenges associated with these, and these must be explored as well.

Many of the enterprise resource planning efforts cited in this article can be traced to the three basic core elements of an ERP: people, process, and systems. Each of these elements were addressed in the various models and frameworks identified by early contributors in the field. As an ERP architecture evolves, each of the ERP elements goes through a maturity state. The evolution of a fully developed and integrated ERP architecture can be inferred from the phases of a basic systems engineering lifecycle. Table 2 illustrates this inference through a framework of key systems engineering concepts that can be applied to the development of an enterprise resource planning architecture.

This suggested framework could be used to develop an enterprise architecture using six key system engineering concepts. To support the ERP development effort, this 6x3 matrix of Table 2 could be used with the six general system engineering concept areas as rows and the three columns depicting the core components of an ERP. This defines the structural framework for systems engineering concepts and their relevance in developing, designing, and deploying an enterprise architecture. ERP maturity states are represented in each of the quadrants of the 6x3 matrix. As an ERP matures, each of the maturity states is realized and can be directly correlated to its respective systems engineering concept. It can be seen from the framework that the phases of the systems engineering lifecycle can be applied to ERP development. The various ERP models presented in this article revealed that a systems engineering paradigm may be inferred. The SE concept framework clearly illustrates a systems engineering orientation with respect to ERP.

Table 2. Key systems engineering concepts framework

Framework of key systems engineering concepts			
Concept Area	ERP Core Components		
	People	Process	Systems
Requirements definition and management	Organizational requirements elicited	High-level operational processes defined	System functions identified
Systems architecture development	High-level architecture developed by team	Architecture supports organizational processes	Systems defined to address organizational requirements
System, subsystem design	Unique data and functionality criteria addressed for each organization	Operational processes at the organizational level are developed	Organizational system components are designed
Systems integration and interoperability	Shared/segmented data and functionality is designed	Operational processes are fully integrated, seamless, and automated	All organizational system components and interfaces are fully integrated and interoperable
Validation and verification	Organizations benchmark and measure operational performance	Operational process efficiencies and inefficiencies are identified	System response time and performance are benchmarked and measured
System deployment and post deployment	Team launches complete and fully integrated ERP architecture	Operational readiness plan is executed and processes are live	Systems are brought online into production environment and supporting customers

SUMMARY

In this article we have attempted to summarize the very important effects of contemporary issues surrounding information and knowledge management as they influence systems engineering and management strategies for enhanced innovation and productivity through enterprise resource planning. To this end, we have been especially concerned with economic concepts involving information and knowledge and the important role of network effects and path dependencies in determining efficacious enterprise resource planning strategies. A number of contemporary works were cited. We believe that this provides a very useful, in fact, a most-needed, background for information resources management using systems engineering and management approaches.

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Chapter 1.26

The Role of Systems Engineering in the Development of Information Systems

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ABSTRACT

In this article, the inter-relationship between information systems (IS), systems engineering (SE), and information system development (ISD) is discussed from past, present, and future perspectives. While SE is relatively a well-established discipline based upon an interdisciplinary approach to enable the realization of successful systems, ISD has evolved to a variant of SE applied mainly for the development of IS. Given the growth in complexity and cost and schedule over-runs associated with software centric systems, well-established methodologies are needed for the development of good IS. Similarities and differences of methodology as well as their evolution and perspectives are also presented herein. We found a positive trend in the evolution of research methodology in SE and its use in IS towards a system's approach as a holistic methodology.

INTRODUCTION

The title of this article seems like tautology or at least a redundancy, but was conceived to support the vision of the new International *Journal of Information Technologies and the Systems Approach*. Applying a system approach (SA) and its interaction with systems engineering (SE) for a better understanding and development of the information systems (IS) disciplines is one of main goals of the new journal and also this article. Our task is twofold: to analyze the significance of IS for SE and its methods as well as the relevance of SA and SE for the development of IS. Both of them are important and distinct. It is impossible to utilize SE and SA methods without proper IS, and conversely you cannot develop cost effective and efficient IS without disciplined SE or SA approaches. However, there has historically been a difference in the methods used for the IS development and other sociotechnical systems using SE. These differences in methods were caused by user experience and established practices although economic and technical developments will lead to their convergence. Our aim in this article is to generalize and highlight these different methodologies and their relevance for research of the vast variety of processes where IS and system's methodologies are essential conditions.

The word "system" can broadly be defined as an integrated set of elements that accomplish a defined objective (INCOSE, 2004). Simply put, a system is a whole consisting of parts and is more than sum of its parts. That was an axiom of ancient philosophers, which accurately anticipated the contemporary definition of systems. Only order, structure, and behavior were added to the meaning of systems in cybernetics and general systems theory. Complex systems are usually understood intuitively, as a phenomena consisting of a large number of elements organized in a multilevel hierarchical structure where elements themselves could represent systems (Mesarović & Takahara, 1989). The word "complex" is used only to indicate that the problem treated here cannot be expressed only in hard (quantitative) relations, and those many relevant characteristics are qualitative. With a conception of complex systems, we think about a system within which a main role is played by a complexity of control and information processes. Undoubtedly, existing SE methodology is applied to small, medium, large scale, and complex process but with complex systems, SE moves to a SA methodology. Fortunately, these same SE techniques that have been successfully applied to complex systems are also being applied to systems of systems (SoS) and large enterprises.

A paradigm of SE has played important rules in the dealing with different aspect of human activity. In the beginning, it was based on empirical knowledge and heuristics in the building of human-made objects like pyramids, fortifications, tools, and so forth. Industrial production and scientific organization began with Ford Motor and F.W. Taylor who contributed to work specialization, planning, and control. The result was mass production, standardization, and higher productivity at defined quality levels. This period of worldview in science and production was known as the Machine Age and was marked by its use of classical analysis for problem solving (Ackoff, 1999). Systems engineering was subsequently born in the telecommunications industry of the 1940s and nurtured by the challenges of World War II (WWII), when project managers and chief engineers with the assistance of key subsystem leads oversaw the development of aircraft, ships, and so forth. The post-WWII creation of more complex systems, mainly in defense and communication systems, led to the formalization of SE as an engineering discipline. Its relevance became indispensable after WWII, when systems—technical, production, and organizational—became highly complex. A landmark for systems philosophy was founded in General Systems Theory (Bertalanffy, 1968) and Cybernetics (Wiener, 1948) and continued to be adapted to the different contexts and tools, taking new meaning and significance with successive ages as indicated by Ackoff (1999). The history of civilization development and growth is closely related to the history of working methodology and organization.

Although modern definitions of SE are of a later date, there are several books and papers on this topic, which discuss SE and the system engineer in great detail (e.g., Martin, 1996; Sage, 2000; *Thomé*, 1993). Some examples of modern SE definitions are shown in Table 1. This explanation is derived from the root of two words: "engine" and "systems." An engine is a device consisting of different parts. Engineers are those who construct

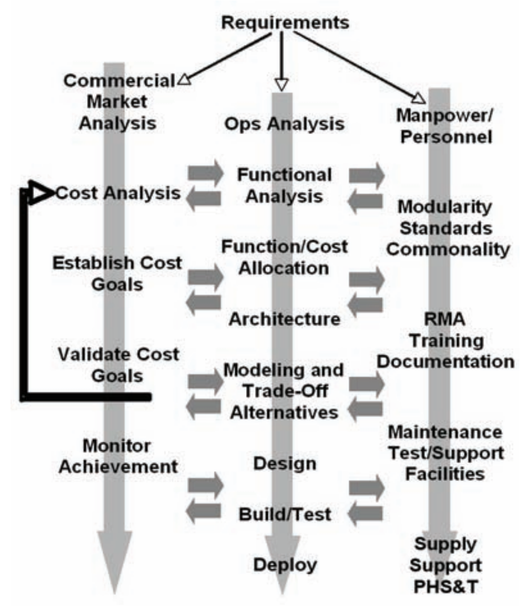
Table 1. Standard definitions of systems engineering

International Council on Systems Engineering (INCOSE, 2004)	Systems engineering is an interdisciplinary approach and means to enable the realization of successful systems.
Military Standard on Engineering Management 499A (United States Air Force, 1974)	The application of scientific and engineering efforts to: (1) transform an operational need into a description of system performance parameters and a system configuration through the use of an iterative process of definition, synthesis, analysis, design, test, and evaluation; (2) integrate related technical parameters and ensure compatibility of all related, functional, and program interfaces in a manner that optimizes the total system definition and design; (3) integrate reliability, maintainability, safety, survivability, human, and other such factors into the total technical engineering effort to meet cost, schedule, and technical performance objectives.
Department of Defense (2004)	Systems engineering is an interdisciplinary approach or a structured, disciplined, and documented technical effort to simultaneously design and develop systems products and processes to satisfy the needs of the customer. Systems engineering transforms needed operational capabilities into an integrated system design through concurrent consideration of *all* life cycle needs.
NASA (1995)	Systems engineering is a robust approach to the design, creation, and operation of systems.

engines according to their knowledge of natural sciences and economic law. "Systems" means a whole consisting of parts. Systems engineering is a methodology of how to "construct" purposeful systems in their surroundings. It is obvious that the meaning of SE has changed with the complexity of the man-made systems and social changes in its surroundings. As a comprehensive definition of SE as methodology for this article, we use *Thomé*'s (1993) definition: "Systems engineering consists of applying a System Approach to the engineering of systems." Figure 1 shows a graphical representation of what might constitute a SA to the engineering of a system. Its domain is the engineering of solutions to systems problems independent of employing a certain technology for realizing systems functions and properties. In this definition, SE was understood as the composition of SA and engineering of solution for systems problems independent of type of process. However, a SA could be considered also as enhanced SE for complex problem solving, taking into accounts not only stakeholders' requirements but also the environments requirements. That means considering a complex system from all relevant points of view in its environment during developing, maintaining, and functioning. The similarity and difference of methodology titles were discussed in Lazanski and Kljajić (2006), where the triadic principle of C.S. Peirce (1998) was used to explain the meaning of methodology in a context of problem solving. According to Peirce (1998), princliple of C.S. Peirce meaning is a triadic relation between a sign, an object, and an interpretant. A general meaning can always be found in genuine triadic relations, but can never be found in degenerate triadic relations. Only a subject gives real value and meaning to the model and methodology in a frame of a context of the problem. Basic principles and requirements for SE and its translation to practice as well as for systems engineering education are described in Martin (1996) and Sage (2000).

The relevance of SE and its variation for complex problem solving and its management could be clarified by a number of articles published in the last decade. Our Internet research results from the Engineering Village (Engineering Village, 2007)

Figure 1. Relationship between the traditional SE functions (center column), cost (left column), and supportability and logistics (right column) (Stevens Institute of Technology, 2007)



and the Web of Science (WoS Expanded, 2007) are shown in Table 2. The Engineering Village database is large and represents all articles from conference proceedings, journals from Journal Citation Records (JCR), secondary databases, and doctoral dissertations. Different results were observed from the Web of Science (WOS) database since it covers only journals from JCR.

Although SE and SA represent just methodologies and IS real systems, we compare their portions in order to see how frequently IS has been used besides established methodology. As shown in Table 2, the relative frequency of SA and SE is 77% and IS = 23% from the Engineering Village database. Our primary interest is IS and its associations with research methodologies like ISD, SE, SA. Simulation and its combination, within the IS database, n1 = 442,767 articles were found: ISD = ISD&IS = 29%, IS&SE = 47%, IS&SA = 18%, IS&SE&SA = 6%, and for IS&SE&Simulation, only three articles. Regarding ISD or ISD&IS, the answer was 29% in both cases. It means that the ISD methodology was used exclusively with IS and is between IS&SE = 47% and IS&SA = 18%. The result of IS&SE&SA is 5.8% while IS&SE&Simulation had only three articles.

Because our primary interest is the use of research methodology like ISD, SE, SA, and its combination with IS from IS database of n = 18,055 articles for the WoS database, the following result has been obtained: IS&SA at 0.4%, IS&SE at 0.4%, ISD at IS&ISD at 2%, IS&Simulation at 3.5%, and for IS&SE&SA and IS&SE&Simulation, only two and five articles were found, respectively. From these findings, only 6% of articles use established methodology with regard to IS; all other (94%) articles do not use labels like ISD, SE, and SA or similar. This finding does not mean that methodology is not used at all but perhaps not explicitly.

This research clearly shows two different trends in publications. In the broader Engineering Village database, the majority of publication content keywords is by SE at 58% and then IS at 23% followed by SA at 19%. From the WoS database, with the journals from JCR most dominant, keywords are IS at 80% followed with SA at 15% and SE at 5%. Keeping in mind that articles in journals from JCR are usually representing finished research, we can analyze the WoS database where IS = 80% (n1 = 18,055) as meaning that these articles considered topics where information systems play dominant roles like Production IS, MIS, Medical IS, Educational IS, and so forth.

Table 2. Engineering village and web of science subject searches

	Engineering Village	Web of Science
Articles in Database (1969 to 2007) Keywords IS, SE, and SA	1,926,146	22,615
% SE	58	5
% IS	23	80
% SA	19	15

SA at 15% could mean that articles also consider, besides SA methodology, another process or just methodology with SA dominant.

We have summarized key concepts for SE and SA and presented an overview of the research trends in SE, SA, and IS as reflected by the two established research databases. The remainder of this article is divided into three sections. The second section contains an overview of some theories and methods relevant for SE. The third section deals with the anticipative concept of SE. This is followed by the simulation approach to SE. Finally, the fourth section provides some concluding remarks and ideas for further research.

OVERVIEW OF SOME THEORIES AND METHODS RELEVANT FOR SE

Even though methodologies do not belong directly to systems theory, they are its products in searching for the means of complex problem solving. The diversity of systems phenomena created a variety of concepts and theories to describe them. The description of a system depends on the describer's point of view, interests, culture, and time (Koizumi, 1993). Experience, learning, knowledge, and motives influence an individual's consciousness and consequently society's awareness, which results in a certain choice of action. A social reality, which is a consequence of a compromise, is an organization and is measurable by its goals and means for achieving these goals. This is an objective matter, although there is a problem of measurability, scale ordering, and subjective understanding of an individual and the individual's values. The objective exists in time and place and is not separated from them, even though it is only partly described. *Awareness that partial description is not wholeness and the fact that we can more or less get close to this wholeness requires a SA* (Kljajić, 1994). *In this way,* Miller's (1978) Living Systems represent a comparative analogy among the structures, functioning and processing energy and information of different living phenomena. A comparative scheme is just an analogy without the power for deeper understanding of the phenomena. Even though we can find some useful similarities among an organism, an organ, and an organization, we can say that these are actually different systems with regards to their behavior. This approach can be partly useful as an analogy with organizational science. Organizational systems are complex goal-oriented systems (Ackoff, 1999) designed to achieve certain purposes. As such, organization is a function of the past, present, and future state and represents an anticipatory system. Therefore, the basic principles of systems development are essentially anticipatory as consequences of decision making based on anticipated and feedback information. To estimate the consequence of decision making, the decision maker needs a model of the system and the environment. System Dynamics (Forester, 1961) and System Thinking (Senge, 1994) are equivalent and can be unified within the systems concept (Kljajić, 1994). Some relevant paradigms for analysis were described in Flood and Carson (1988) and Rosenhead (1989), including soft systems analysis, hard systems analysis, critical thinking, and strategic options development and analysis. It is not surprising that a number of works have been dedicated to these topics. There are almost no differences among them; different names are a result of the complex context and the author's point of view. As Forrester (1994) states, all these titles have one and only one aim "to emphasize that this is the wish following an integral research of complex phenomena through its feedback connections." It is the eternal wish of a human being for the complete yet never-ending description of his surroundings. The cybernetics and general system theory expose these wishes even more. We can accept a SA or systems point of view as being proper. More so, thinking and rethinking is the mental process of a human being. It can be true or false in relation to a matter of thinking. If taken terminologically, it is a metaphor, with which we would like to expose a working method for mathematics (mathematical thinking) or philosophical method (philosophical thinking). This is the reason that the basic concept of General System Theory was the interdisciplinary work for complex problem solving. It is obvious that we cannot find an actual solution with just formal methods. Abstract matters need concrete ones and vice versa. The philosophy of SA is typical for complex problem solving and can be expressed with two words: interdisciplinary methodology + context problem solving = SA. Its openness and transparency satisfy Popper's (1968/1973) requirements for provability: "Within a methodology we do not define only a problem and search for a solution, but also set conditions for verification of solutions and validation of alternatives" (p. 131). All complex phenomena are systems in their essence, whose methodology derives from Cybernetics and GST.

In order to illustrate the interconnection of the above theory, ISD methodology relevant for IS and its evolution, the articles (Jan & Tsai, 2002; Xu, 2000; Zhu, 2000;) will be analyzed. As a good example of Miller's living systems analogy and Ackoff's (1999) lucid systems classification (Jan & Tsai, 2002), a three-stage ISD has been analyzed: methodology for the IS as machine, methodology for the IS as part of an organization, as well as IS as part of a social system. The study investigates the changing roles and missions of IS for the three stages and explores the evolution of ISD strategies. In the early phase of IS development for the organization as machine, IS was developed by information specialists. The role of the IS is to support transaction processing systems and operational control. In the organic stage, the IS role is to support transaction processing systems at all organization and management levels. In the social stage, the IS role is to support organization as a social system, and its mission should take account of organization as part of larger systems, even ecological ones. Similarly, in Xu (2000), the author reviewing the contribution of systems science to information systems research stressed how concepts and findings in systems science have to be applied, extended, and refined in IS research.

In Zhu (2000), the author presents "WSR: A Systems Approach for Information Systems Development," which is derived from traditional oriental thinking and contemporary practice in that sociocultural setting. As a philosophical framework, WSR (wuli-shili-renli) contends four principles: seeing ISD as a differentiable whole, treating ISD methods as complementary opposites, conducting ISD as a spiral bubble-management process, and searching for ISD methodologies in a form not independent from that of general management approaches. In this way, ISD researchers should develop methodologies in a form familiar to users and, at the same time, incorporate the best aspects of various methods, which nicely coincide with Ackoff's (1999) classifications. Samaras and Horst's (2005) SE perspectives on the human-centered design of health information systems are described. With human-centered design, the authors require that the SE method take into account human ergonomics (although cognitive aspects would be better), which in other words mean SA. An example of an IS for community nursing is presented in Šušteršič, Rajkovič, Leskovar, Bitenc, Bernik, and Rajkovič (2002). The goal of IS, in this case, is to reduce the workload with modern information and communication technologies and to improve the quality of nurses' work. It relies on an integrated and structured information picture, with special emphasis on transparency and interpretability. In Mouratidis, Giorgini, and Manson (2003), the security of information systems is considered as an integral part of the whole system development process. The above-mentioned articles, dedicated mostly to IS and its developing methodologies, clearly show the evolution of ISD to a systems approach methodology.

ANTICIPATIVE NATURE OF SA AND SE METHODOLOGIES

Many problem-solving methodologies are roughly similar regardless of the type of the process or purpose of the article. Three types of articles could be found on SE topics: SE Methodology, SE Application, and SE Education. This triad of methodology, application, and education are interrelated; each methodology is context dependent as well as dependent on education curricula. Therefore, common bases of all articles are also at high levels. Within this rough classification, there are large variations and combinations of methods. The best example of that is the fact that almost 94% of articles devoted to IS do not use in the keywords ISD, SE, or SA. With respect to the keywords in these 94% of articles, some implicit methodology has to be used.

The most common terms used with respect to SE can be divided into three stages: the initiation stage, the growth stage, and the maturity stage, which correlate to Jenkins' four phases cited in Flood and Carson (1988): Systems Analysis, Systems Design, Implementation, and Operation. Each of these phases could have several subphases for detail analyses. Thus, in Martin (1996), SE is defined with three parts:

A. SE Management Plan (organizes, controls, and directs the technical development of a system or its product)
B. Requirements and Architecture Definition (defines the technical requirements based on the stakeholders requirements)
C. System Integration and Verification (integrates the components at each level of the architecture and verifies that the requirements for those components are met)

The relevance of concurrent engineering in order to reduce design changes in the developing phase is stressed in Martin (1996). Similarly, in Sage (2000), the problem of SE education was dealt with from the point of view of SE as method, process, and management. In the context of education of SE, Sage (2000) elaborates three groups of knowledge: a natural science basis, an organizational and social science basis, and an information science and knowledge basis. This curriculum was further elaborated (Shenhar, 1994) into courses: mathematics and statistics, technical and engineering disciplines, economic and financial disciplines, management and organization theory, and SE procedures. Asbjornsen and Hamann (2000) approach unified SE education from a systems theory concept appealing to the SA concept to define the ratio between theory and applicative knowledge in curricula.

Perkins (2002) presents an educational program in which an industrial process SE was analyzed. His analyses show what is common in SE education curricula as well as differences caused by the specifics of the chemical process. Finally, Brown and Scherer (2000) compare SE programs in the United States. They note that there are relatively small numbers of students in SE and that none of the associations covering SE have a successfully defined core body of SE knowledge embraced by academic institutions. INCOSE (2007) has developed a standard reference for graduate programs. However, SE programs can range from operations research, control theory, information systems engineering, to industry standards of SE. Yet in the future, the first concerns of the "integration of information technology subject into the SE curricula" must be addressed. Similarities in these diverse processes suggest that there is a general process that might be closely related to human thinking (Bahill & Gissing, 1998). Bahill and Gissing defined these procedure swith the acronym SIMILAR which means: State the problem, Investigate alternatives, Model the system, Integrate, Launch the system, Assess performance, and Re-evaluate.

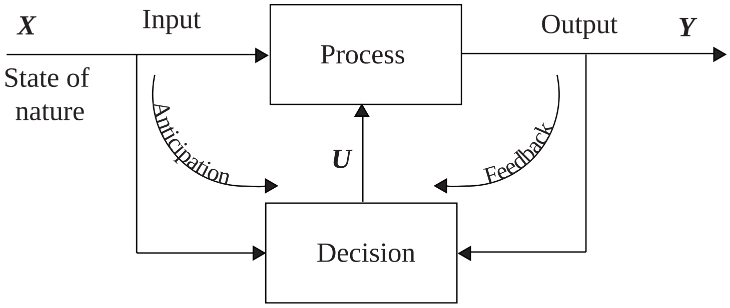
From a decision point of view, the systems approach to systems engineering as described by SIMILAR could be unified as in Figure 2. As portrayed, the process represent the progress of problem solving at anticipated systems performance in environment ***X*** (systems requirements on Figure 2), decision means action ***U*** according chosen methodology while feedback means interactive control and adaptation of realized task ***Y*** in phases of design, development, and deployment. Figure 2 clearly shows the interdependence of problems to be solved (process), users as decision makers, and methodologies used. Yet the simulation method for dynamic testing of alternatives for the anticipated system performance could be a very useful tool within SE.

SIMULATION METHODS AS A PART OF THE SA METHODOLOGY

The role of the simulation methodology in understanding x systems is constantly evolving and increasing. Today, in modern organizations, two words are dominant: change and learning, from which are derived change management and learning management. Human knowledge, the simulation model, and decision methodology combined in an integral information system offer a new standard of quality in management problem solving (Simon, 1967). The simulation model is used as an explanatory tool for a better understanding of the decision process and/or for defining and understanding learning processes. An extensive study on using the simulation method in enterprises can be found in Gopinath and Sawyer (1999). Information systems and decision support are important areas in Management Information Systems (MIS) as the part of complex SE. That could be clarified by number of articles associated with IS and Simulation: 3.5%. The majority of them discuss IS related to decision assessment. For example, in Mora, Forgionne, Gupta, Cervantes, and Gelman (2003) and Mora, Forgionne, Cervantes, Garrido, Gupta, and Gelman (2005), a new framework of identifying and classifying the support capabilities provided by the full range of decision-making support systems is posed with special regards to the information and knowledge representation and processing capabilities. However, only a few papers were used for simulation methods and SE in IS research. In Gao and Li (2006), business process re-engineering (BPR) is regarded as a revolution of enterprise management. Advances in modeling languages, such as the Unified Modeling Language (UML), is an industry standard that is used in modeling business concepts when building software systems in an object-oriented manner has also become mainstream for most SE organizations. Recently, XML has gained ground in becoming a key enabler of these systems in terms of transport of information and commands. All of this demonstrates the growth in tools and languages needed to describe and model a system.

Using a hybrid simulation model, decision assessment of BPR was analyzed in Kljajić, Bernik,

Figure 2. General model of a goal oriented system

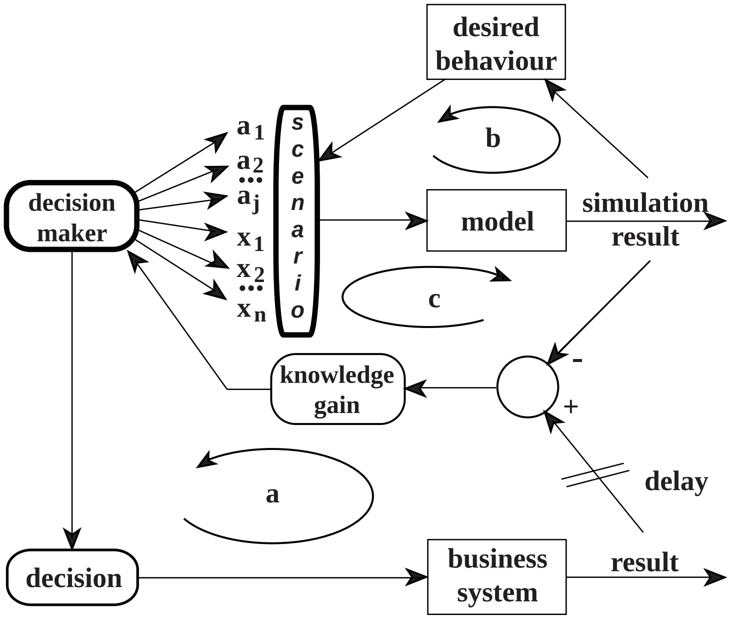


and Škraba (2000). The decision assessment has been organized at two hierarchical levels. The model at the upper level is used for the assessment of an enterprise's strategy (continuous simulation). At the lower level, the model is used for discrete event simulation, necessary for operations planning and testing production performance. The simulation approach seems to be an appropriate methodology for obtaining anticipative information for decision making as shown in Figure 2. Roughly speaking, this involves the concepts of state, goal, criteria, alternative, and the state of nature combined in a dynamic model interacting with decision-making groups. In both of these, simulations interacted with human experience create a new quality. The representation of the proposed approach is shown in Figure 3, adapted according to Kljajić (1994).

Figure 3 shows the interaction between the user, simulation model, and scenario in the process of seeking a solution to a managerial problem as decision support in a business system. The following three basic loops are emphasized:

a. The causal, or the feedback loop, representing the result as a consequence of former decision making, and as a part of management experience and history of the system. From the learning point of view, this loop could be named "learning by experience."
b. The anticipative or intellectual feedback loop, which provides the feed forward information relevant to the formulation of the system strategy. This loop consists of the simulation model of the system, criteria function, and scenarios. The simulation scenarios consist of two subsets: a subset of input x_i that anticipates the state of nature (or exogenous scenarios) and a subset of alternatives a_j (or endogenous scenarios). The generation of scenarios of the simulation system that responds to the *what-if* is based on different scenarios anticipating future impacts of the environment and desired performance of the system. They usually represent the extrapolation of past behavior and an expert evaluation of development targets employing the brainstorming method. The

Figure 3. The principle diagram of simulation approach for decision support in enterprises



most delicate part of this circle is above all (principally) the methodology of the system simulation that facilitates "experimenting" on the system model and the model of the process itself.

c. The *a posteriori* information concerning model applicability and former decision making. This loop represents the pragmatic validation of the model. The comparison of the prior information concerning the impact of the selected strategy on the system behavior with the achieved results allows us to gain knowledge and evaluate the value of the model and improve it. In this way, learning is facilitated on the basis of *a priori* assumptions on the model and not just on the basis of empirical experiences, which is usually delayed.

Loops a and c are the basic ones for the knowledge generation and experience for learning and quality decision making. Loop b represents the knowledge validation. In literature, major attention has been paid to the methodology of design, testing, and evaluation of the model. As such, a simulation could be very useful in testing alternatives in the SIMILAR methodology or merely SA. The user is, however, the key element of the three circles because the user is the one who makes decisions. As most of simulation projects necessitate teamwork, considerable attention should also be paid to the presentation of findings in the decision-making process. The advantage of the simulation method application for decision support is proved by the laboratory experiment on the business simulator (Škraba, Kljajić, & Leskovar, 2003; Škraba, Kljajić, & Borštnar Kljajić, 2007). The authors tested the efficiency of decision making (DM) (value of criteria function and its variation) at three different conditions: (a) DM-based on problem understanding, (b) DM-based on problem understanding and using simulation model as feedback, and (c) DM, which in addition to individual feedback, also uses information of group decisions. The best results were achieved for condition c over b and the worst at group a.

Advantage of the simulation model as part of SA lies in the fact that the problem defined in natural language could be easily transformed in a directed graph convenient for qualitative analysis and then transformed in a computer program. In this case, the user can always check the correctness of the stated problem within a certain theory and further its translation to computer programming. This is important, especially in case of a complex problem, where the feedback loop and stochastic relation are present, no matter if the process is a continuous or discrete event. Rich graphic presentations and 3D animation of the simulated process make this technique unique for testing systems performance in the phase of system design and deployment.

Modeling and simulation (M&S) have become ever more central to the development of modern systems. Unprecedented advances in digital processing have made high fidelity representation of systems and subsystems in computer models possible from the simplest of our systems to the most complex. This has made it possible to examine the projected performance of systems over wide excursions of design and environmental assumptions very early in the development process when key resources are committed. Today's M&S tools make it possible to perform extensive SoS and enterprise-wide simulations and evaluate alternate architectures at affordable cost and early enough to make a difference.

SUMMARY AND CONCLUSION

In this article, the relationship among information systems, SE, SA, and ISD was discussed from past, present, and future perspectives. While SE is a well-established methodology for developing different kinds of man-made objects from components to enterprises, ISD is a variant of SE applied for IS development. Based on a library study, it is possible to see a positive trend in the evolution of research methodology in IS and the use of IS for SE implementation toward the SA methodology. All classical methods initially developed for specific problems and processes converge with the development of IT and society into one holistic methodology colored with specific problems (context) and user preferences. A common name for SE or ISD could be SA or more precisely SA to SE and SE with SA as a holistic methodology for complex problem solving. A core substance for the management of all these methods is IS. Conversely, when IS itself should be developed and deployed in such a complex situation as the Internet, intranet, e-everything, GIS, e-market, and MIS of complex global environment, then ISD have to move to SA combining with principles of SE but combined with different methods and tools for dynamic testing of IS in all phases of SE by means of system simulation. One cannot imagine how to test reliability, stability, functioning, and behavior of global (complex) systems, where IS represents the backbone and Central Nervous Systems, after disaster impact without SA methodology combined with systems simulation.

No matter how we call a certain methodology for complex systems managing—systems thinking, system approach, soft systems methodology, critical systems methodology, or dialectic systems (that remains the preference of authors)—the essence of such methodology has to be intent to cope with the wholeness of the process in its environment. Or more precisely, the environment is a relevant part of the tangible problem solving local or global. Nanotechnology, computer science, and software systems offer new possibilities in developing information technology for more complex IS. In that case, a working methodology, more than ever, has to be holistic and user friendly. It means that it has to contain all existing particular methodologies (context oriented) in one working methodology where the user has to be in the first plan—anthropocentric orientation.

In our opinion, the systems approach, as a worldview on the systems dynamic originated from GST and systems engineering with its tradition in the production process, is a proper candidate for that. It can unify all methods dealing with complex systems like ISD, SE, software engineering, operations research, and especially, modeling and simulation. SA, in a natural way, provides synthesis of structure, behavior, and utility via goal, state, criteria, and feedback control as an anticipated property of the complex systems.

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Chapter 1.27

Enterprise Resource Planning Systems in a Global Environment

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ABSTRACT

Companies around the world are placing increasing emphasis on strategy development and implementation. Some argue that this increased emphasis is in response to market forces of increased competition and globalization, and the need to be flexible and adaptive to the business environment. Strategy development and implementation is a multifaceted task reliant on a number of interdependent factors. One of these is the role of information technology which in recent times has become an integral part of most companies' strategies. This chapter discusses the role of strategy development and the importance of the alignment of business and IT strategies in a global environment. It discusses the role of enterprise resource planning systems on strategy development and how these systems underpin many strategic objectives companies strive for in a global environment.

STRATEGY DEVELOPMENT

There is a plethora of articles, books, and presentations on the importance of strategy in today's companies (Mintzberg, 1994; Porter & Miller, 1985; Kaplan & Norton, 1996). But even with this emphasis, companies struggle with their strategy development and implementation. This is reflected by a much cited reference to a *Fortune* magazine article which stated: "Less than 10% of strategies effectively formulated are effectively executed" (Kaplan & Norton, 1996). In other words more than 90% of companies that are able to create an effective strategy struggle to implement it.

A possible reason for this finding may be the diverse views of what a strategy is. The increased focus on strategy has resulted in the word "strategy" and its derivatives being concatenated with a broad range of terms in an attempt to imply a higher level of importance—for example, strategic planning, strategic learning, strategic thinking, strategic leadership, corporate strategy, business strategy, and functional strategy. This is further reinforced in Mintzberg's (1994) landmark article "The Rise and Fall of Strategic Planning," where he argues the virtues between strategic planning and strategic thinking. In terms of what a strategy actually is, Minztberg (1992) defined strategy as:

> *A plan—some sort of consciously intended course of action, a guideline (or set of guidelines) to deal with a situation. By this definition strategies have two essential characteristics: they are made in advance of the actions to which they apply, and they are developed consciously and purposefully.*

He further attempted to define strategy from the perspectives of being a plan, a ploy, a position, a pattern, and a perspective (Ikavalko & Aaltonen, 2001). Porter's (1996) definition of strategy focuses more on the outcome: "the creation of a unique and valuable position, involving a different set of activities." He believes that a strategy is a way an organization seeks to achieve its vision and mission, and that a successful strategy allows a company to capture and sustain a competitive advantage.

The emphasis on the effective development and implementation of strategies has resulted in a number of methodologies being developed to facilitate this process. Two of the more accepted methodologies are Porter's Value Chain (1985) and Kaplan and Norton's (1996) Balanced Scorecard. Both methodologies adopt a multifaceted approach involving a number of perspectives to strategy development and implementation. This assists in identifying the interrelationships between the various facets that impact upon strategy and facilitates the devolution of the strategy to operational terms.

The Balanced Scorecard (Kaplan & Norton, 1996) views strategy development and implementation from four interrelated perspectives:

- Financial
- Customer
- Internal
- Learning and growth

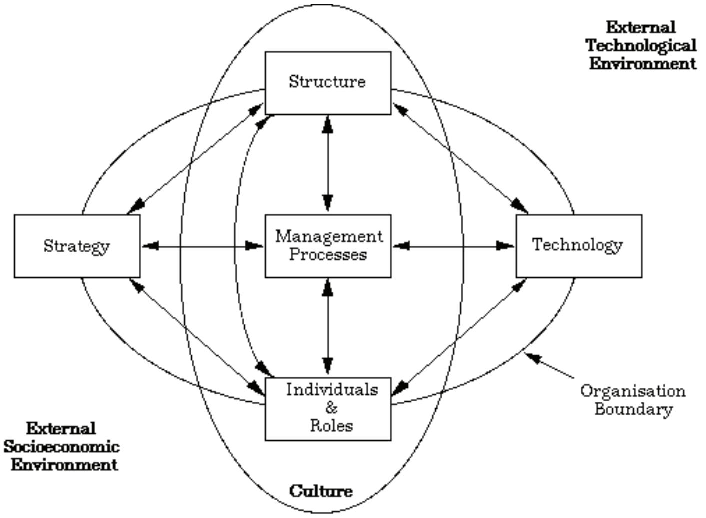
Within each of these strategic perspectives, a number of objectives are developed, and for each objective, key performance indicators (KPIs) are identified and targets determined. The methodology then encourages companies to identify initiatives whereby these targets can be obtained (BSC, 2003). For many companies this has involved the adoption of information technology solutions. Porter and Millar (1985) proposed an information intensity matrix to assist in identifying where information technology could be used strategically in the value chain. Somogyi and Galliers (1987) supported this concept by identifying how information technology could be used to assist companies in attaining competitive advantage in the various strategic focuses across the value chain.

Over the last three decades, companies have increasingly identified the importance of information technology in the achievement of strategic objectives. Scott Morton (1991) identified five interrelated factors that influence the attainment of strategic objectives. One of these factors was information technology (see Figure 1).

INFORMATION TECHNOLOGY ALIGNMENT

Even though the role of technology in strategy development and implementation has been identified, one of the major issues facing companies is the alignment of information technology (IT) strategy with their business strategy (CSC, 2000; Price Waterhouse, 1996). A recent survey of more than 300 CEOs and CIOs identified the alignment of IT and business strategy as their number one priority (Beal, 2003). The importance of this alignment has been identified as a priority for

Figure 1. Scott Morton's (1991) five forces influencing strategic objectives



companies for the past 20 years (Brancheau, Janz, & Wetherbe, 1996). Bakos and Treacy (1986) argue that the increased attention being paid to the role IT has in the corporate strategy is mainly due to the publicity received by companies who have gained significant advantage due to their IT utilization.

Researchers have validated the value to be gained from the alignment of IT and business strategies (Chan & Huff, 1993). Tallon and Kraemer (2003) in a survey of 63 companies found there was significant value gained from the alignment of these strategies. However lack of alignment can result in failure to gain value from IT investments (Gerstein & Reisman, 1982). Factors that have been identified and that have contributed to this lack of value realization include: lack of understanding of the potential of IT by senior management, lack of communication between IT managers and business managers, change management issues, lack of focus on opportunities for competitive advantage, and lack of availability or use of instruments to quantify possible business benefits (Gerstein & Reisman, 1982).

Broadbent and Weill (1993) define this IT-business alignment as "the extent to which business strategies were enabled, supported, and stimulated by information strategies" (p. 164). An alternative definition is: "the degree to which the information technology mission and objectives, and plans support and are supported by the business mission, objectives, and plans" (Reich & Benbasat, 2000, p. 82).

Both definitions involve a bi-directional alignment whereby other than the IS/IT strategy supporting the overall business strategy, it also can be a catalyst for the business strategy. Knoll and Jarvenpaa (1994) believe that this bi-directional reciprocal relationship is important for a company's competitive advantage—a view also supported by other researchers (Oesterle, 1991; Tallon & Kraemer, 2003).

Teo and King (1997) proposed four different scenarios or degrees of integration between the business and IT strategies. These included:

- **Administrative integration:** This is where there is littler relationship between the business and IT strategy.
- **Sequential integration:** This is where the business strategy is developed firstly in isolation to the IT strategy. The IT strategy

is then developed to support the business strategy.

- **Reciprocal integration:** This is where a reciprocal and interdependent relationship exists between both strategies. The IT strategy is used to support and influence business strategy.
- **Full integration:** This occurs when both strategies are developed concurrently in an integrated manner.

This increased need for closer alignment has resulted in companies focusing on strategic information systems planning (SISP) and the development of methodologies to support this (Pant & Hsu, 1995; Hackney, Burn, & Dhillon, 2000). Hackney et al. (2000) identified the assumptions which underlie SISP and discussed their validity. They identified the main assumptions as:

- Business strategies must exist as a precursor to SISP.
- Business strategies are different from IT strategies.
- IT and business strategies can be aligned.

They argue that as business strategies evolve, it is often difficult for IT strategies to respond. They believe that IT applications often require an environment of stability and predictability to enable their development and that the maintenance or modifications to developed applications are often expensive and sometimes impossible. This requirement of stability and predictability may be at odds with the iterative approach to business strategy development. Accordingly, a business strategy may be constrained by the existing legacy IT systems which were developed and implemented in accordance with a previous business strategy. Another premise which underlies SISP is that IT is a source of competitive advantage. For many organizations their IT systems make up a standard infrastructure to support generic information processing. Carr (2003) in his seminal article on the value of IT would argue that as IT solutions become generic and commoditized, there is no competitive advantage to be gained. He makes the analogy with the introduction and diffusion of electricity, whereby companies who initially adopted this technology gained a competitive advantage, but as other companies increasingly introduced the technology, the competitive advantage dissipated.

It can be argued that the technology in itself does not provide the competitive advantage, but how it is used to support business activities. From a different perspective Vitale (1986) proposed that rather than achieving a competitive advantage from the use of IT, IT can be used to avoid a competitive disadvantage. This is where a competitor has achieved a competitive advantage through the use of technology and a company rather than being disadvantaged by this adoption implements the same technology. Hackney et al. (2000) refer to Mintzberg's reasoning for strategic planning being an oxymoron and apply the same reasoning to SISP.

He further highlights the flaws in SISP when it is applied to the impact that enterprise resource planning (ERP) systems have had on business strategy (Hackney et al., 2000). ERP systems are widely adopted in a diverse range of organizations and define the business model on which they operate. For many companies they were relieved that an ERP system could help them define a business strategy and provide the IT infrastructure to support it (Davenport, 2000). Hackney et al. (2000) believe that ERP systems can provide a "dynamic stability" to the alignment of business and IT strategies. These systems can provide a stable predictable environment of which their usage can evolve in accordance with a company's business strategy.

ENTERPRISE RESOURCE PLANNING SYSTEMS

The term 'ERP systems' did not appear until the early 1990s. These systems evolved from material requirements planning (MRP), manufacturing resource planning (MRP II), computer integrated manufacturing (CIM), and other functional systems responsible for the automation of business transactions in the areas of accounting and human resources (Klaus, Rosemann, & Gable, 2000). The attempt to integrate all these systems coined the term 'ERP systems'.

Due to the purported benefits of ERP systems, many companies consider them as essential information systems infrastructure to be competitive in today's business world and provide a foundation for future growth. A survey of 800 top U.S. companies showed that ERP systems accounted for 43% of these companies' application budgets (Somer & Nelson, 2001). The market penetration of ERP systems varies considerably from industry to industry. A report by Computer Economics Inc. stated that 76% of manufacturers, 35% of insurance and healthcare companies, and 24% of federal government agencies already have an ERP system or are in the process of installing one (Stedman, 1999). The ARC Advisory Group (2006) estimated that the worldwide market for ERP systems was $16.67 billion in 2005 and is forecasted to surpass $21 billion in 2010. The major vendor of ERP systems is SAP with approximately 56% of the market.

Researchers believe the growth in the uptake of ERP systems is due to several factors: the need to streamline and improve business processes, and better manage information systems expenditure; competitive pressures to become a low-cost producer; increased responsiveness to customers and their needs; the need to integrate business processes, and provide a common platform and better data visibility; and as a strategic tool for the move towards electronic business (Davenport, Harris, & Cantrell, 2003; Hammer, 1999; Iggulden, 1999; Somer et al., 2001; Markus, Petrie, & Axline, 2001).

For many companies, underestimating the impact the system would have on their organization caused them initially to struggle with their ERP implementation. For some the barriers associated with the lack of skilled resources and inexperience with projects of this scope became insurmountable (Calegero, 2000). Davenport (2000) believes that ERP systems by their very nature impact on a company's strategy, organization, and culture. The move to become process rather than functionally focused and the resultant need for business process integration can result in a loss in competitive advantage in particular areas. However the potential benefits across the entire organization often outweigh the losses in individual areas (Holland & Light, 2001). The lack of understanding of the role ERP systems play within an organization often leads to conflict and hinders benefit realization of the ERP system implementation.

As mentioned previously, for many companies their business strategy is now being influenced by the existence of an ERP system. This is reflected in the views of researchers who believe that a bi-directional reciprocal relationship between the business strategy and the IT strategy is important for a company's competitive advantage and that the IT strategy can act as a stimulus for the overall business strategy (Oesterle, 1991; Tallon & Kraemer, 2003; Knoll & Jarvenpaa,1994; Teo & King, 1997). Companies have made a significant investment in their ERP system and realize that it has the potential to support new strategic directions. This contention is reflected in the landmark Deloitte study (1998), where 49% of the sample considered an ERP implementation to be a continuous process, as they expect to continually find value propositions from their system. This was also the finding of other researchers (Davenport et al., 2004). They surveyed 163 organizations in Europe, the United States, and Australia who had implemented an ERP system and found that no company had finished implementing the system to support all business processes. Over time the benefits companies expect to achieve from their ERP system changes in accordance with their business strategy and the improved functionality provided by the ERP vendors.

Accordingly ERP vendors added increased functionality and "bolt on" solutions to extend the reach and penetration of the ERP system, while at the same time increasing its strategic value. In 2000, the Gartner Group coined the term ERPII to describe such offerings and defined the term as a "business strategy and set of industry domain specific applications that build customer and shareholder value by enabling and optimizing enterprise and inter-enterprise collaborative operational and financial processes." They considered that ERPII would have a global focus and would extend the current ERP systems by incorporating customer relationship management (CRM), supply chain management (SCM), and other strategic solutions (Mohamed, 2002).

ERP Usage Models

Many researchers and analysts have attempted to develop models to illustrate the evolution of ERP benefits and ERP usage. Five main models have been identified from the literature: Deloitte (1998), Holland and Light (2001), Cap Gemini Ernst and Young (2002), Davenport et al. (2003), and Nolan and Norton (2000). These models are based on the premise that companies initially implement a functional component of their ERP system. After a period of time this component's usage is accepted and becomes part of normal work practices. This stabilization results in companies learning from its usage and investigating how to extend this functionality across the company and/or implement other functionality. In other words there is a significant learning curve associated with ERP usage and capabilities.

All the ERP usage models identify the evolutionary nature of how companies use these types of systems to gain greater business value. The use of these systems moves from automating transactional processing to more strategic analytics and forecasting to assist in improved decision making. This is reflected in the two major studies that investigated the drivers and benefits of ERP usage (Deloitte, 1998; Davenport et al., 2003). The earlier study identified the key drivers/benefits of an ERP implementation as operational factors: Y2K compliancy, and disparate systems limiting information integration. Davenport et al. (2003) identified more strategic drivers/benefits in terms of improved management decision making and financial management. The different models and previous research indicate that there is a strong interdependent relationship between business and IT strategies, especially in companies that adopted ERP systems. ERP vendors accordingly have evolved their product offerings from a transactional focus to a more analytical strategic focus. This has created an extremely complex ERP environment where solutions are interdependent of each other. Many of the solutions such as customer relationship management, supplier relationship management (SRM), business intelligence (BI), and supply chain management extend the transactional focused ERP system while at the same time they are reliant on its existence. This means that the implementation of an ERP system could be considerably different from company to company due to the range of functionality and solutions available. This evolution of ERP systems has seen the increased usage of the term "enterprise wide systems."

The usage models reflect the evolutionary nature of ERP systems in supporting various strategic goals. However they do not identify specific functionality usage or solutions implemented in each stage. They indicate goals of ERP usage and organizational focus. The identification of specific functionality and solutions relevant to each phase can assist companies in developing their ERP and IT strategy. It could provide them with a roadmap while at the same time providing input into the overall business strategy. There is limited if any research in this area, and the outcomes of this type of research would greatly assist companies with decision making in relation to their ERP strategy.

These usage models tend to cover additional functionality rather than considering the penetration of functionality across the company. This becomes increasingly important when considering global and transnational companies. These companies face pressures from a number of different fronts and are becoming increasing reliant on quality information through business intelligence solutions to assist with effective decision making. However, what underpins the access to quality information is the standardization of master data definitions, business processes, and key performance indicators. Many companies struggle with this standardization in a single country operation, but the problem grows exponentially in global operations.

Many global operations are using ERP systems to support their operations in an attempt to provide this standardization. However there is the continual struggle between balancing global standardization and local customization. The concept of shared services, whereby corporate-wide activities are centralized and standardized, are becoming increasingly prevalent. The remainder of this chapter discusses how one company implemented an ERP system to support its global operations.

CASE STUDY

A case study research methodology was used for an exploratory look at how a company uses an ERP system to support its overall business strategy. The case study focused on a large company involved in the process manufacturing industry. The data collection process will include examination of existing documentation, content analysis of internal documentation, and interview of key personnel. Yin (1994) suggests that a single, in-depth case study is an appropriate research approach under a number of conditions, one being that it is a critical case whereby it meets all the necessary conditions for testing a theory.

Initial contact was made with case study company (Fonterra) after representatives of the company presented at an ERP user group conference. They agreed to participate in the research activity. Background material about the company was collected from the company's Web site. Further contact was made with the company in February 2004, and a key staff member was identified to be interviewed. The interview was conducted at the company's head office in Auckland, New Zealand, in late February. During the interview a number of documents relating to company strategy and IT strategy were supplied. A follow-up interview was conducted with another key staff member in October 2004 via telephone conference call.

Company Background

The dairy industry is New Zealand's largest industry which accounts for in excess of 20% of the country's exports and 7% of its gross domestic product (GDP) (Fonterra, 2004a). To facilitate the export market, in the 1930s the New Zealand Government established the New Zealand Dairy Board in partnership with the numerous small dairy companies. Over the years in an attempt to achieve greater efficiencies and economies of scale, there has been numerous mergers of the smaller companies. By the end of the 1990s there existed four main dairy companies, but it was realized that extra efficiencies and maintenance of competitive advantage could not be achieved unless a major reform was undertaken. In conjunction with a consulting company, the industry identified three major focuses for its future strategy. These included:

- Maintain competitive advantage as low-cost producer of diary products

- Improve performance of existing business
- Pursue aggressive growth opportunities

A number of options were considered to how best to achieve these strategic goals, and it was concluded that "a single, integrated company that collects, manufactures and sells commodities and ingredients would create [the] most value" for the stakeholders (Fonterra, 2001, p. 5).

The proposed consolidated company, which was later to be known as Fonterra, was expected to achieve an annual savings of $310 million by the end of the third year. These savings would be achieved by a combination of: elimination of duplicated facilities and activities; an increase in productivity through the integration of manufacturing, marketing, and distribution activities; and the exploitation of new markets technology and biotechnology opportunities.

Fonterra Corporation

Fonterra is a New Zealand dairy cooperative formed in 2001 (Fonterra, 2004a). The company is responsible for the collection and processing of more than 96% of New Zealand's milk involving more than 13,000 farmers. It has an annual turnover of US$6.8 billion, which accounts for 20% of New Zealand's export receipts and 7% of its GDP; it is the largest dairy ingredients producer in the world. Its supply chain extends from New Zealand to customers in 140 countries. To support this supply chain, the company has sites in 40 countries and a workforce of more than 20,000.

The three organizations, which merged to form Fonterra, were culturally, structurally, and operationally significantly different. In an attempt to achieve its strategic goals, Fonterra developed a number of strategies to facilitate the changes that needed to occur in the company. The company identified seven strategic themes and associated metrics:

- **Lowest cost supplier of commodity dairy products:** Fonterra believed that this was its main competitive advantage and aimed to achieve an improvement across its supply chain of at least 3% per annum.
- **Leading price and inventory manager in the global commodity market:** Fonterra identified opportunities to increase its global markets through access to improved information. This will enable Fonterra to develop enhanced analytical approaches to supply chain management and product development.
- **Effective developer of dairy ingredients partnerships in selected markets:** Fonterra identified the need for improved integration and collaboration with key customers. These improved interactions will strengthen relationships with existing customers and provide opportunities to establish strong relationships with new customers.
- **Leading specialty milk components innovator and solutions provider:** Fonterra believes there are opportunities to develop new innovative products customized for particular customers and niche markets.
- **Leading consumer nutritional milks marketer:** Fonterra believes that there is an increased demand for nutritional dairy products, and accordingly strengths in branding and go-to-market capabilities need to be enhanced in existing and new markets.
- **Leading dairy marketer to food service in key markets:** Fonterra believes that opportunities exist in extending the company's presence in the food service market, and that this can occur by the development of innovative products and enhance its product and distribution coverage.
- **Develop integrated strategies for four key regional markets:** Fonterra believes that there are opportunities to be realized in the global market, but there is a need for integrated strategies across the value chain

which maximizes opportunities while at the same time manages risks (Fonterra, 2004a).

Jedi Project

Fonterra developed a number of strategic projects to facilitate change in accordance with its strategic themes. One of these projects was titled "Jedi" which commenced in November 2003. The Jedi project consisted of 40 interconnected projects with the common goal of ensuring that Fonterra would realize its strategic goals as a leader in the dairy industry. The project's underlining objectives were to provide a global business model which involved common business processes, systems, and classification of customers with a focus on simplicity. Specific goals of the project were (Fonterra, 2004b, p. 20):

- "Operations work well with all other parts of the ingredients business."
- "Managers have a better understanding of costs so they can make the right decisions."
- "All the people working in Operations have the skills and equipments they need to do their jobs to the best of their ability."
- "We have one way of doing things across the manufacturing sites."
- "People want to actively share best practice and good ideas with other sites."
- "Existing projects are completed and all projects work towards common goals."

The Jedi project consisted of four major components: sales network structure (SNS), global customer service center (GCSC), global back office (GBO), and empower.

Sales Network Structure

Before the commencement of the Jedi project, Fonterra's customers receive the same level of service independent of the revenue they generate. The sales network structure was designed to segment Fonterra's customers in an attempt to customize the level of interaction and service relevant to the customer's revenue stream. This would enable Fonterra to strengthen the collaboration and integration with key customers and thus deepen the relationship. The customers were segmented into four different categories:

- **Segment 1:** Large customers who account for more than 40% of Fonterra's revenue
- **Segment 2:** Customers who provide good business and have good growth potential
- **Segment 3:** Customers who provide a steady stream of income but have limited growth
- **Segment 4:** Intermittent customers

The customers in segments 1 and 2 would receive a highly personalized sales channel through account managers, while segment 3 and 4 customers would use self-service facilities available in the global customer service center. The sales network structure proposes how offices around the world can best service each customer segment. As part of this service, the global customer service center will be established.

Global Customer Service Center

This component is designed to be a link between sales activities and order fulfillment, and will directly service both account managers acting on behalf of customers and customers dealing with the center directly. The functions will be centralized and located in Auckland, New Zealand. Due to the organization's sales network, the GCSC needs to provide worldwide support, operate 24x7, and will have multilingual facilities with approximately 120 staff members. One of the perceived advantages of this service will be a common price list, which did not exist previously and caused the company quite a lot of embarrassment when large customers could quote different prices for the same product from different sources.

Global Back Office

This component is responsible for the handling of the majority of Fonterra's accounting and human resource transactions. It will provide a mechanism to standardize business processes in these areas while at the same time deliver efficiencies through centralization and economies of scale. The company realized finance, human resources, and the associated information systems are key areas which underpin operations across the supply chain. This realization reinforces Porter's view of the value chain (Porter, 1985). Fonterra believes that once "best practice" is adopted in these areas throughout the company, then greater attention can be paid to customer-focused operations.

Empower

This supply chain management component encompasses order management, logistics, and planning. It is envisaged to change the traditional business focus from one that was reactive to a more proactive approach whereby people would work to a plan. In other words it would allow customer orders to be matched to planned customer demand. This component is expected to drive efficiencies across the supply chain by implementing standard end-to-end processes and business rules, and integrating planning and execution.

Information Systems Strategy and Jedi

Fonterra believed that the effective selection and use of information system solutions would be essential to the project's success and thus success of the overall strategy. As the company was the result of a merger of a number of existing companies, there was already a plethora of IS solutions implemented. These included various ERP systems such as J.D. Edwards, Oracle, and PeopleSoft, which indicated a considerable investment by each corporate entity.

The first phase of the Jedi project was the implementation of Empower which had an aggressive implantation with a go-live date at the end of March 2004. It was decided to implement SAP's supply chain management solution to support these functions at an expected cost of $NZ120 million (Gifford, 2004). SAP was selected as it was considered to have incorporated "best business practice" and would ensure standardized end-to-end processes in accordance with the project's goals. One of the issues with the existing SCM solutions was that they were extensively customized, which resulted in considerable maintenance problems, and therefore it was decided that to facilitate future upgrades and the global rollout of the SCM solution, minimal customization would occur in the Empower project. To facilitate integration between its various components and across the global supply chain, Fonterra implemented the WebMethods integration solution.

The second phase of the Jedi project involves the rollout of GCSC and GBO. The sales network structure was implemented in the United States with an expected go-live date in August 2004. The rollout around the rest of the world occurred in 2005. SAP solutions were implemented to underpin this phase of the Jedi project. The financial and human resource modules were implemented to support the global back office component. This will replace in-house systems and an existing Oracle ERP system. The financial module will incorporate general ledger, accounts payable and receivable, and assets management. While the HR component will involve the implementation, the "manager's desktop," and the "employee self service" (ESS). The manager's desktop enables managers quick access to information and transactions related to employee who they are responsible for, while the ESS solutions use a Web-based interface which enables employees to view and maintain personal details, as well as quick access to transactions relating to their working environment such as applications for leave, overtime, training, and so forth. A quick win for this solution will be the savings gained by the implementation of electronic pay slips.

Although the company has implemented SAP solutions, a number of existing ERP systems will remain in some areas of distribution and financial activities in factories. This will require a number of interfaces to be developed to Jedi solutions. The non-ERP systems will remain until ROI is achieved, but eventually will be phased out for SAP solutions. Fonterra intends to adopt a "vanilla" approach to its implementation whereby minimal customization of the system occurs. This is expected to facilitate the global rollout and future upgrades, and minimize the impact of future acquisitions. There will be a single implementation of the SAP system (instance) in New Zealand, and this will be based on a global template which will have restricted localization in each of the 40 countries where it will be rolled out. This ensures standardized definitions and business processes throughout the company. This will facilitate the information flow, and thus improved reporting and decision making.

Fonterra has a number of other proposed implementations to support their strategic directions which include data warehousing, advanced planner and optimization, and customer relationship management. Eventually the company will have replaced 15 core systems with SAP solutions.

The implementation of the ERP system is considered by Fonterra as fundamental to its business transformation in a global environment. The company believes that in its global operations, it has moved from autonomous independent localized operations to standardized business processes, rules, and configurations. Fonterra has centralized its business processing and customer service center as well as centralized planning and supply chain management. It now believes that the company is in a position to quickly adjust its corporate strategy to market demands.

CONCLUSION

When companies expand their operations globally, they struggle with their information systems infrastructure to support the extended business processes. ERP systems are seen as a tool to assist in this process. However the ERP systems global model varies from company to company. This is dependent on the level of standardization of processes, master data, reporting, and user interfaces required. The greater level of standardization usually occurs at the expense of localization needs. The case study company has opted for a global template to ensure an increased level of standardization.

FUTURE TRENDS

Globalization of ERP systems is becoming a major issue for many companies. There is an increased tendency to implement a global template to ensure greater standardization and compliance. As companies' global ERP systems implementations become more mature, there may be modifications made to the global template to address localization issues. The adoption of service-oriented architecture technology will assist in this variation to the global template.

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Chapter 1.28

The Integrated Enterprise Life Cycle:

Enterprise Architecture, Investment Management, and System Development

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ABSTRACT

The enterprise architecture provides benefits to the organization that embraces it. However, in many organizations, the enterprise architecture effort is not tightly coupled and integrated with other enterprise level programs such as investment management and system development processes. This chapter will identify the process integration and enterprise architecture touchpoints from the perspective of the investment management process and it outlines an overall integrated enterprise life cycle process flow. Specifically, this chapter explores Why it is important for an organization to follow an architecture-driven integrated enterprise life cycle? What are the processes of an enterprise life cycle and how do they fit together, specifically the enterprise architecture, investment management, and system development processes? What is an organizational structure for managing and executing the integrated enterprise life cycle? What is an approach for implementing an integrated enterprise life cycle?

INTRODUCTION TO ENTERPRISE ARCHITECTURE AND THE INTEGRATED ENTERPRISE LIFE CYCLE

An enterprise architecture provides significant benefits to an organization that embraces it. However, in many organizations the enterprise architecture effort is not tightly coupled and integrated with other enterprise level programs such as investment management and system development processes. (Bernard, 2005; Rechtin, 1991)

The target enterprise architecture and the IT initiatives needed to achieve the target should be managed in an IT portfolio within an overall investment management process. Additionally, as these IT initiatives are being implemented and deployed, there is a need for oversight and good project management. To ensure comprehensive IT governance and business/IT alignment, the enterprise architecture must be integrated into an overall "integrated enterprise life cycle" that includes not only the enterprise architecture, but also an investment management process as well as the individual system development life cycles. The challenge for most organizations is that the guidance, responsibility, and skill sets for these various processes can be spread out across the organization and are often implemented in a silo, nonintegrated fashion. Only by viewing these processes as a whole can an organization achieve the maximum benefits that an enterprise architecture can provide. This chapter will identify the process integration and enterprise architecture touchpoints from the perspective of the investment management process and it outlines an overall integrated enterprise life cycle process flow. Specifically, we will discuss:

- Why it is important for an organization to follow an architecture-driven integrated enterprise life cycle?
- What are the processes of an enterprise life cycle and how do they fit together, specifically the enterprise architecture, investment management, and system development processes?
- What is an organizational structure for managing and executing the integrated enterprise life cycle?
- What is an approach for implementing an integrated enterprise life cycle?

BACKGROUND AND MAJOR PROCESSES OF THE ENTERPRISE LIFE CYCLE

We start by defining the major processes of the integrated enterprise life cycle (IELC) which include the following:

- **Enterprise architecture:** The enterprise architecture establishes a comprehensive understanding of an organization's core business processes and defines the technology that supports and optimizes them. (Armour, Kaisler, & Liu, 1999a)
- **Investment management planning and oversight:** The investment management process (IMP) is a fluid, dynamic process by which an organization selects and monitors both proposed and ongoing IT investments (initiatives) throughout their life cycle. An organization evaluates IT investments to assess the impact on future initiatives and to benefit from any lessons learned. The IMP can contain three phases (GAO, 2004):
  - The *select phase* discovers and selects the IT investments that best support the organization's mission needs and identifies and analyzes each project's risks and returns before committing significant funds to a project.
  - The *control phase* ensures that, as the investment is implemented, the project continues to meet mission needs at the expected levels of cost and risk.

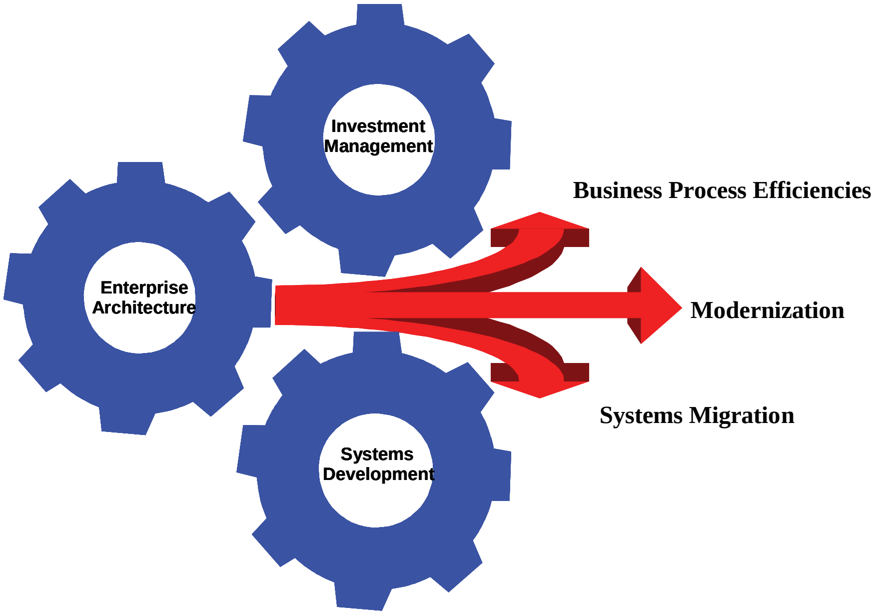
  - The *evaluate phase* compares actual vs. expected results for the implemented project.
- **System development life cycle:** A system development life cycle (SDLC) program provides guidelines and procedures for system acquisition, development, implementation and deployment, and project management. The SDLC guidelines address such areas as configuration management, risk management, requirements management, design, acquisition management, test management, and quality assurance throughout the life cycle of a project from its inception to its completion. The SDLC supports the organization's enterprise architecture and investment review processes by providing guidance for selecting appropriate methods, techniques, and tools based on specific organizational and project factors.

Figure 1 expresses an IELC that encompasses investment management, enterprise architecture and systems development (SDLC). Key components of the enterprise life cycle are discussed in the next sections.

Integrated enterprise architecture, investment management, and systems development processes are similar to a set of gears whose output is greater then the sum of the parts. The enterprise architecture provides the structure and vision as to where the organization is and where it needs to go. The investment provides the IT governance, discovery, selection, and control for the portfolio of initiatives that are needed to acknowledge the enterprise architecture target vision. For each of the individual initiatives, a system development life cycle methodology provides standard detailed guidelines for project managers. The investment management process, enterprise architecture, and systems development life cycle (SDLC) should be highly integrated to ensure projects have the needed process support.

To be most effective, these enterprise processes need to be highly integrated with multiple touchpoints. For example, to maintain alignment

Figure 1. Integrated enterprise architecture, investment management, and system development



with the organization's goals and objectives, the investment management processes should perform portfolio management to select, prioritize, and control its key IT initiatives, as this highly influences and is in turn influenced by the target enterprise architecture including its business, application, data, and technical dimensions. As new initiatives are proposed, they need to be mapped against and comply with the enterprise architecture. (Armour et al., 1999a; Armour, Kaisler, & Liu, 1999b). New initiatives are guided by the organization's defined architectural principles. (Lindstrom, 2006; Open Group, 1999) As these initiatives are developed and implemented, they need to follow an organizationally defined system development life cycle (SDLC) that specifies the project management and technical activities. The SDLC has touchpoints with the enterprise architecture to ensure that an initiative's evolving requirements, designs, and technology continue to adhere to the target enterprise architecture. In addition, the SDLC specifics integration points to the investment management process in such areas as project status reports to a project review board and risk management. This chapter identifies the process integration and touchpoints from the perspective of the enterprise architecture and outlines an overall IELC process flow. The outcome of the IELC is improved business efficiencies and more efficient system mitigation and modernization. Without an IELC:

- Organizations will have a difficult time aligning IT initiatives to strategic business goals and objectives.
- These initiatives will tend to be selected and developed in isolation of each other.
- Ongoing initiatives will not have the needed project and program oversight to ensure that they adhere to their functional cost and resource metrics.

The organization's mission and business objectives provide the key input into the IELC. They can include the organization's mission, vision, business drivers, strategic goals, strategic business objectives, information needs, IT vision, IT objectives, and guiding architectural principles. This business direction is used as a guidance tool and remains relatively stable over time. It is critical that alignment among IT applications and technology and the organization's mission and objectives be defined and maintained throughout the entire IELC. In this chapter, we use the investment management process as the framework to demonstrate the integrated of the investment, enterprise architecture, and SDLC activities.

Throughout this chapter, we will use an example to combine the concepts in this chapter with an example of a technology implementation. The example we will use is the implementation of an asset inventory system that will support the business on managing their assets.

INTEGRATED ENTERPRISE LIFE CYCLE ORGANIZATION

For an organization to fully implement and institutionalize the IELC there needs to be:

- Leadership and strategic direction, whether the organization is a sole proprietorship or a Fortune 500 company, are required to ensure the services, products, and processes are completed. Leadership and strategic direction are demonstrated by having a viable Investment Review Board (IRB), a Modernization Board, and the enterprise architecture.
- Process controls are needed that include information security, project management, SDLC, change/configuration management, and data management. These are among the normal components that should be in place to manage repeatable and ever improving processes for business efficiencies. Many individual companies use the CMMi as a

way of providing a guide to creating and maintaining those processes.

- The final key element is financial control through investment management and quality assurance processes. These two elements ensure appropriate use of funding and ensure that the processes being used by the organization are followed and efficient.

With these three elements, your organization starts to have the components needed to establish an IELC. From financial management to strategic direction to controlling the quality and security of the product, the IELC ensures that the support mechanisms are in place.

To implement the IELC, an integrated organization needs to be created. The components of the organization that will be discussed in this chapter include the following in Table 1.

Table 1 lists the organizational components of the IELC. The Investment Review Board is made up of key leadership positions representing the head of the organization, the business units, the chief financial officer (CFO), and the chief information officer (CIO). This board ensures that the strategic direction, transition plan (sequencing), and the prioritization of scarce resources are allocated to the correct portfolio.

For example a proposed asset control system that is presented to the IRB will have an executive sponsor, a project management team, and an implementation team that combines technical staff from the CIO and business subject matter experts from the business unit(s).

IELC INVESTMENT MANAGEMENT PROCESS

The Investment Management Process (IMP) is a fluid, dynamic process by which an organization monitors proposed and ongoing IT investments throughout their life cycle. The process evaluates IT investments to assess the impact on future initiatives and to benefit from any lessons learned. The IMP contains three phases—select, control,

Table 1. IELC organizational components

Organization component	**Role/Responsibility**
Investment Review Board (IRB)	Directs the strategic direction of the transition plan; approves the portfolio; assigns executive sponsorship; and sets priorities for the organization.
Office of Information Technology (OIT) (or similar organization)	Responsible for leading the planning, acquisition, implementation, operation, and management of the automated information systems.
Modernization board	Responsible for establishing and maintaining the organization's enterprise architecture reviews project proposals to ensure alignment with the enterprise architecture as part of the funding process researches new technology.
EA program office	Provides architectural oversight of all EA and SDLC projects.
Enterprise Architecture (EA) executive steering committee	Provides IT technical and managerial oversight of the EA.
Project Review Board (PRB)	Project oversight; oversees all projects assigned to OIT; monitors schedules, costs, and risks.
Information technology outreach	Coordinates with stakeholders; receives feedback on issues and progress.
Change Control Board	Addresses SDLC change issues/requests.
System Development Life Cycle methodology	Quality assurance and system development guidance

and evaluate as defined earlier in this chapter.

The IMP has been designed to scale to the unique characteristics of the information technology projects. The steps are grouped into the three phases—select, control, and evaluate to align with the investment management framework. The process described in this section is intended as a starting framework for an organization. An organization, based on such factors as size, culture, and the external environment that it operates in, should be prepared to adjust and modify this process to meet its specific needs.

THE SELECT PHASE

The first phase of the IMP includes procedures for ranking and selecting new investments and related projects based on several factors including costs, value, risk, alignment with the enterprise architecture, and the portfolio.

The activities in the select phase help to ensure that there is a solid alignment with mission and business needs and that the investments will fit within current portfolio of IT investments. This phase also provides an initial determination of the oversight level and validates whether an IT investment meets all technical and project requirements. Figures 2 and 3 highlight the key activities within the select phase; the activities are discussed in more detail next.

Yearly/Annual Budget Formulation-Select Phase Process

Before the start of every fiscal year, a budget formulation process determines the approved, baselined IT portfolio for the coming year. The yearly/annual budget call begins with a call for new projects or a renewal of projects for the next fiscal year. The OIT, working closely with the business stakeholders, compiles the projects into a proposed IT portfolio. The proposed IT portfolio is then submitted to the investment review board (IRB). The IRB reviews and analyzes the IT portfolio, making any needed adjustments to the portfolio (based on such factors as cost, benefit, risk, and priority) and approves the IT portfolio for the upcoming year. The portfolio is then baselined to include costs, alignment, as well as conformance with the enterprise architecture transition plan to that demonstrates the transition from the current state of business to the to-be state of the business.

For example, if an asset management system had been proposed, it could be selected as an item for development during this process and be weighed against other processes. If the IRB approves the development of a new asset management system, then a formal project would be started. In order for the IRB to make that determination, a concept of operations, a costing proposal, and a cost benefit analysis would be included in a business case for the initiative. The

Figure 2. Annual investment review select phase

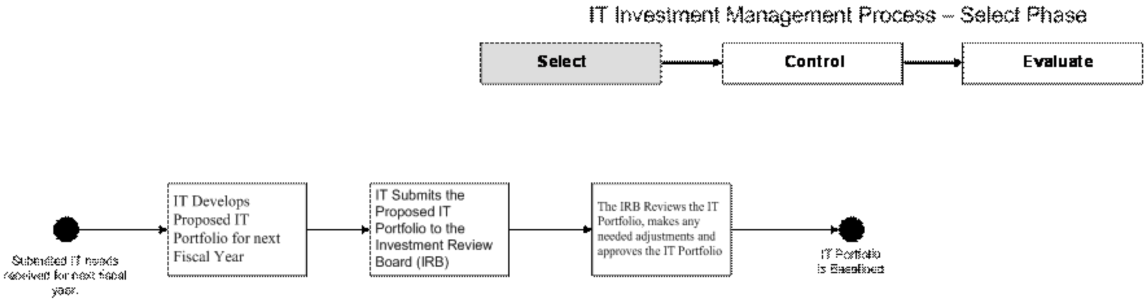
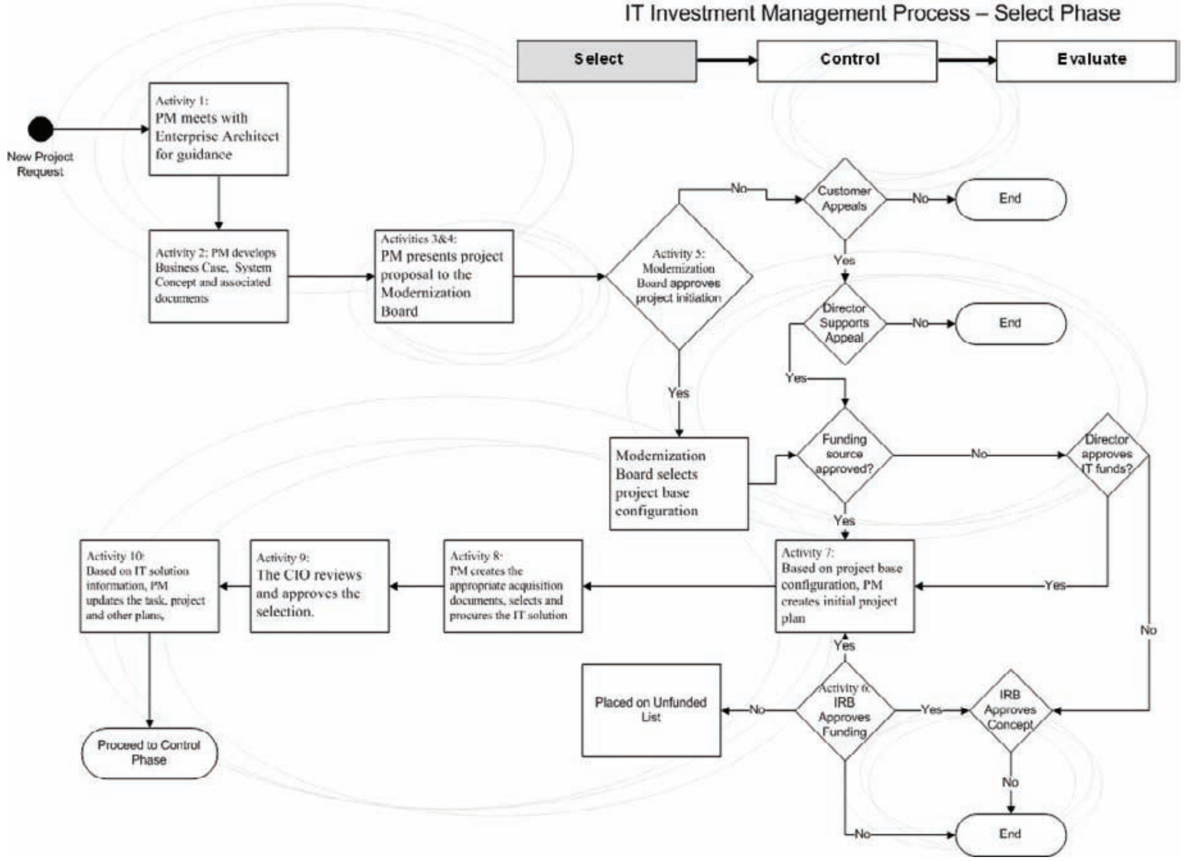


Figure 3. Ongoing investment review select phase



business case would also address how the initiative is aligned with the enterprise architecture's target vision, architectural principles, and the appropriate EA technical standards. Ranking of the project should be from the IRB only after the CIO has had an opportunity to review and pre-rank the projects.

Ongoing Select Review Process

During the fiscal year, when a new IT project request is received, the following ongoing select review process occurs as depicted in Figure 3. This includes reviewing the EA transition plan (Armour & Kaisler 2001) to ensure that integration points are not out of sequence as timetables, costs, and deliverables change. We will assume that an asset management system has been proposed as a new IT project in the following discussion.

Activity 1: Initial Project Setup Meeting

The project manager meets with the Enterprise Architect and Modernization Board representatives for guidance on the project approval process[1]. The EA and Modernization Board representatives, based on the initial understanding of the project's scope and characteristics, provide the project manager with guidance and advice that includes, but is not limited to:

- Initial advice on ensuring conformance with EA target vision and alignment with goals, objectives, and business processes.
- The needed documents for the Modernization Board review such as new project request form, system concept, cost benefit analysis, and feasibility studies.
- Advice on engaging additional stakeholders.
- Initial review to determine if the proposed effort is already part of the IT portfolio.

The system development life cycle (SDLC) methodology is used throughout the IMP to provide guidance and documentation support to the project manager. The SDLC also ensure cost controls during the project by creating natural milestones for financial review. At this time, the asset management system would be an outlined proposal.

Activity 2: Develop a Business Case

The project manager develops a business case for the Modernization Board for review and inclusion into the proposed IT portfolio. Other documents that may be submitted but are not necessary include a detailed costing proposal, concept of operations, detailed cost/benefit analysis, and resource plan. The business case is a means for the business community to engage and ensure that the asset management system they are proposing has the buy in of its stakeholders and the IT community. Some key questions that should be answered by the business case include:

- Will the asset management system supporting the goals and objectives of the organization?
- Does it make fiscal sense to build an automated system?

Activity 3: Submit Business Case to the Modernization Board

The project manager submits the request for a new project to the Modernization Board. The request must be submitted with all associated documents prior to the review meeting in order to allow sufficient time for the Modernization Board review.

The requestor will also work with a Modernization Board representative, the sponsoring office, enterprise architect, a senior CIO representative, and the designated project manager to score the project against a pre-defined set of value and risk criteria and to determine the base project configuration. The project manager and sponsoring office representative present the business case to the Modernization Board.

Activity 4: Presentation to the Modernization Board

Requests for new or upgraded IT projects are initially presented to the Modernization Board, which either approves the item as being in alignment with the enterprise architecture (EA), agrees to grant a waiver for the item or denies the request, possibly with a request for modifications before resubmittal. The Modernization Board will bring in stakeholder subject matter experts as appropriate to provide input on proposals.

When the Modernization Board reviews the business case, it is specifically reviewing it with the following in mind:

- Determines if the project adheres to all elements of the enterprise architecture such as architectural principles, business roles, technology standards, application data, and security principles.

- Determines key risks on the project and recommends how to address them.
- Determines if the project fits within the IT portfolio (for cost, risk, benefit, and priority).
- Determines if the project aligns with the organization's goals, objectives, and business processes.
- Recommends a base SDLC project configuration template to use. Example templates include small project, medium project, and infrastructure project.
- Determines a project's mission criticality.
- Determines if IRB approval is needed.
- Provides other guidance as needed.

Activity 5: Modernization Board Approval

The Modernization Board approves/disapproves the project. If the project is approved, it is added to the IT portfolio. The Modernization Board can also ask that it be resubmitted with modifications or additional information.

If the project is denied, the project requestor has the right to appeal to the IRB or executive agent of the organization along with the signature of the CFO and the CIO, for a final and binding decision. A waiver will be granted only by consensus (consensus in the context of this document means the majority opinion of the Modernization Board). Generally, waivers are decided on a case-by-case basis, but a few possible reasons are:

- Replacement of existing proprietary technology where it would be too expensive to convert to an entirely new set of platforms (hardware, software, telecom).
- Only one vendor provides the necessary functionality (with a proprietary system) and this can be justified based on cost, schedule, or satisfying certain unique requirements. Or if it would be too costly to customize a commercially available package to meet the requirements.
- The system is required to interface with an externally provided system that uses proprietary technology which is mission critical to the.

If the project under consideration has an impact on the EA technical reference model (TRM), the Modernization Board will determine, based on project characteristics such as risk, cost, and benefit, whether to accept or reject the proposal and what updates, if needed, will be made to the TRM. The Modernization Board will then make the final determination of proposal acceptance or rejection.

In our example, the asset management system will need to develop a proposal for purchase or development of the system. During that time, the approval of the Modernization Board would help mold that proposal based on the current technology investment, standards, and costing for the project. The asset management system may have constraints because it has to integrate with the financial system. If so, during the impact analysis with respect to the EA, the asset management system may have additional requirements added to the scope of the project including business functions as well as technical integration requirements.

Activity 6: Investment Review Board Approval

Once a project has been approved by the Modernization Board, and if it is a project that requires funding beyond what the organization can accommodate in its current budget, it will go to the IRB. The project manager will present the business case along with a concept of operations, cost benefit analysis, and feasibility study to the IRB. Projects that need funding are addressed under two scenarios: During the annual budget cycle (new project requests) and previously unplanned projects that come up during the year (e.g., new legislation, technology no longer supported by vendor, etc.) for which funding is not available.

The IRB will vote to approve or deny funding. If denied, the business unit may appeal to the CEO or head of organization based on the merits of the project. However, the CIO and the CFO as official stewards of information technology and financial management must be included. It is important that these appeals be reflected in the EA transition plan as well as the target enterprise architecture to reflect the decisions by senior management. The CEO or head of the agency that approves this may ask for an impact analysis by the enterprise architect to have an independent view of the impact to the organization as a whole.

For example, the EA transition plan may show that a delay of the acquisition of an asset management system is required if the business functions are not completely defined or the development of other systems have not been done that have more strategic importance. The enterprise architect would discuss with the CIO with IRB the relationship between systems and develop a transition plan that would help ensure the successful completion of the portfolio. The asset management system may be delayed if a major shift in the financial system was going to be done the same year because of risk or cost.

Activity 7: Initial Project Plan Development

Based on project characteristics (size, risk, etc.), the project manager develops the initial project plan, initial task plan (WBS), and other associated documentation. The focus on initial project plan is detailed planning for the upfront procurement and analysis activities. The project task plan is entered into a project management tool. (*Note: Regular PRB status reporting starts at this point*). The asset management system project plan would be input here.

Activity 8: Acquisition and Source Selection

Working with procurement, the project manager creates the appropriate acquisition documents and selects and procures the IT solution. This a strong touchpoint to enterprise architecture. Part of the acquisition and source selection of a tool or product to automate a process should be reviewed by the enterprise architect to ensure coherence with the future alignment of the business and the technology.

This is an iterative process because the business subject matter experts should ensure the system works for them. The OIT should ensure that the systems are interoperable and the CFO before the signature of the selection should ensure that it is fiscally responsible. The asset management system acquisition cycle should include those reviews to ensure business function, financial feasibility, and system integration are included.

Activity 9: CIO Approval

The CIO (senior IT manager) and executive sponsor (business unit representative) review and approve the selection to ensure that the IT solution continues to align with the goals, objectives, and business objectives.

Activity 10: Updated Project Plan

Based on IT solution information, the project manager updates the task, project, and other plans and updates them in the project management tool. As the project plan changes, deviations greater than 5% require that the enterprise architect check to see if the EA transition plan is being impacted.

THE CONTROL PHASE

The control phase of the IT investment management process provides the consistent monitoring of ongoing IT projects, reprioritizing them as conditions change, and re-selecting them for continued funding. This phase ensures that the project remains aligned and compliant with the EA.

The control phase focuses on oversight and review of a project from requirements validation through implementation. The purpose of this phase is to ensure that the project manager manages and implements the approved project in a structured manner, using sound management practices and ensuring involvement of all key parties. Each approved investment must ensure:

- Continued compliance of the proposed solution with the enterprise architecture.
- Ensure that the project adheres to the SDLC.
- Ensures scope is maintained during the project design and implementation.
- Continued alignment with goals, objectives, and business processes.
- Compliance with the systems development life cycle processes (project planning and management, requirement management, configuration management, quality assurance, testing, contractor management, etc.).
- Compliance with systems security standards and requirements.
- Continued viability assessed by compliance with project costs, schedule, and performance measures.

The project review board (PRB) has primary responsibility for ensuring that the project manager properly manages investments on an ongoing basis. Projects will continue to draw on and utilize the SDLC for direction in these areas. The IRB ensures that the investment continues to meet business and mission objectives and address any critical issues related to these. Figure 4 highlights the key activities within the control phase; the activities are discussed in more detail next.

For example, the asset management system that was purchased may have financial functions for deprecation and for investment cycles. This is where the IELC is of great value. The enterprise architect, the business subject matter experts, executive sponsor, and the project manager would work with the vender and the business units involved to resolve where the functions of the financial management of assets belongs. If the original concept of operations didn't include this business function, then the Modernization Board would review the scope change and recommend to the IRB a change. If the business function is automated in another system then it is hoped that the concept of operations included an integration point, if not then a change of scope would happen again. The enterprise life cycle should be flexible enough to include these changes.

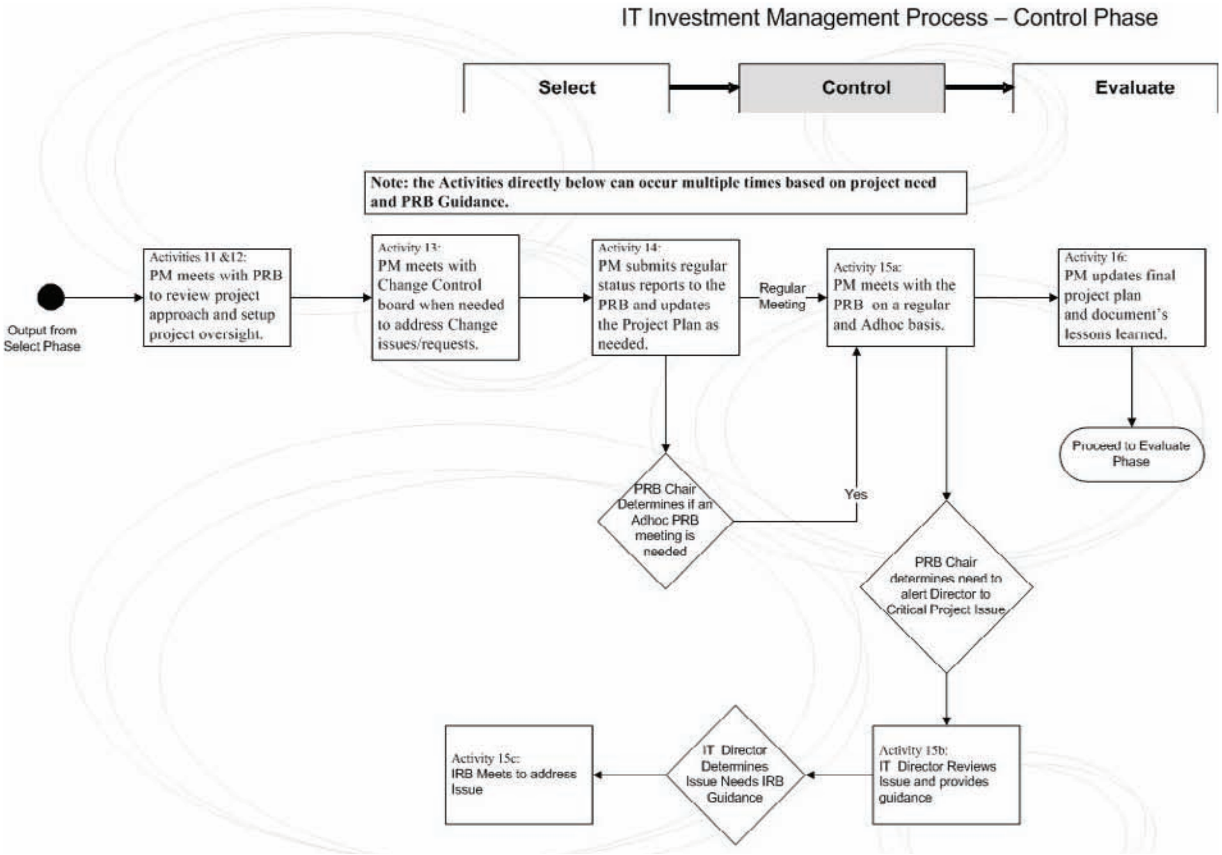
Activity 11: Initial Project Review Board Review

The project plan and any associated information is submitted to the PRB. The project manager meets with the PRB to review project approach and setup project oversight including project review schedules, as well as SDLC artifacts and activities. The PRB provides input, guidance, addresses risks, determines review gates, and approves the project. In the case of the asset management system, the PRB may identify a scoping issue that would be sent to the modernization office.

Activity 12: Baseline Project Plan

The updated initial project plan is baselined. At this point again, any changes to the associated milestones or resource allocation changes should be reported to the enterprise architect to ensure that the sequencing plan is updated and dependencies are reviewed. If there are financial impacts those should be submitted to the financial management office to ensure funding is available.

Figure 4. Investment review control phase



Activity 13: Change Control Review

The project manager meets with Change Control Board (CCB) when needed to address change issues/requests. (*Repeated throughout the project as needed*). The role of the change control board are to maintain the integrity of the system life cycle during the life of the project. This includes the documentation, code, and requirements during the design and implementation of the system.

Activity 14: Project Status Reporting

The project manager submits regular project status to the PRB chair. The PRB chair may, based on the status reports, initiate a meeting with the project manager and/or call a PRB review. Project status reports and any actions taken are captured for program management reporting. (*Repeated throughout the project*). A copy of the project status report should be given to the enterprise architect and a full project status review should be conducted if the deviation from the baseline is greater than 5%.

Activity 15: Project Status Review

The project manager meets/informs with the PRB based on a regular and adhoc review schedule. The PRB will review the project deliverables and provide guidance. The enterprise architect will continue to monitor the project during these reviews to ensure continuing EA alignment. During this activity, the appropriate SDLC artifacts are reviewed (e.g., project plan, requirements documents, design documents, test plan, etc.) to determine their quality and provide feedback and guidance to the project team. (*This activity is repeated throughout the project as needed*).

If the PRB chair determines that the project has incurred such risks or issues that a higher-level review is required, the CIO is alerted. The CIO will review the project status and provide direction and guidance. If however, there are critical risks and issues that will significantly affect the project's outcome and alignment with business objectives and performance measures the IRB will be alerted.

The IRB may review the project, its progress, and issues and make a determination as to corrective action, including cancellation of the project. This review can be requested at any time.

Project statuses and any actions taken are captured for program management reporting.

Activity 16: Update Final Project Plan

At the conclusion of the project, the project manager will update the final project plan and document the lessons learned.

THE EVALUATE PHASE

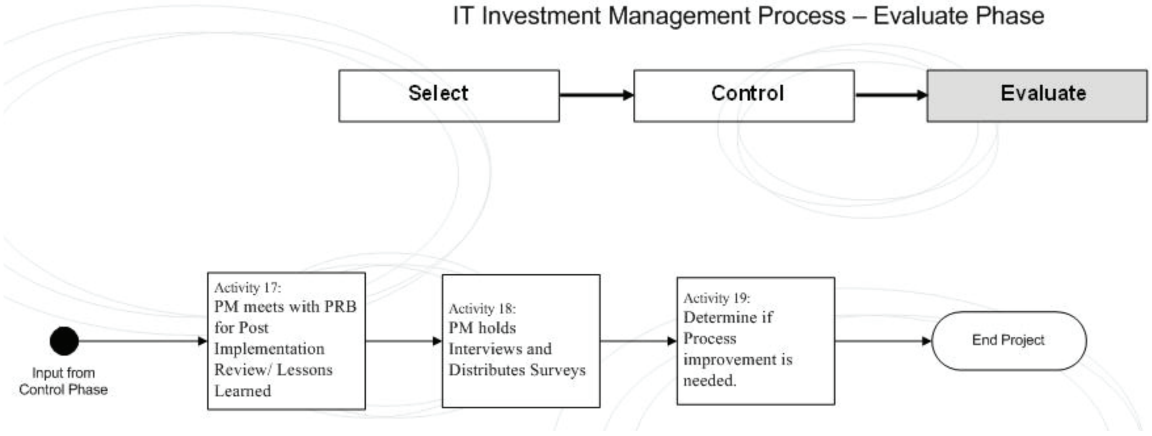
The final phase of the investment management process is the evaluate phase. A "lessons learned" (post implementation review (PIR)) meeting will be held to evaluate completed projects, a set of user satisfaction interviews/surveys will be performed, and any needed process improvements will be recorded.

Information captured will:

- Include best practices used in completing tasks in an effective and efficient manner, as well as suggestions on activities to be modified.
- Feedback on the application of the SDLC, its artifacts, and activities.
- A final assessment of a project's impact on commission the completed project.
- Capturing measurements of actual vs. projected performance.
- An updated EA based on the deployed project's impact to the organization's business, technical, and information characteristics.

The lessons learned will be feedback into the selection and control phases. The main goals of

Figure 5. Investment review evaluate phase



the evaluate phase will be to answer the questions "Were the business objectives accomplished by completing this project?" and "Were the means the most effective and efficient way to get to the end result?" Adjustments to the investment review and project monitoring process will be made. In addition, baseline project plans and costs will be compared to the actual project timeline and cost in order to improve future estimation efforts. Figure 5 highlights the key activities within the evaluate phase; the activities are discussed in more detail next.

This step is not just a review of the project but also the associated processes to ensure that they are efficient. The evaluation process should include answering the question of whether the IELC was cost effective and reduced business risk. This question is both objective as well as subjective so the evaluation should be a quantitative as possible.

In our example, the asset management system was have been deployed at this point. Like most projects, the implementation of the system had surprises along the way at this point the IELC processes could be improved. For an example, a change in scope may demonstrate that a more detailed concept of operations should have been done before the start of the project. The requirements may not have been fully vetted and that caused a change in scope or missed requirements, which had an impact on costs.

At this point, it is important to also review any gaps in business processes or in integration to ensure that the next review of the portfolio reviews these business functions. Finally, an evaluation of the cost benefit analysis should be performed to see if the automation improved the business function.

Activity 17: Post Implementation Review/ Lessons Learned (PIR)

The project manager will meet/submit with the OIT Deputy Director/PRB for the project closeout meeting. The project manager will submit the final project plan, lessons learned, and completed system user and technical documents for review and closeout approval.

Activity 18: Surveys and Interviews

Perspectives and insights of project participants, executive sponsor, and sponsoring business and end users, is also collected through:

- Surveys and interviews of end users, customers, project management, project staff, contractors, and developers.
- Project management and staff interviews.
- Interviews with senior decision makers involved in investment oversight.

Activity 19: Process Improvement

Information from the quantitative data, the post implementation review, and the surveys are used to make adjustments to the investment management process. In addition, baseline project plans and costs will be compared to the actual project timeline and cost in order to improve future estimation efforts. These reviews and post process analysis are often over looked so organizations become habitual in these inefficiencies. It is strongly recommended that just like a financial audit of an organization, the organization ensures that post implementation reviews are done to look at the health of the internal controls and systems.

CONCLUSION

Throughout this chapter, we have discussed the integration of the enterprise architecture, investment management process, and the system development life cycle. While we did this via an investment management framework of select, control, and evaluate, the critical aspect is the actual integration itself. Whatever approach an organization takes, it should be aware of the importance of the overall IELC and the multiple integration and touchpoints between the activities that make it up.

Going forward, the U.S. Office of Budget and Management (OMB) has issued and continues to evolve a set of enterprise architecture reference models (FEA) (OMB, 2005) that address the business, application, data, service component reference model, and performance dimensions of an organization. Organizations are expected to develop and specify these views (both baseline and target) and formally document how a proposed application will adhere to them in its business case. An organization is then expected to track the performance of initiative as it progresses to ensure that it remains in alignment with the views. At the same time, the U.S Government's General Accountability Office continues to evolve its investment management maturity framework (GAO, 2004) that addresses how IT projects are determined, tracked, and controlled.

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ENDNOTE

[1] The Modernization Board representative and other personnel will be available to consult with the project manager throughout the investment management process.

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Section II

Development and Design Methodologies

This section provides in-depth coverage of conceptual architectures, frameworks and methodologies related to the design and implementation of strategic information systems. Throughout these contributions, research fundamentals in the discipline are presented and discussed. From broad examinations to specific discussions on particular frameworks and infrastructures, the research found within this section spans the discipline while also offering detailed, specific discussions. Basic designs, as well as abstract developments, are explained within these chapters, and frameworks for designing successful management information systems, data warehouses, and decision support systems are discussed.

Chapter 2.1

Strategic Technology Engineering Planning

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ABSTRACT

This chapter presents a methodical strategic technology engineering planning (STEP) approach, to effectively cope with the design complexity in service-oriented architecture and manage the strategic planning of solution development of information systems. This holistic model comprises four modules: Want-Is-Target (WIT) model, Transition and Alignment Grid (TAG), Comprehensive Architecting Process (CAP), and Joint Analysis & Roadmapping (JAR). The characteristics and features of the constituent elements in the STEP model are articulated in great detail. The WIT model defines three stages of architecture states – current, target, and end state. TAG specifies two dimensions for architecture planning, namely current-to-future state transformation and IT-to-Business alignment. CAP presents an overarching method for step-by-step engineering and design in system architecture and portfolio optimization. JAR comprises the best-of-breed strategic analysis techniques, accompanied by a hybrid method with strategy-driven and initiative-driven planning streams. Applying the framework in planning and future trends are also discussed in the context. This overarching framework provides a comprehensive multi-disciplinary approach to conducting strategic and tactical technology planning for both near-term needs and long-term goals.

INTRODUCTION

The e-business models in today's dynamic business world demand increasing flexibility and responsiveness of information systems applications. It becomes mandatory for the information technology (IT) group in an organization to provide a higher level of services and better quality products at a lower cost for the business to compete and succeed in a globalized economy. The reality is that IT must build more complex, interoperable, scalable, reusable, innovative, forward-thinking, and sustainable technical solutions, to satisfy the ever-growing business needs.

Most large companies like worldwide financial institutions have built, acquired, or purchased virtually hundreds, if not thousands, of IT systems through the years to provide electronic services for external customers and internal staff, resulting in heterogeneous technologies and architectural platforms to satisfy diverse functional requirements from different lines of business. In the banking industry, the business process generally contains different business sectors that address retail, small business, commercial, corporate investment, wealth management, and capital management markets. In particular, services are delivered through a variety of channels. In order to effectively manage the architectural assets and design high-quality IT solutions in such a diverse environment, a highly structured methodology is crucial to achieve an array of goals – separate concerns, divide responsibilities, encapsulate complexity, utilize patterns, leverage best practices, control quality, ensure compliance, and establish operationalization processes.

A majority of today's information system development planning is still ad hoc, manual, subjective, incomprehensive, and error-prone, which inevitably leads to chaotic outcomes and failures in the execution. According to recent surveys, a vast majority of information systems projects are behind schedule, over budget, or canceled. A lack of a systematic framework describing the key design practices and disciplines in the planning of service-oriented information systems is a major cause of this situation.

A new model is proposed in the next section, with more detailed descriptions of the key characteristics and features of the components presented in the section that follows. The subsequent section discusses how to apply the framework in planning, followed by sections on future trends and related work. The chapter is concluded in the last section.

BACKGROUND

Most of the previous architecture planning methods reveal the architectural aspects of a software application to some extent at a fairly high level or from a restricted perspective. A comprehensive approach to architecting the end-to-end information system solutions has become a necessity, calling for a systematic disciplined mechanism. To meet this growing need, a highly structured method is designed in this article to present a comprehensive and holistic view of the core architectural elements, components, knowledge, platforms, planning, and their interrelationships. Design procedures are established accordingly in this methodical approach to facilitate the creation, organization, and management of the architectural assets and solutions at different levels in a large organization.

Design Philosophy

Developing the disciplined mechanism followed a set of key design principles, partly derived from TOGAF (The Open Group, 2008), but significantly modified/expanded to be tailored to the services-oriented development process of information systems.

Business Principles

- ***Primacy of principles***: All stakeholders and relevant groups in an organization must follow these principles of technology planning.
- ***Maximize benefits***: Maximum benefits will be achieved for the entire organization, rather than individual divisions.
- ***Business continuity***: Business operations are not interrupted despite system and process changes.
- ***Active engagement***: All stakeholders are actively involved in the process to accomplish business objectives.

- ***Compliance with regulations***: The architecting processes comply with all relevant regulations, policies, and applicable laws.
- ***IT accountability***: The IT group owns and implements the IT processes and infrastructure that build solutions to satisfy business requirements for functionality, service levels, cost, quality, delivery timelines, and operations supports.
- ***Innovations***: The stimulation and protection of the corporate innovations is enforced in the IT architecture, design, management, and governance processes.

Technical Principles

- ***Flexibility***: The technical model is agile and adaptive to be nimble in quick response to future business needs.
- ***Incremental change management***: Changes to the corporate architecture/infrastructure environment are planned and implemented in a phased approach.
- ***Requirement scope control***: The scope creep and waterfall approach are avoided.
- ***Technology standardization***: Technological diversity is controlled to minimize immature and proprietary products, platforms, and solutions.
- ***Interoperability***: Software, hardware, network and infrastructure should conform to established standards and policies that promote compatibility for data, applications, services, communications, integration, security and technology.

Solution Principles

- ***Ease of use***: Solutions are straightforward to implement and use. The complexity of the underlying technology is abstracted from users, so they are able to focus on business functionalities and processes.
- ***Technology independence***: Technical solutions are immune from specific technology choices and hence can run on different technology platforms.
- ***Common services and processes***: Minimize the redundant development of similar functionalities to promote common services and processes across the organization.

Data Principles

- ***Data asset***: Data is an asset that has a business value to the enterprise and is managed in a federated fashion.
- ***Data ownership***: Each data element is owned by an entity accountable for the data quality.
- ***Common vocabulary and metadata***: The data definition is consistent throughout the organization, and the metadata are standardized and available to all authorized users.
- ***Shared data***: Data is shared across business lines for individual applications and systems to perform their duties.
- ***Data access***: Data is accessible for users to perform the business transactions.
- ***Data security***: Data is protected from unauthorized access and disclosure. This includes the protection of pre-decisional, sensitive, and proprietary information, besides the traditional aspects of national security classification.

General Model

The Strategic Technology Engineering Planning (STEP) approach is developed in this article as a multi-disciplinary framework. It defines a comprehensive analysis and planning method to control the application design and development practices for the quality delivery of information systems. The *STEP* model is a holistic structure to facilitate analyzing and optimizing the strategies, thought processes, methods, tradeoffs, and patterns in the IT design.

STEP forms a foundational knowledgebase to plan service-oriented architecture, integration, process and management in information systems. Its primary focuses are on architecture, execution environment, application frameworks, domain modeling, business process, information, integration, methodology, system management, security, quality of services, and governance. *STEP* is a cohesive set made of four modules, as illustrated in Figure 1:

- ***Want-Is-Target (WIT) Model***: a triangle model intended to denote the staged approach of technology evolution and interrelationships of the constructs and artifacts in the strategic technology engineering planning, and further build consensus with regard to the roles and responsibilities in the planning process.
- ***Transition and Alignment Grid (TAG)***: a quadrant model with two dimensions for technology migrations from current state to future state, and seamless IT-to-business alliance.
- ***Comprehensive Architecting Process (CAP)***: an overarching method for the step-by-step engineering and design in system architecture and portfolio optimization.
- ***Joint Analysis and Roadmapping (JAR)***: a pragmatic analysis technique for all stakeholders and parties, and subsequent future planning to construct a roadmap and action plans.

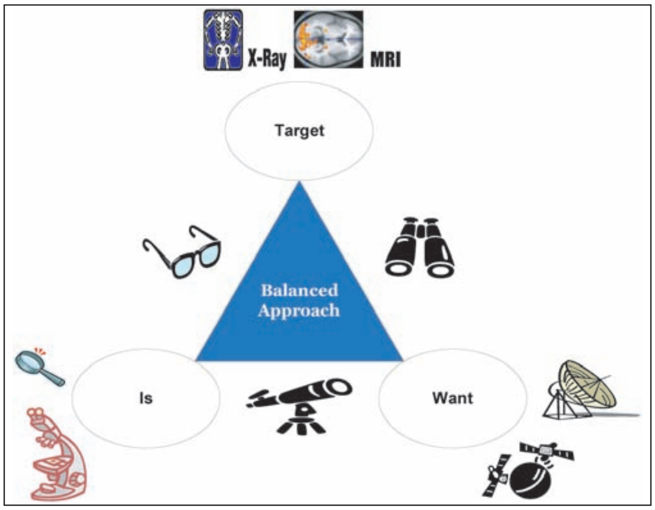
STEP FRAMEWORK CONSTITUENTS

Want-Is-Target Model

The Want-Is-Target (WIT) model for IT planning is shown in Figure 2. In spite of its apparent simplicity, the value of the model is actually its strength of abstraction at a high level. The “Is” component represents the current-state architecture we have built or acquired via mergers. The “Want” component describes the end-state architecture we wish to have in the long run. The “Target” component prescribes the target-state architecture that is feasible and reachable in the near future. The target state phase is typically a tactical approach to migrate the exiting portfolio to a strategic position through a multi-generation plan in an incremental fashion.

Figure 1. Strategic technology engineering planning

Figure 2. Want-is-Target model



To fully understand the existing situation, investigate the near-term possibilities, and explore the long-term potentials, it is not only important but also necessary to leverage tools to help analyze and investigate the details in depth. As an analogy, various tools are illustrated in the diagram. For example, when evaluating the "Want" component, a telescope is needed to see things from a distance, whereas a pair of eyeglasses may be sufficient to observe the near-term state. On the other hand, in order to inspect greater details of the "Is" component, a microscope is necessary as a magnifying glass would not reveal the fine points at the level of granularity desired. Nevertheless, these tools still can not disclose the internal structure. To overcome this limitation, more advanced tools must be used, such as X-ray or Magnetic Resonance Imaging (MRI) instruments. Likewise, more sophisticated tools (radar and satellite) augment what a telescope is capable of providing.

In reality, it is not uncommon that, due to time constraints and lack of acquaintance with tools, different parties misuse tools inadvertently from time to time when investigating various aspects in different domains. It is, however, critically important to utilize appropriate tools to look into the details of the components for analysis and synthesis. The metaphor indicates that we need not only "do things right", but also "rely on right tools to help do things right". Some tools, methods, and techniques for strategic planning will be articulated further in the sections that follow.

The Balanced Approach, represented as a triangle in the middle of the diagram, is the architecture planning process that balances the pros and cons, and resolves the conflicts with tradeoffs and compromises to lay out a reasonable path to the needed changes. Usually the balanced approach takes a hybrid approach to meet the immediate needs in the near term, but still aligning the architecture efforts with the strategic goals and vision.

Arguably, the most important factor in the strategic planning efforts are the "Stakeholders", which are all of the relevant people who have impacts on or are significantly affected by the architecture decisions and changes. The key stakeholders comprise the client users, business partners, business analysts, architects, developers, testers, system administrators, DBAs, network engineers, system managers, security specialists, risk officers, vendors, standards organizations, legal entities, consultants, and other subject matter experts. They may be for a change, be against it, be neutral, or not even know about it yet. Due to the different interests, relevant expertise, and roles played from various parties, the decision-making process must inevitably deal with conflicting forces and factors.

The process to establish the inventory of the "Is" component and define the models of the "Want" and "Target" components in a large organization is typically iterative. The current, end and target states can be represented in various formats from different viewpoints, such as business, technology, infrastructure, risk, finance, compliance, and standards.

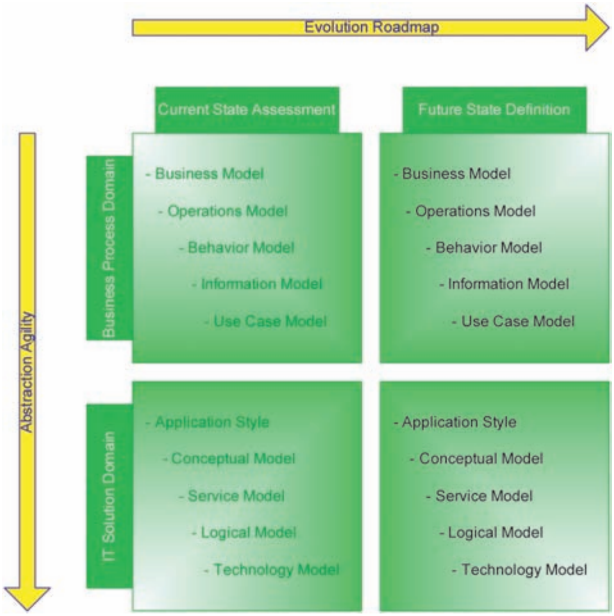
Transition and Alignment Grid

Based on this triangle model, a Transition and Alignment Grid (TAG) is constructed to identify the key artifacts and design concerns in technology planning, as depicted in Figure 3. There are two dimensions defined – current-to-future state transition, and business-to-IT alignment.

In the transition dimension, the "Is" component is mapped to the current state assessment, which collects the input data and analyzes the existing environment. Similarly, the "Target" and "Want" components are mapped to the future state definition, which combines the vision of the near-term state and the end state. The future state specification serves as a blueprint of the desired form. The gap analysis is subsequently conducted to bridge the three states. A roadmap is thus defined to transit the current state to the future state in a controlled manner. Usually the transitions are staged in multiple phases in an incremental fashion. Depending on the timeframe desired, the end state vision is typically strategic and targeted to the long term. However, tactical solutions are often needed to deliver required business functionalities in a short period of time. This creates a dilemma between the strategic and tactical needs. It is of vital importance to have the end-state vision well defined, so that the strategic goals are not deserted when pragmatic approaches are crafted for the short-term demands in the target state.

This approach serves as a use-case driven pattern-based procedure for iterative architecture planning. Round-trip architecture engineering is enforced to articulate the multi-perspective views,

Figure 3. Transition and Alignment Grid



using the industry standards on visual modeling and semantic ontology, such as UML, SysML/DSL, BPMN, XPDL, BPEL, and OWL. Loosely-coupled interface and integration are imposed in the principle of design by contract. The 80-20 rule is leveraged in the use case drill-down for objective sizing and empirical estimation in the service-centered paradigm.

To provide better abstraction and individual agility, the spectrum in the alignment dimension is divided into two areas: Business Process Domain and IT Solution Domain. The goal is to make IT responsive and adaptive, so it will be nimble and flexible to support the business operations for quicker changes. The Business Process Domain captures the information pertinent to the static and dynamic structure on which the business runs – the business process, the operations method, the behavioral process, the information requirements, and the usage scenarios. The IT Solution Domain describes the IT systems supporting and realizing the business operations. The key artifacts in the IT Solution Domain are application domain styles, conceptual model, service model, logical model, and technology model. The gap between the business model and IT model is daunting in almost every large organization. There have been constant conflicts in the alignment of IT models with business models due to delivery schedules, resources, skillset, risks, and budgets. The strategy to alleviate this pain is to seamlessly integrate the models in these two areas. The engaging of end-to-end round-trip engineering principles with traceability and auditability is a necessity to make IT models adaptive, and eventually proactive in the long run.

The key drivers in the alignment dimension are value proposition, expectations, goals, end-to-end process, degree of complexity, lean models, situational context, purpose-driven adaptation, quality, and consistency.

Comprehensive Architecting Process

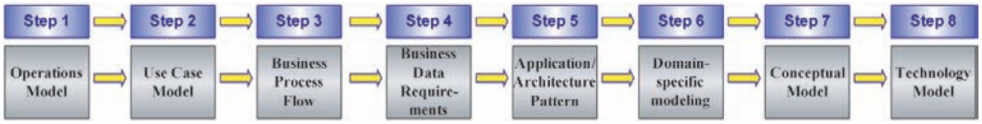
A pragmatic Comprehensive Architecting Process (CAP) is further defined in Figure 4 to facilitate the current state evaluation and future state specification. The key activities are grouped in 8 steps in the procedure:

- Step 1 – Operations Model.
- Step 2 – Use Case Model.
- Step 3 – Business Process Flow.
- Step 4 – Business Data Requirements.
- Step 5 – Application/Architecture Patterns.
- Step 6 – Domain-specific Modeling.
- Step 7 – Conceptual Model.
- Step 8 – Technology Model.

Operations Model

The operations model copes with the alignment and facilitation between the business operations and information systems. It is the business driver to all other technical models in the stack, forming the foundation of the strategic alignment of technical models with the business process mission. The in-depth analysis of the business processes often leads to the reengineering effort to improve the business operations in such a way that different divisions in a large organization can share common solutions for the business needs. The commonalities of the technology components and business logic modules are identified and reusable assets are constructed, resulting in reduced portfolio total cost of owner-

Figure 4. Comprehensive architecting process



ship (TCO) and increased operational efficiency. Business patterns are generally identified to group processes into different categories in the business domain. Common business languages are usually used.

Use Case Model

A use case model is a specification describing the functional requirements of an information system. Use cases convey the usage scenarios that characterize how the system interacts with the actors, what the system boundaries are, and how the use cases are related to each other, thereby describing the total functional behavior and specific business goals of the system.

No standard template exists for documenting use cases in detail. Different schemes and formats have been proposed, and individual teams tend to adapt from what is available or create a customized template that works for their specific situations. Standardization may be enforced at appropriate level, depending on the maturity and applicability, e.g., project, portfolio, domain, division, enterprise, industry sector, etc.

Although terminologies, section structure, and orderings may differ significantly, most use cases share an underlying similarity, so that the core sections in a use case specification look alike. Typical sections in a use case specification include: use case name, ID, version, description, actors, iteration, dependency, preconditions, postconditions, triggers, happy-path flow, alternative paths, business rules, errors, notes, author and date. Different templates may have supplementary sections, such as assumptions, exception handling, recommendations, technical constraints, and non-functional requirements. Other industry or project specific sections may be included as well. Figure 5 depicts a use case diagram for a supply chain management application.

Business Process Flow

The use cases are further decomposed to capture the details in the business process flows. Flow charts are traditionally used to illustrate the logic flow in an informal but intuitive manner. The UML activity diagram provides a standard way to specify the workflows in the Use Case Model. As an example, Figure 6 shows an activity diagram for Use Case 2 defined in Figure 5.

Other notations and standards are maturing and available for business process design and execution, such as BPMN, XPDL, and BPEL. The Business Process Modeling Notation (BPMN) is a standard graphical notation for visualizing business processes in a workflow.

Figure 5. Use case diagram example

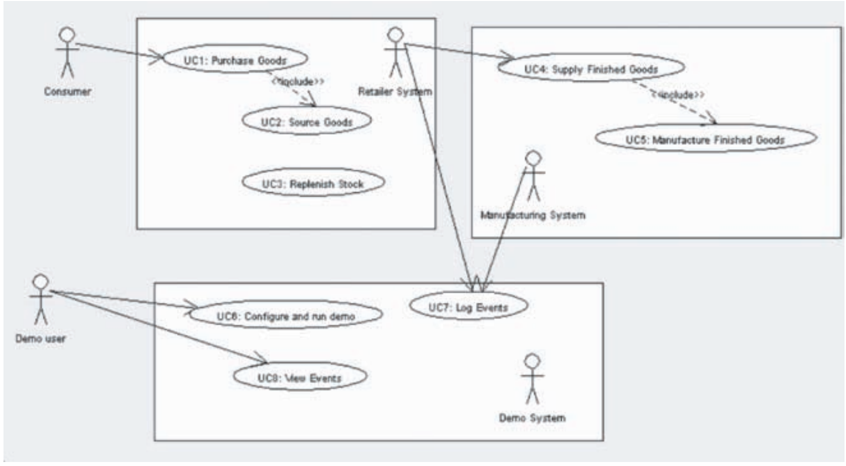
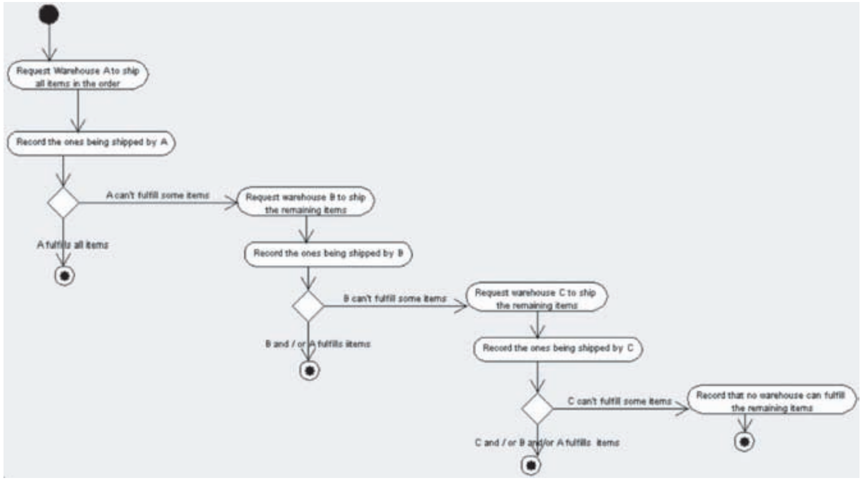
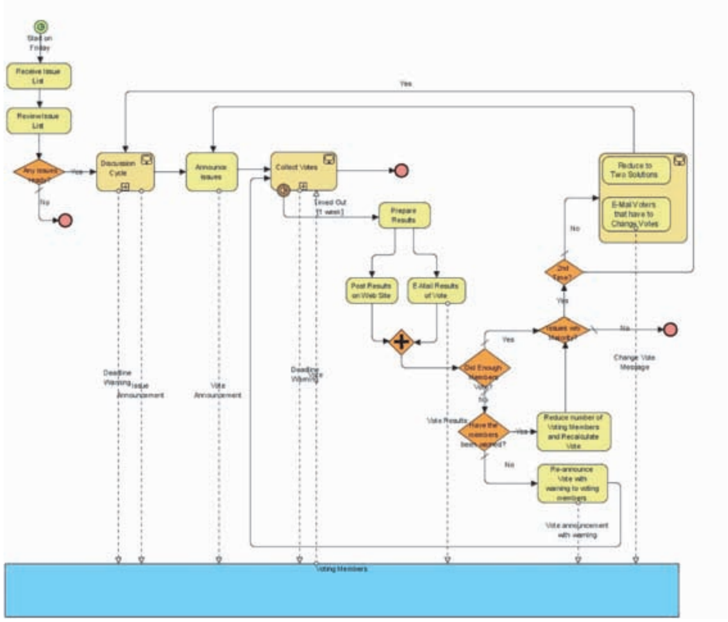


Figure 6. Source Goods Activity Diagram Example



The standardization of BPMN for the description of business processes bridges the gap in communications, which often arises between the business process design and implementation, thereby facilitating the interactions between all business stakeholders, including the business analysts who identify and specify the operations, the technical designers who defines the process orchestration or choreography using a process engine, the solution developers who are responsible for implementing the process scripts, and the business managers who monitor and manage the processes in execution. Therefore BPMN is designed to serve as a common language that is understandable by all stakeholders involved. Figure 7 displays a BPMN diagram for an email voting process.

Figure 7. BPMN diagram example



The XML Process Definition Language (XPDL) is a standard format designed by the Workflow Management Coalition to exchange the definitions of business processes between different workflow products such as the workflow engines and modeling tools. A XML schema is defined in XPDL to specify the declarative part of workflow. XPDL is created to interchange the process design, both the graphical representations and the semantics of a business process workflow. The elements contained in XPDL hold the X and Y position of the activity nodes, together with the coordinates of points along the lines that link these activity nodes. By contrast, although BPEL is a process definition format as well, it is solely for the executable parts of the process. The elements to represent the graphical aspects of a process diagram do not exist in BPEL.

In the open source space, tools are available for BMPN, XPDL and BPEL, such as Intalio BPMN Modeler, JaWE, and ActiveBPEL, respectively.

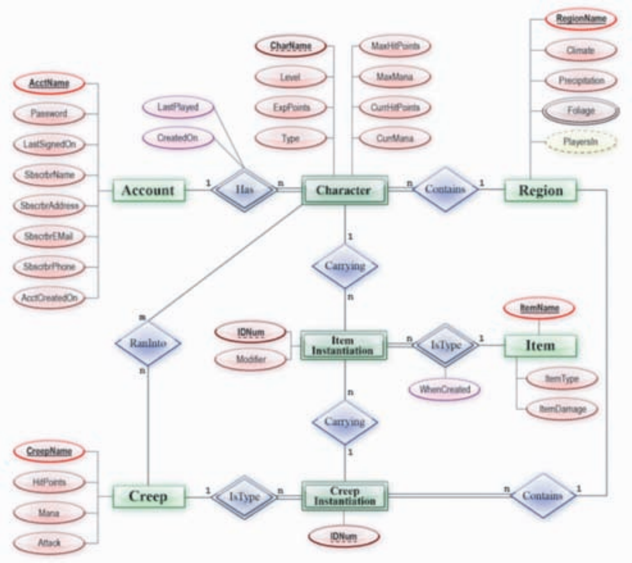
Business Data Requirements

The business data requirements are captured to specify the information requirements for the system. A logical data model is constructed with all the necessary definitions of data elements. A detailed data flow diagram specifies the data exchange and processing in the business operations. A schema is designed to map the business data to a persistence repository, predominantly a relational database system. The data structure and relationship can be defined using a variety of techniques. A graphical notation to represent data models is required in data modeling. One of the most widely used approaches is the entity-relationship modeling process, the end-product of which is an entity-relationship (ER) diagram. An ER diagram represents the schema as a logical data model for the system, which is a type of conceptual data model or semantic data model, as displayed in Figure 8 as an example.

Application/Architecture Patterns

Application/Architecture patterns are high-level artifacts that are used to describe the principal business purpose and architectural style of a solution. They identify the high-level participants who interact in the solution based on the primary objectives of the solutions, and define the nature of the interactions between the participants. In the

Figure 8. Entity-relationship diagram example



banking sector for example, the primary patterns may be classified in the following list.

- Business-to-Business Enterprise: enable business partners to collaboratively provide services with seamless navigation between sites – e.g. user account aggregation, and co-marketing with external vendors.
- Business-to-Person Self-Service: enable users to access the business functionalities via the graphical user interfaces of a thin client (web browsers), thick client (typically Windows GUI applications), and rich client (like Ajax-enabled web applications) as well as other pervasive platforms like personal digital assistants (PDA) and mobile devices such as cell phones – e.g. money transfer between accounts, and bill payments.
- Person-to-Person Collaborations: enable users to communicate with other people like loan officers or brokerage account managers electronically – e.g. emails, and web-based instant messaging.
- Person-to-Data Data Aggregation: enable users to access product information, service details, directory, branch locations, and data summary – e.g. check images, and interim account statements.
- Person-to-Application Access Integration: enable the integration of front ends of servicing applications, typically at the web server tier – e.g. Single Sign-On (SSO), and portal services.
- Application-to-Application back-end Integration: enable inter-system integration – e.g. asynchronous messaging middleware, and web services.

The pattern categories serve as a baseline to classify various information systems into appropriate groups. The cataloging effort builds a common taxonomy for the technology portfolio, and facilitates the further technology planning and technical design. Commonalities among similar systems help rationalize the portfolio and optimize the asset use in the IT environment.

Domain-Specific Modeling

Domain-Specific Modeling (DSM) is a way of designing and developing systems, via the systematic use of a graphical Domain Specific Language (DSL) to represent the various facets of a system. The support of higher-level abstractions distinguishes the DSM languages from the general-purpose modeling languages, meaning that they require less effort and fewer low-level details to specify a given system.

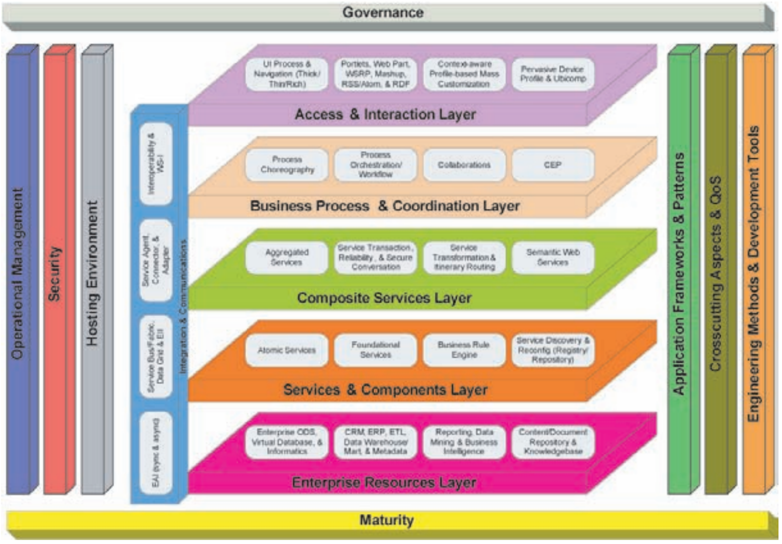
A DSM environment automates creating program components that are otherwise expensive to construct from scratch, such as domain-specific editors, browsers and components. All a domain expert needs to do is to define the domain specific rules and constructs, and the DSM environment provides a modeling tool tailored for the target portfolio. Consequently, the overall cost of obtaining tool support for a DSM language can be considerably reduced by means of a well-designed DSM environment.

Almost all existing DSM activities leverage DSM environments, via commercial tools like MetaEdit+, open source tools like GEMS, and academic tools like GME. Thanks to the increasing popularity of DSM, DSM frameworks have been bundled into existing IDEs, as seen in the Eclipse Modeling Framework Project with Graphical Modeling Framework and Graphical Editing Framework, and in Microsoft's DSL Tools for Software Factories.

Conceptual Model

A conceptual architecture model is designed in Figure 9. The layering architectural pattern is applied to organize the internal structure of an application. The structure extends the concept of the well-known Model-View-Controller (MVC) design pattern to form a generic skeleton of

Figure 9. Conceptual model



service-oriented component-based application architecture. For example, the scope of the application *View* is expanded to include the portal for easy customized navigation and content aggregation, as well as the interaction services to deal with multiple pervasive computing devices. Likewise, the application *Controller* is extended to deal with process choreography and collaborations.

The application structure is made of a stack of 5 layers and 1 vertical block. The *Access & Interaction Layer* supports various devices, handles user interface processing, and integrate single sign-on and authorization. The *Business Process & Coordination Layer* deals with process choreography, orchestration, human workflow, collaborations as well as complex events. The *Composite Services Layer* hosts the aggregated services, service transformation, itinerary routing, semantic web services, and advanced services such as transaction, reliable messaging, and secure conversation. The *Services & Component Layer* contains atomic services, foundational services, business rule engine, service registry/repository, and other servicing components. The *Enterprise Resources Layer* has enterprise ODS, federated database, CRM, ERP, data warehouse/marts, content/document repository, reporting, and analytics suites. The *Integration & Communications Block* copes with inter-application integrations, interoperability, service bus/fabric, data grid, EII, and service agent/connector/broker that encapsulates the integration logic to access internal data sources and external services.

In addition, the *Security, Hosting Environment* and *Operational Management* pillars are across the layers in the runtime environment, whereas the *Application Frameworks & Patterns*, *Crosscutting Aspects & QoS* and *Engineering Methods & Development Tools* pillars are pertinent to various aspects in the development construction. The *Governance* and *Maturity* modules are for the overall program management, policies & standards, conformance enforcement, and evolution measurements.

Technology Model

The technology model defines a detailed structure chart with complete module specifications, and system architecture of servers, nodes, and communications lines. Infrastructure network and topology of data centers is a key part of the technology model. Figure 10 illustrates an end-to-end enterprise infrastructure in a hosting environment for both Internet and Intranet as well as Extranet communications, which includes remote access, routers, switches, firewalls, Domain Name Service (DNS), print services, certificate authority, storage, database, web services, middleware, proxy, Virtual Private Network (VPN) services, high-availability failover, and backup services.

Joint Analysis and Roadmapping

All stakeholders and parties are engaged to conduct a joint analysis on the current, target, and end states. Based on this comprehensive study, the strategic planning is kicked off to construct a roadmap and action plans. A combination of best-of-breed roadmapping methods are used in this effort.

SWOT

The Strengths, Weaknesses, Opportunities, and Threats (SWOT) technique is employed to conduct a thorough inspection on each major factor and option. The analysis reveals the requirement conflicts and design constraints as well as presumptions from a particular stakeholder's point of view. Focus on a single factor is meant to minimize risks only from that attribute perspective at a fine level. This is often insufficient when a variety of conflicting attributes play an equivalently important role in the system and a balance between these interacting attributes must be established. The outcome of the SWOT exercise is the key to the unbiased justification of tradeoffs in a balanced approach. The harmonious approach resolves the conflicts in local/individual attributes to reach a global optimization.

As shown in Figure 11, SWOT is used as inputs to generate possible strategies. Based on the results, a hierarchy of objectives, strategies, and tactics (HOST) diagram can be drawn to facilitate the drill-down on each major objective. By assessing the what, when, why, who, where, which, and how (6W+1H) on these objectives and strategies, the top rank objectives can be identified and prioritized. Dependencies and interrelationships among the objectives and strategies are also elaborated in this exercise.

Porter's Models

The Porter's Five Forces Analysis is a more robust framework than a SWOT analysis for business management. The concepts designed in Industrial Organization (IO) economics are utilized to derive

Figure 10. Technology model example

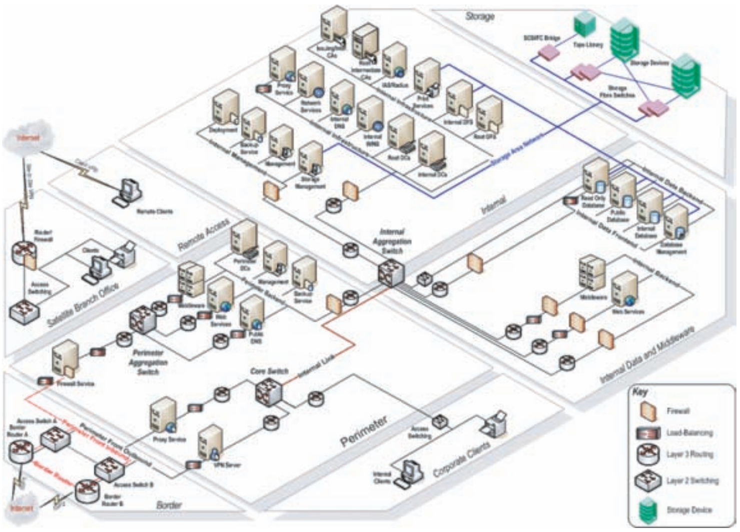
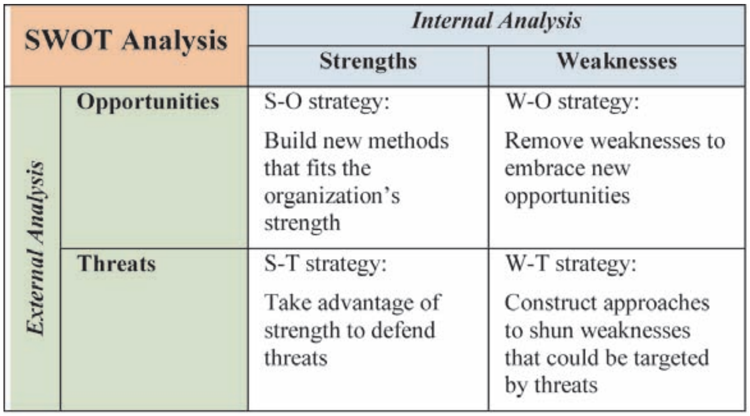


Figure 11. SWOT diagram



SWOT Analysis		*Internal Analysis*	
		Strengths	**Weaknesses**
External Analysis	**Opportunities**	S-O strategy: Build new methods that fits the organization's strength	W-O strategy: Remove weaknesses to embrace new opportunities
	Threats	S-T strategy: Take advantage of strength to defend threats	W-T strategy: Construct approaches to shun weaknesses that could be targeted by threats

5 forces that determine the attractiveness of a market, as demonstrated in Figure 12. A change in any of these 5 forces generally triggers a reassessment of the marketplace for an organization. The four primary forces are the bargaining power of suppliers, the bargaining power of customers, the threat of new entrants, and the threat of substitute products. The fifth force – the level of competition in an industry – is influence by the four primary forces in combination with other variables. An extension to Porter's 5 forces model is called Six Forces Model, in which the sixth force is introduced, namely the government or public.

Porter also introduced a value chain model and a generic strategies framework in his seminal work. The value chain model consists of a sequence of value-generating activities that are common to a variety of companies. The principal activities are marketing, sales, inbound logistics, operations, outbound logistics, and service. The support activities comprise infrastructure, human resources management, technology development, and procurement. The value chain model helps define a company's core competencies and the activities that a company can undertake to pursue cost advantage or differentiation. On the other hand, the generic strategies framework is composed of cost leadership, differentiation, and market segmentation. The three strategies can be further mapped to three basic value disciplines – product innovation, customer intimacy, and operational excellence. The cost leadership may be implemented as either a low cost strategy or a best cost strategy.

These two models are useful to align the technology strategies to the overall business strategies in an organization. The generic strategies help define the key drivers for the technology domain, while the value chain model helps identify the key activities in the technology area.

Figure 12. Porter's 5 forces analysis

Portfolio Planning (BCG Growth-Share Matrix)

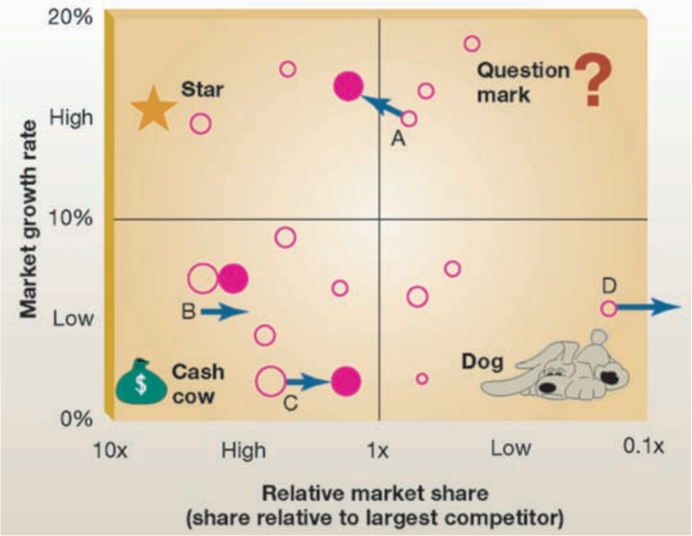
Bruce Henderson of the Boston Consulting Group designed a portfolio planning model called the BCG Growth-Share Matrix, founded on the observation that the business units in an organization can be categorized into four types – dogs, question marks, stars, and cash cows, depending on combinations of market growth and market share (growth-share) relative to the prevalent competitor in the market. The market growth is an indicator for industry attractiveness, whereas relative market share signifies the competitive advantage. Thus the Growth-Share Matrix demonstrates the positioning of a business unit along with the two most important determinants of profitability.

The original design of the Growth-Share Matrix was targeted towards allocating resources among different business lines in an organization. It can also be leveraged in the resource allocation for the products in a portfolio. The single diagram in a simple format helps visualize the relative positions of the entire business portfolio in an organization, as illustrated in Figure 13. However, the model has some limitations. Firstly, there are other important factors in the industry attractiveness and competitive advantage share that are not included in the matrix. Secondly, the business divisions on the chart are presumably independent from each other. The inter-relationship between the units is not addressed in the model. Lastly, the breadth of the market definition has a big impact on the positioning of a business group, which may dominate its small niche, but have a very low market share in the overall industry.

Scenario and Situation Planning

The Scenario Planning was originated in the military strategy studies, when Herman Kahn founded the scenario-based planning in his work related to the possible scenarios associated with thermonuclear war (Kahn, 1985). Pierre Wack transformed the scenario planning into a business tool in the development of a scenario planning system at Royal Dutch/Shell. The efforts made Shell well-prepared to cope with the oil shock in late 1973 and significantly enhanced the company's competitiveness in the industry during the oil crisis and the subsequent oil glut.

Figure 13. BCG growth-share matrix



Scenarios are efforts to detail a hypothetical succession of events that could conceivably lead to the circumstance envisioned. The Scenario Planning is essentially about making choices now with an understanding of how the selections might turn out. A common misconception about the Scenario Planning is that it is perceived as a tool of accurate future prediction or forecast. Instead, it is an approach to laying out the possible situations and combinations, leading to a set of distinct but plausible future states, which help formulate plans and tactics to cope with each of the possible circumstances.

The key benefits of scenario planning are to force the stakeholders to break their routine thinking mode, in order to identify the blind spots that might otherwise be neglected in other normal approaches. Scenarios are recognized in an early stage, enabling informed decision-making and well-preparedness for the difficult situations. The source of disagreements can be better communicated, understood, and resolved when different scenarios are analyzed and walked through.

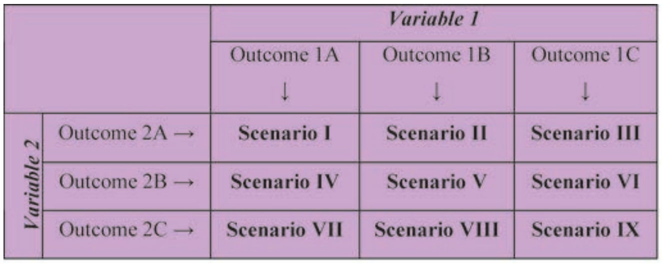
The Scenario Planning sessions are usually conducted with the key stakeholders such as executive sponsors, technical leaders, industry specialists, program/project managers, and subject matter experts. This enables a sufficient range of perspectives to be considered without leaving out important details or situations. Inputs, participation, and contributions from those who will formulate and implement strategies derived from the scenario analysis are critical to aptly address the issues and pain points that are vital to the teams who will later execute the strategy.

Figure 14 outlines the typical steps that constitute a process of scenario planning.

A matrix of scenarios is created for the analysis of the interaction between the variables, using the two most important variables and their possible values. As displayed in Figure 15, each cell in the matrix represents a single scenario. For straightforward reference in discussions and

Figure 14. Scenario planning process

Figure 15. Scenario planning matrix



		Variable 1		
		Outcome 1A ↓	Outcome 1B ↓	Outcome 1C ↓
Variable 2	Outcome 2A →	**Scenario I**	**Scenario II**	**Scenario III**
	Outcome 2B →	**Scenario IV**	**Scenario V**	**Scenario VI**
	Outcome 2C →	**Scenario VII**	**Scenario VIII**	**Scenario IX**

communications, it is a good practice that each scenario has a descriptive name. In case there are more than two critical factors, a multidimensional matrix is developed. However it is hard to visualize beyond 2 or 3 dimensions. Instead, factors can be taken in pairs to generate several two-dimensional matrices.

PEST Analysis

The Political, Economic, Social, and Technological (PEST) analysis is a framework of macroenvironmental factors used in environmental scanning.

As a part of the external analysis in market research, it provides an overview, to a large degree, of the different macroenvironmental factors worth consideration by an organization. The political factors focus the areas of employment laws, environmental regulations, trade restrictions, tariffs, tax policy, and political stability. The economic factors include the economic growth rates, interest rates, exchange rates and inflation rates. The social factors are usually related to the cultural aspects, consisting of health consciousness, population growth rate, age distribution, career attitudes and emphasis on safety. The technological factors comprise ecological and environmental aspects that determine the barriers to entry, minimum efficient production level and outsourcing decisions. The core elements include the R&D activities, automation, technology incentives and the rate of technological changes.

From a technology engineering planning perspective, the prominent factors in technological analysis are recent technology advancements, technological impact on solution offerings, influence on cost, effect on the value chain model, and rate of technology diffusion. These PEST factors and other external micro-environmental factors can be categorized into the opportunities and threats cells in a SWOT analysis.

Hybrid Roadmapping Method

To effectively conduct strategic planning to meet the needs in both short and long terms, a hybrid method is necessary to take account of all factors and interests from different parties. Two streams are defined in this hybrid method – initiative-driven and strategy-driven.

The strategy-driven roadmapping is conducted at four levels:

- Macro-level: trend analysis
- Meso-level: competitor analysis
- Micro-level: enterprise analysis
- Nano-level: portfolio analysis

The technological trend analysis identifies the technological factors/trends that have impact on the organization. The competitor analysis determines the competition levels, analyzes competitive forces, examines competitor behavior, and identifies competitor strategies. The enterprise analysis analyzes the internal environment and identifies its competencies. The portfolio analysis investigates the conditions and maturity in a technology domain. The results of these analyses can be captured in a set of SWOT matrixes.

The initiative-driven roadmapping deals with the requests from the current initiatives, which are typically for immediate needs and near-term goals. The activities include supporting the existing business operations, replacing obsolete vendor technologies, making minor modifications to meet regulatory requirements, retiring outdated applications, and adding short-term feature enhancement in the existing information systems. A target state is defined to build out these capabilities, which serves as a transformation step towards the end state as described in the foregoing section. A value chain model can be used to assess the impact and margins in the initiative-driven efforts.

Based on the results of the strategy-driven and initiative-driven streams, a roadmap is devised, which is usually in the format of a multi-generation plan. It outlines the long-term goals, and details the specific strategies and pragmatic goals that are to be pursued. The strategic and tactical concerns and challenges are articulated and addressed in depth. Areas of risks are analyzed and specific means for mitigating those risks are adopted.

APPLYING STEP IN PLANNING

The *STEP* framework forms a coherent set of components that can be used to compose a pragmatic approach for technology planning in the real-world context. The *WIT* module serves as a basic structural model to assess the current state and define the end state as well as the intermittent target states. The *TAG* module deals with the business-to-IT alignment and roadmap transforming the current state to future state, which is the outcome of the *WIT* module. An array of models are used in the *TAG* module to describe the prominent aspects and attributes of a domain, such as business, operations, behavior, information, use case, application, conceptual, service, logical, and technology. Further, the *CAP* module provides a practical process with 8 steps grouping the activities and artifacts in this effort. Some models introduced in the *TAG* module are articulated in greater detail in this process. Templates, checklists, UML diagrams, ER diagrams, reference architecture, and patterns may be used to facilitate the standardization of the notations and practices in this procedure. Finally, a range of roadmapping methods presented in the *JAR* module can be leveraged to conduct tradeoff analysis of the roadmaps developed in the *TAG* module, and balance the constraints and conflicts to reach a compromised agreement among the stakeholders with different interests and priorities.

FUTURE TRENDS

As the advance in the technology field continues at an unprecedented pace, a practical approach is to be adaptive and build out the strategy plan in an incremental manner. An iterative process should be established to refresh the plan and re-examine the internal and external influencing factors. The strategic planning tends to become semi-automated, with a pragmatic mechanism in place to monitor the changes and trigger necessary reassessment. Various techniques and methods will converge to formulate a complete strategic framework for the digital age, from concept to execution to termination. The focal point will be on the future and people, who are involved in planning and developing the strategy and measures, so that the execution can be accelerated. It can be foreseen that a more balanced approach will be taken between the tactical actions and strategic activities, resulting in lower cost, well-managed risk, efficient alignment, higher flexibility, enhanced quality, and faster time-to-market. The matured methodology and disciplines are expected to make a real difference, create values, and build sustainable competitive advantages in an organization.

RELATED WORK

Previous studies in the last few decades have strived to tackle the issue of architecture design complexity, which has grown exponentially as the computing paradigm has evolved from a monolithic to a service-oriented architecture. The Zachman Framework (Zachman, 1987) is a logical structure for categorizing and organizing the descriptive representations of an enterprise IT environment. In the form of a two-dimensional matrix, it has achieved a level of penetration in the domain of business and information systems architecture and modeling. It is largely used as a planning or problem-solving tool. Nevertheless, it tends to implicitly align with the data-driven approach and process-decomposition methods, and it operates above and across the individual project level. Extended Enterprise Architecture Framework (E2AF) (IEAD, 2004) takes a very similar approach seen in the Zachman Framework. Its scope contains business, information, system, and infrastructure in a 2-D matrix. E2AF is more technology-oriented. Both of these approaches are heavyweight methodologies, which set a fairly steep learning curve for a team to learn and successfully adopt either method.

Rational Unified Process (RUP) (Kruchten, 2003) made an effort to prevail over these shortcomings by leveraging the Unified Modeling Language (UML) in a use-case driven, object-oriented and component-based approach. The concept of 4+1 views interprets the overall system structure from multiple perspectives. RUP is more process-oriented, and is generally a waterfall approach. RUP barely addresses software maintenance and operations, and lacks a broad coverage on physical topology and development/testing tools. It essentially operates at the individual project level. RUP has recently been expanded to Enterprise Unified Process (EUP) and part of it has become open source – OpenUP in Eclipse.

Another heavyweight approach, The Open Group Architecture Framework (TOGAF), is a detailed framework with a set of supporting tools for developing an enterprise architecture to meet the business and information technology needs in an organization. The three core parts of TOGAF are Architecture Development Method (ADM), Enterprise Architecture Continuum, and TOGAF Resource Base. The scope of TOGAF covers Business Process Architecture, Applications Architecture, Data Architecture, and Technology Architecture. The focal point of TOGAF is at the enterprise architecture level, rather than the individual application architecture level. On the other hand, Model-Driven Architecture (MDA) (Object Management Group, 2008) takes an agile approach, aiming to separate business logic or application logic from the underlying platform technology. The core of MDA is the Platform-Independent Model (PIM) and Platform-Specific Model (PSM), which provide greater portability and interoperability as well as enhanced productivity and maintenance. MDA is primarily for the software modeling part in the development lifecycle process.

Other related works on IT architecture frameworks are for the most part tailored to specific domains. They are useful references when a team intends to create their own models for their organization. The comprehensive architectural guidance for the various Commands, Services, and Agencies within the U.S. Department of Defense are documented in the C4ISR Architecture Framework (DoD, 1997), for the sake of interoperability endurance and cost-effectiveness in military systems. The Federal Enterprise Architecture (FEA) framework (Federal Office, 2007) gives direction and guidance to U.S. federal agencies for designing enterprise architecture. The Treasury Enterprise Architecture Framework (TEAF) is to guide the planning and development of enterprise architectures in all bureaus and offices of the Treasury Department. The Purdue Enterprise Reference Architecture (PERA) (Purdue University, 2008) is aligned to computer integrated manufacturing. ISO/IEC 14252 (a.k.a. IEEE Standard 1003.0) (IEEE, 1995) is an architectural framework built on POSIX open systems standards. The ISO Reference Model for Open Distributed Processing (RM-ODP) (Putnam, 2001) is a coordinating framework to standardize the Open Distributed Processing in heterogeneous environments. It creates an architecture that integrates the support of distribution, networking and portability, using five "viewpoints" and eight "transparencies". The Solution Architecture of N-Tier Applications (Shan & Hua, 2006) presents a multi-layer and multi-pillar model for web-based applications.

CONCLUSION

To effectively manage the complexity in service-oriented architecture and perform strategic technology planning in information systems, a comprehensive model is a necessity to abstract concerns, define methods, and present a holistic view of the planning aspects in a highly structured way. The Strategic Technology Engineering Planning (STEP) model introduced in this article is a holistic framework to facilitate planning information systems applications strategically and tactically. It provides comprehensive coverage of the planning artifacts from both analysis and execution perspectives. It defines a comprehensive multi-disciplinary approach to conduct strategic and tactical technology planning for both near-term needs and long-term goals.

The design principles of the framework are presented in the context. The model comprises an array of multiple modules: Want-Is-Target (WIT) model, Transition and Alignment Grid (TAG), Comprehensive Architecting Process (CAP), and Joint Analysis & Roadmapping (JAR). The characteristics and features of the constituent elements in the SETP model are articulated in great detail. The WIT model defines three stages of architecture states – current, target, and end state. TAG specifies two dimensions for architecture planning, namely current-to-future state transformation and IT-to-Business alignment. CAP presents an overarching method for step-by-step engineering and design in system architecture and portfolio optimization. JAR comprises the best-of-breed strategic analysis techniques, accompanied by a hybrid method with strategy-driven and initiative-driven planning streams. Furthermore, the elements and features of each module are detailed and the future trends are discussed.

The comprehensiveness and agility of this coherent framework has made it possible for the model to be extensively used in the service-oriented application planning in one format or another, and its usage has proved to be an enormous success. Furthermore, this structure is so scalable and flexible for dynamic extensions and expansions that the model can serve as a meta-framework to incorporate other general or specialized frameworks.

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Chapter 2.2

A Technology-Focused Framework for Integrating Knowledge Management into Strategic Innovation Management

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ABSTRACT

Today's business environment is characterized by highly transparent markets and global competition. Technology life cycles are decreasing due to the fast pace at which development of new technologies is progressing. To compete in this environment, it is necessary to identify upcoming innovations and trends as early as possible to decrease uncertainty, implement technology leadership, and create competitive advantage. In a parallel development, the amount of information available is already vast and increasing daily. As a result of these developments, strategic innovation management has become increasingly challenging. The goal of our chapter is to investigate to what extent knowledge management technologies support and improve strategic innovation management to face the aforementioned problems successfully. Consequently, we will develop a characterization scheme which works as a framework for the subsequent evaluation of knowledge management technologies and apply this to a real-world case.

INTRODUCTION

Competition in today's business environment is intense. The influences of the rapid pace of globalization, and of national and international markets' on-going liberalization lead to the emergence of new problem settings and, consequently, increased pressure on companies. Companies therefore face greater risks due to the higher number of players in the market. However, environmental influences created outside the market are not the only factors that have an impact on companies' complexity. The increasing speed at which innovations and new developments occur, the resultant shorter product life cycles, and decreasing production costs also add to the pressure felt by firms and their decision-makers. High technology companies that have high research and development (R&D) expenditures, have to specifically plan their research programs more carefully, because they run a higher risk of losing the competitive advantage when "going the wrong way". Consequently, decision-makers have a greater need to anticipate or forecast future developments and apply these insights in business strategies and strategic innovation management in order to keep risk levels low and the company competitive. According to Bright (1979), all "firms and governments dealing with technology have been and are doing technology forecasting. This is because each decision to explore, support, oppose or ignore a technological prospect incorporates the decision-maker's assumptions about that technology and its viability in the future" (p. 228).

Over the last few years, firms have increasingly realized that knowledge plays a key role in the development of strategies for future success and stronger market positions. The most striking examples of such firms are technology and service-oriented companies, but retailers also engage in activities to use knowledge as factors of competitive advantage. A paradigm shift can be observed in business strategies: from a focus on tangible assets to one that prioritizes intangible assets (Drucker, 1996, p. 203; Stewart, 1997, p. 23). However, information and information sources' quantity is continuously increasing, and what at first seemed to be the solution to several business problems has itself become a unique problem for today's companies—too much information. In order to gain from information and to facilitate knowledge creation within a company, new ways of filtering and selecting information have to be applied. Furthermore, the nature of knowledge is highly dynamic. The value of knowledge is difficult to measure and can change from one moment to another. Companies try to control this uncertainty to some extent and to obtain as much advantage as possible from their knowledge by integrating knowledge management paradigms into competitive strategies.

The question arises if it is possible to successfully support knowledge and strategic innovation management alignment on an operational level. With technology forecasting being an essential discipline of today's innovation and innovation management processes, it is of specific interest to know whether technology forecasting can be improved by integrating knowledge management—particularly by means of current knowledge management technologies. In the following, we understand the latter as instruments of information and communication technologies that support knowledge management processes.

In order to answer the stated question, this chapter's objective is to develop a characterization scheme that integrates aspects of both fields: knowledge management as well as innovation management process's technology forecasting. Furthermore, selected knowledge management technologies will be evaluated by applying this scheme to derive conclusions regarding the most promising solutions with which to support technology forecasting.

The section following this one introduces and defines technology forecasting and illustrates the associated standard technology forecasting process, which is tailored to comply with strategic innovation management. Thereafter, an overview of several forecasting methods is given. The section *Knowledge Management Needs Within Technology Forecasting* explains the motivation for knowledge management's integration into technology forecasting and describes the strategic and organizational reasons. The subsequent section leads to the development of a characterization scheme in order to evaluate the knowledge management technologies data mining, case-based reasoning, information retrieval, topic maps, and ontologies. The next section comprises the actual evaluation of the mentioned technologies and is followed by an integrative discussion of the findings to close the evaluation. The transfer of the developed insights to the real world through discussion of an example case is covered in the section *Towards an Exploratory Case Study*. This is taken from an innovation project at DETECON Inc., conducted for Deutsche Telekom AG. The subsequent section summarizes the main results and the concluding section suggests fields for further research.

DELIMITATION AND CONCEPTUAL DEFINITIONS

Technology Forecasting

As Granger points out, technology forecasting evolved from the argument that, in the long run, technological change is one of the most important influencing factors of economies (Granger, 1989, p. 209). Thus, technology forecasting seems to be most valuable when applied to long time horizons, which becomes even more important in strategic innovation management. For example, decisions pertaining to general strategic business planning are often based on a forecast time horizon of three to twenty years (DeLurgio, 1998, p. 8).

Besides longer time horizons, the scope of the results is another specific property of technology forecasting. Such forecasts "are generally concerned with the characteristics of a technology rather than how these are achieved" (Granger, 1989, p. 210). It was Bright (1979) who incorporated this fact into a definition of technology forecasting:

> *Technology forecasting is a quantified statement of the timing, the character or the degree of change in technical parameters and attributes in the design, production and application of devices, materials and processes, arrived at through a specified system of reasoning.* (p. 235)

Other authors (for example, DeLurgio, 1998, p. 10) stress that uncertainties about future developments can be modeled with the help of probabilities that help decision-makers plan for a variety of contingencies and scenarios. For this reason and the fact that technology forecasting mostly deals with long time horizons, we revised Bright's definition to attain a more rigorous and precise definition of technology forecasting:

> *Technology forecasting is a probabilistic, long-term estimate of the timing, the character or the degree of change in technical parameters and attributes in the design, production, and application of devices, materials, and processes, arrived at through a system of reasoning consciously applied by the forecaster and exposed to the recipient.*

In different situations, the exact technology-forecasting process can vary from a relatively simple process with just a few stages, to a process comprising a complex structure of stages and subprocesses (DeLurgio, 1998, p. 26). Armstrong (2001) divides the process into six basic steps: formulate problem, obtain information, select methods, implement methods, evaluate methods, and use forecasts (p. 8). These steps also appear in other literature, in the same or a very similar order (DeLurgio, 1998, p. 27; Reger, 2001, p.538), sometimes in combination with additional stages.

In addition to this process structure, DeLurgio (1998) mentions that on-going maintenance and verification are necessary to ensure that the results are valid and effective (p. 27). Hence, it is recommended that reality be monitored and compared to the forecasting results in order to respond to possible inaccuracies. In the context of innovation management, the suggested on-going monitoring becomes even more important, since companies have to respond to changes as quickly as possible to stay competitive. Moreover, it can be assumed that in a large company, the individuals who conduct the forecast and the decision-makers are not the same persons. Additional steps to prepare and make decisions are therefore necessary for a complete view of the process. To include these thoughts into the process, the last step of the process has to be split and a more detailed structure created. The resulting technology-forecasting process for strategic innovation management is shown in Figure 1.

Overview of Forecasting Methods

For the later discussion of technology forecasting, it is important to get a basic understanding of available classes of forecasting methods. This section is based on the "Methodology Tree" by Armstrong which illustrates the characteristics of forecasting methods and their relationships. Figure 2 depicts the Methodology Tree.

Armstrong begins with a separation of judgmental and statistical methods. He mentions, however, that judgment pervades all aspects of forecasting (Armstrong, 2001, p. 9). The further down a method is positioned in the tree, the higher the amount of judgmental and statistical integration. On the judgmental side of the tree, the methods are split into those predicting one's own behavior and those predicting the behavior of others, mostly by including experts into the forecasting process. On the side of method types predicting one's own behavior, the methods are characterized by the influence of a role. If a role influences the decision to make, *role playing* is a valuable tool for forecasting the outcome of the decision through the simulated interaction of roles affected by the decision. In case there is no influence of a role, the *intentions method* can be used in which people predict their own behavior in different situations. *Conjoint analysis* goes a step further than the *intentions method* by trying to create a connection between personal intentions and certain features of a situation through statistical analysis. For example, "a forecaster could show various designs for a computer and ask people about their intentions to purchase each version" (Armstrong, 2001, p. 9).

Forecasting methods within the *others* branch are based on *expert opinions* about how organizations or others will behave. There is a broad number of forecasting methods which belong to this type, with the Delphi method being the most famous one. In this method, questionnaires are sent out to experts in the targeted fields who answer the questions by the use of their subjective judgment. Once the questionnaires are sent back and analyzed, they are sent out again to the same experts together with the results of the first round in order to get a second estimation. The reason for this is to share the results and create a common knowledge base among all participants of the forecast. This process can be repeated for one or two more rounds after which

Figure 1. The technology-forecasting process (following Armstrong, 2001)

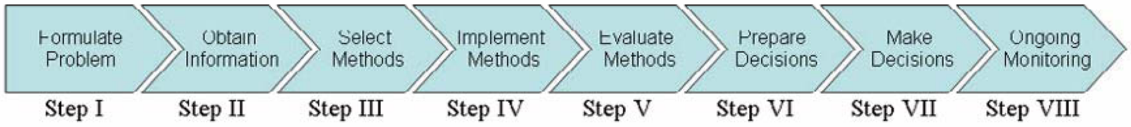
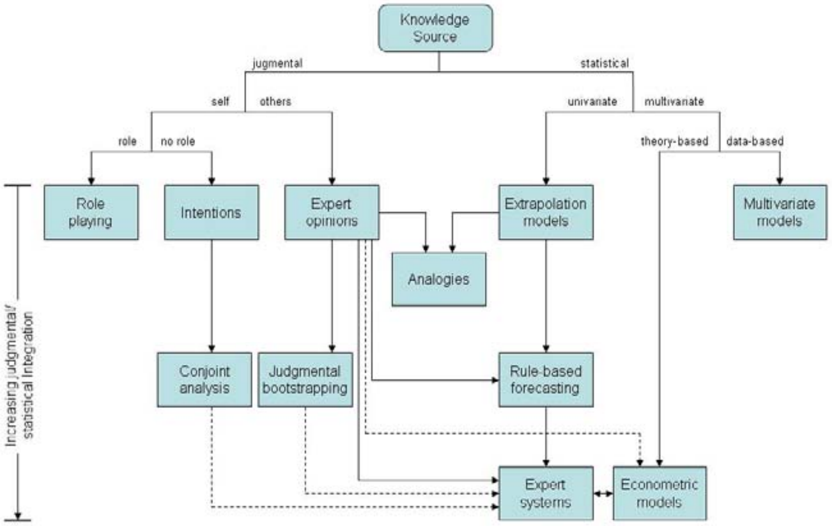


Figure 2. Methodology tree by Armstrong (2001, p. 9); dotted lines present possible relationships



the final conclusions are drawn and the forecast is created. Further information about the Delphi method can be found in the forecasting literature (e.g., Armstrong, 2001; DeLurgio, 1998; Granger, 1989; Martino, 1983). *Judgmental bootstrapping* refers to methods which use regression analysis in order to draw conclusions and rules from expert opinions and, to a certain extent, belongs to the class of expert systems.

Judgment and statistics are merged into one method type when *analogies* are used. Based on statistical data, experts try to forecast the development of a situation. The success of such an approach depends on the degree of similarity between the situation which has to be predicted and the one the statistical data are taken from.

The statistical side of the tree is split into univariate and multivariate methods. The *univariate* part of the tree contains extrapolation methods (Armstrong, 2001, p. 10); that is, values are predicted by the use of older values within a (time-) series. The simplest method of this type is using today's number of sales to predict tomorrow's number. When domain knowledge and knowledge about forecasting procedures is combined in a type of expert system to achieve this task, one speaks of *rule-based forecasting*. Full *expert systems* utilize an even greater integration of expert rules (rules which are similar to the way experts create their judgments) in order to support forecasting.

Multivariate forecasting methods are distinguished whether they are based on statistical data or theory. The latter leads to *econometric models* which base on domain knowledge or findings from prior research. "Econometric models provide an ideal way to integrate judgmental and statistical sources" (Armstrong, 2001, p. 10).

In general, one can argue that the focus of the following sections lies within the area of quantitative or statistical forecasting methods. However, it is the goal of this chapter to identify possible knowledge management technology support throughout the entire technology forecasting process as introduced in the section before and not only for a specific type of forecasting method. Therefore, the dedicated analysis of specific statistical and nonstatistical methods with regards to knowledge management needs could lead to further improvements of the forecasting quality and is suggested as an area of future research.

KNOWLEDGE MANAGEMENT NEEDS WITHIN TECHNOLOGY FORECASTING

There are three major perspectives that have to be considered in order to determine the need for knowledge management within technology forecasting. First, knowledge management needs within technology forecasting can be considered natural implications emerging from business and knowledge strategies which companies formulate to sustain or increase their competitive advantage. Second, the topic can be approached from an inside-the-company view: which other strategic, technological, or organizational factors within a company necessitate integrating knowledge management into the technology-forecasting process? Third, a company's forecasting process is obviously influenced by the company's environment. Therefore, an analysis from an outside-the-company perspective is also crucial to achieve a complete view of the need for knowledge management within technology forecasting.

Business and Knowledge Strategy Implications

As business strategies are formulated to set the overall company goals and define a company's unique strategy to gain profits, one needs to understand that these strategies are built from different components, each delivering a fundamental part to realize a company's objectives. Various authors, for example, Geschka (1992), broadly accept that "the innovation strategy is one means to achieve overall strategic company goals" (p. 70). Therefore, innovation is becoming increasingly important within companies and is moving from an activity often conducted solely within marketing or research and development departments to a process spanning several departments steered by dedicated innovation management. Furthermore, the nature of innovation is such that it can be the sole source of a company's competitive advantage and business success. O'Hare (1988) states that "truly successful innovation does not just lead to some extra sales volume, or a temporary improvement in performance. … Rather, it is about achieving fundamental improvement in competitive position, about re-establishing the competitive equilibrium at a new, more favorable point" (pp. 39-40). However, the value of innovation and, therefore, its ability to function as a basis for competitive advantage, declines over time. This can be observed on a daily basis and examples can be found everywhere, from food to consumer technology and from health care to aviation; what seems to be a unique and exclusive product justifying a premium price today becomes a commodity product tomorrow.

It is essential to continue the development of further innovations to successfully build and sustain competitive advantage based on innovation. This undertaking is, however, influenced by many factors that determine the future of a company as well as the economy and society to which the company belongs. These factors could, for example, belong to political regulations, trends, and hypes within a society, or technological and scientific breakthroughs. Therefore, the development of innovation faces risks and uncertainty that are all future related and with which the company needs to cope through stringent innovation management. It is essential to recognize that this uncertainty with regard to future developments is the main reason for technology forecasting being a core part of current companies' efforts to plan innovation roadmaps and business strategies in keeping with future challenges. Armstrong (2001) says that:

> *We have no need to forecast whether the sun will rise tomorrow. There is also no uncertainty when events can be controlled; for example, you do not need to predict the temperature in your home. Many decisions, however, involve uncertainty, and in these cases, formal forecasting procedures … can be useful.* (p. 2)

A knowledge management strategy defines the basic direction of an organization's knowledge management structures and activities (Riempp, 2004, p. 77). The overall aim of these structures and activities is the improved utilization of knowledge that contributes to the better achievement of an organization's goals; that is, the knowledge management strategy is part of the overall business strategy. When thinking about technology forecasting and transferring it to the domain of knowledge strategies, technology forecasting can be regarded as a means to define and evaluate what Abou-Zeid (2005) calls the Knowledge-Scope (K-Scope); "K-Scope deals with the specific domains of knowledge that are critical to the firm's survival and advancement strategies" (p. 100). In other words, technology forecasting helps a company to understand which path technological innovations will follow to identify the implications for the company's own innovation roadmap and its overall competitive strategy. According to Abou-Zeid (2005), this is part of the Knowledge Strategy External Domain (p. 100). Thereby, technology forecasting is a means to support knowledge strategy creation by supporting the Knowledge-Scope definition as well as an essential part of a company's innovation management by being a driver for innovation strategy formulation.

Needs Emerging from Inside the Company

Inside a company, technology forecasting is closely linked with decision-making processes. It is part of the activities incorporated in strategic innovation management in order to support planning of innovation and R&D programs. DeLurgio (1998) argues that "it is important to recognize the role of forecasting in expanding the knowledge base of organizations and whole societies" (p. 6). Thus, technology forecasting itself can be regarded as a knowledge-creating activity; that is, knowledge in the sense of enabling managers to make strategic decisions, plan a technological innovation path for the company, and adjust business strategies. Therefore, decision-makers need an as comprehensive view of future developments as possible, which cannot be achieved with the help of technology forecasting alone. The end product of forecasting activities is, in most cases, some sort of study or report that represents all analyzed future developments. However, it can be assumed that this report does not contain enough information for a decision-maker to recreate all the knowledge that has been created by participants through the entire forecasting process. Knowledge, like perspectives and prior experiences shared by forecasters, might be valuable for a decision-maker. This facilitates interpretation of the information contained within the reports in a more efficient and comprehensive fashion, thus leading to decreased uncertainty and better-informed decisions. Moreover, reports cannot contain all the information available to the forecasters. In order to provide precise information and to reduce the document's complexity, some information has to be omitted. However, this information might become useful later in the decision process. Without efficient ways of recovering the missing information, the decision process is either slowed down, due to the additional time spent analyzing or acquiring the missing information for a second time, or it becomes less accurate.

In summary, from an inside-the-company perspective, two major reasons can be identified for the emerging need of knowledge management support for technology forecasting within strategic innovation management. Moreover, the last two major reasons have the potential to improve the quality and efficiency of the process:

- Technology forecasting is itself a knowledge-creating process.
- Knowledge that has been created during the process is not transferred to decision-makers due to, for example, the limited amount of information that can be conveyed via documentation.

Needs Emerging from Outside the Company

Making the right decisions with respect to future developments and technologies is vital for a company's competitiveness. One reason for this is the decreasing length of technological life cycles as "technological change is one of the most important forces affecting a firm's competitive position" (Burgelman, Maidique & Wheelwright, 1996, p. 6). Additional dynamics and uncertainty are created by the phenomenon of unexpected, disruptive innovations with which a company has to cope and which can never be fully excluded. Another factor that increases the pressure felt by decision-makers is cost. Vanston (1996) states that "under pressure to contain these [higher] costs, it has become increasingly important for R&D programs to focus on projects that will result in enhanced profits and sustainable competitive advantage" (p. 57). All these factors are evidence of how crucial it is for a company to make the right decisions in a constantly decreasing time frame.

On the other hand, the same reasons lead companies to face increasing uncertainty with respect to future developments. In order to deal with this uncertainty, companies have to collect and assess more information swifter and more efficiently than they used to. This is also true in the context of technology forecasting within strategic innovation management. It can be assumed that more information leads to a reduced uncertainty and thus to a better-informed decision. At the same time, however, more information also leads to greater complexity and, consequently, to a decrease in efficiency and a slower process. The amount of information required to decrease uncertainty and the time needed to collect, assess, and process information are in inverse proportion to each other. As far as possible, companies should therefore find equilibrium on the information side to keep uncertainty low, while keeping complexity on a level that the forecaster can still handle.

Hence, two main factors—related to a technology-forecasting process's efficiency and emerging from outside the company—that influence a company's competitive advantage and business strategy, and create a need for knowledge management within technology forecasting, are:

- Decisions have to be made faster to stay ahead of competition.
- More information with an increasingly complex relational structure has to be collected, assessed, and processed to decrease uncertainty.

DEVELOPMENT OF A CHARACTERIZATION SCHEME FOR KNOWLEDGE MANAGEMENT TECHNOLOGIES

In this chapter, we will develop a characterization scheme to evaluate and delineate knowledge management technologies. Since these technologies differ with respect to knowledge management as well as technology forecasting, the scheme will combine these two fields by integrating a dimension for each of them.

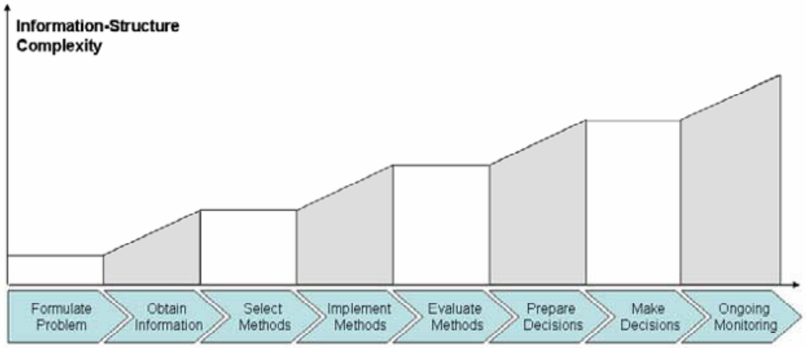
We have shown that one can argue that technology forecasting itself is a knowledge-creating process. A second look at the forecasting process reveals that each step can be regarded as a transformation process with specific inputs and outputs. Step II, for example, needs the definition of the forecasting objectives, the scope, and the time horizon as inputs. This information is utilized within the process step's activities and transformed into information of a greater complexity by combining the input with new information. New relations are identified between certain information objects, leading to the observed information structure's greater complexity. The subsequent step III also requires input from the preceding steps. It is, however, different from step II with respect to the transformation of information. While the activities of process step II increase the information structure's overall complexity, the complexity remains constant during step III, because the information is only analyzed to select suitable forecasting methods. An analysis of the other process steps reveals that the technology-forecasting process's steps can be characterized by their varying degree of complexity; in other words, either the level of complexity is increased or it remains unaltered. Figure 3 illustrates this relation on an abstract level without claiming to represent the actual degree of complexity increase.

On examining Figure 3, it is possible to identify four steps that cause the information structure's increasing complexity within the forecasting process. These steps are: obtain information, implement methods, prepare decisions, and ongoing monitoring. Reasons can be found for these four steps' contribution to the complexity when comparing each step's activities. They all have the combination of previous steps' results and newly acquired information in common, which leads to the creation of new knowledge. Such knowledge is needed to complete each process step's tasks.

Accordingly, the level of the information structure's complexity is chosen as a dimension of technology forecasting and is expressed by the four process steps identified. This dimension enables knowledge management technologies to be classified according to their capability to support these four process steps, and allows an implicit description of the level of information complexity within the technology-forecasting process that a knowledge management technology supports.

While the development of the technology forecasting dimension is based on the analysis of the forecasting process, a different approach has to be found to define the knowledge management dimension. As a starting point, the definitions of data, information, and knowledge should be considered. Since there is a defined difference between these terms, one can argue that data, information, and knowledge's definitions could be used as a structure with which to categorize knowledge management technologies; for example, the category "information" contains all those technologies that target information. Furthermore, transformation processes are required to turn data into information and information into knowledge. A categorization structure based only on the definitions of the three terms is not capable of integrating such transformation processes, and it is obvious that there are knowledge management technologies that, for example, specifically support the transformation of data into information. Aamodt and Nygård (1995) propose a model for data, information, and knowledge that takes the three terms' specific relationships into account (p. 8). The model explains the processes that are needed to transform, for example, data into information, in addition to providing data, information, and knowledge's basic structure. However, with regard to the development of a dimension for knowledge management technologies' charac-

Figure 3. Information-structure complexity



terization from a knowledge management point of view, it can be argued that this model is not applicable. Knowledge, as understood in this chapter, is closely linked with human action and the human mind, with learning being one way of creating knowledge. While there might be a number of knowledge management technologies that support learning, it is impossible for technologies to target knowledge itself.

Another disadvantage of such a model is its granularity. It can be assumed that there are several types of knowledge management technologies that target information, but each with a different focus or different application areas. Consequently, a finer granularity is needed which, in an optimal case, can be based on a single and continuous criterion to facilitate adoption and the development of a knowledge management dimension for the characterization scheme as stated previously.

Smolnik et al. (2005) suggest an approach called "the continuum of context explication", which fulfills the mentioned requirements and is based on the importance of context. Here, context explication means "discovering implicit meanings and expressing those meanings explicitly" (p. 28). The authors stress that context is an important aspect that many definitions of knowledge have in common (Smolnik et al., 2005, p. 30) and they compare several definitions of context. Dey and Abowd (2000), for example, define context as follows:

Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves. (pp. 3-4)

Besides its role in the definition of knowledge, context also plays an important role in the definition of information. Nonaka and Takeuchi (1995) argue that "knowledge, like information, is … context-specific and relational" (p. 58). Smolnik et al. (2005) found that knowledge management technologies "focus on contextual information in different ways and with varying intensity" (p. 36). Consequently, the authors present five approaches to "find and use information objects and contextual information …, each with a differing degree of context and explication ease" (Smolnik et al., 2005, p. 36). The continuum distinguishes the following five approaches:

- **The data approach:** Data are symbols or signs without a meaning or context. Thus, context cannot be explicated. Nevertheless, technologies can be applied to transform data into information or domain-specific knowledge. The data approach encompasses these methods.
- **The information approach:** Most important for the definition of information is that information includes meaning and a specific context. However, the "context is … interwoven with the content and difficult to conceptualize, which means that the methods implemented to find requested information objects have to rely on the content and cannot access contextual information" (Smolnik et al., 2005, p. 37).
- **The descriptor approach:** The addition of explicit contextual information to information objects, thereby providing context-aware methods for information search and discovery, is called a descriptor approach.
- **The metacontext approach:** This approach extends the descriptor approach, as explicit contextual information no longer resides only within information objects, but is integrated into a metalayer that lies above and spans a variety of information.
- **The knowledge approach:** The knowledge approach focuses on the human being and considers characteristics of knowledge. It is about knowledge creation through actions like communication, construction, or cognition.

The continuum's consideration of context and its explication offers a continuous criterion through which it is possible to distinguish different knowledge management technologies. This makes the continuum of context explication an ideal basis for the development of a knowledge management dimension. Each approach forms one category that can be used to classify knowledge management technologies. The only exception is the knowledge approach. Since it is closely linked to the human mind and human action, knowledge management technologies cannot explicate the person-specific context. This approach is therefore not used within the knowledge management dimension.

The combination of the developed technology-forecasting dimension with the knowledge management perspective dimension results in the context-complexity matrix. This matrix allows the characterization of knowledge management technologies with regard to the degree of context as well as to the technology-forecasting process's degree of information structure complexity. The background of each dimension implicitly provides further characteristics of the classified knowledge management technologies. A categorization of, for example, the metacontext approach within the knowledge management domain and step VIII of the technology-forecasting domain means that the knowledge management technology is capable of supporting step VIII's great information structure complexity and also comprises a high level of explicit contextual information.

EVALUATION OF KNOWLEDGE MANAGEMENT TECHNOLOGIES

The breadth of available knowledge management technologies ranges from very simple to very complex. The set of knowledge management technologies for the following evaluation has therefore been selected to represent this breadth, namely, data mining, case-based reasoning, information retrieval, topic maps, and ontologies. We evaluate these technologies in the following with respect to the presented characterization scheme.

Data Mining

Authors in the field of data mining often state that the identification of specific patterns enables the extraction of knowledge embedded within databases (e.g., Han & Kamber, 2001, p. 4; Lusti, 2002, p. 260). This view is not absolutely precise. The consideration of data-mining applications like market basket analysis, fraud detection, or risk analysis leads to the thought that data-mining functionalities enrich data through the identification of patterns or classes in a way that a person familiar with the domain is capable of deriving a meaning from the presented results. Hence, domain-specific information is generated, which can then be combined with other information and knowledge to create new knowledge. But data mining contains no functionality that specifically supports this combination of information. By considering the continuum of context explication as a dimension for a knowledge management categorization, the discussion above can be summarized by assigning data mining to the category "data approach".

With respect to technology forecasting, Armstrong (2001) argues that "an immense amount of research effort has so far produced little evidence that data-mining models can improve forecasting accuracy" (p. 10). Thus, the quality of forecasts that are solely based on data mining is debatable and, consequently, so is the support of step IV. However, it is our opinion that with the exception of the implementation of forecasting methods, data mining can be successfully utilized to facilitate specific tasks within the technology forecasting process's steps. As we explained in the previous section, step II and step VIII require the analysis of great amounts of information with respect to specified criteria. In step II, information is needed that can be associated with the forecast's objectives as defined during step I, while an on-going analysis of information based on the results of a forecast is required within step VIII. In combination with other technologies, data mining might be a suitable way to improve the efficiency of identifying interesting information objects through classification and association analysis. Data mining can therefore be assigned to the categories "step II" and "step VIII" of the technology-forecasting dimension.

Case-Based Reasoning

Compared to data mining, case-based reasoning is a concept which targets information rather than data. A case provides the solution to some problems, which can basically be viewed as providing domain-specific information (Riesbeck & Schank, 1989, p. 24). Case-based reasoning comprises certain functionalities that allow the emulation of cognitive processes in order to generate solutions (Riesbeck & Schank, 1989, p. 24). These functionalities are the capability to adapt old cases to suit the needs of new cases and the fact that a system enlarges its case base by evaluating and retaining cases that have either been solved, or provide information about faults. Systems following the structural case-based reasoning approach (Bergmann, Althoff, Breen, Göker, Manago, Traphöner & Wess, 2003, p. 21) integrate these functionalities and apply general domain knowledge to a model to improve case storage and retrieval, thereby putting the different cases into a certain context. The context is defined by a set of features that are used to index a case and to determine similarity between different cases (Aamodt & Plaza, 1994, p. 50). Thus, features are descriptors of information objects and the corresponding context.

On the other hand, there are also case-based reasoning systems that do not have an underlying domain model, like those that use the textual case-based reasoning approach (Bergmann et al., 2003, p. 21). Such systems work directly on the information and utilize certain algorithms to compare and match new cases with those contained in the case base. Consequently, with respect to the knowledge management dimension, case-based reasoning belongs equally to the category "information approach" and to the category "descriptor approach".

With regard to the dimension for technology forecasting, an appropriate characterization and the corresponding identification of the potential for supporting the technology-forecasting process is a more difficult task. Gaines and Shaw (1986) argue that as far as technology and innovations are concerned, it seems that the past is not appropriate for predicting the future (p. 3). Case-based reasoning is, however, designed around previous experiences. This leads to the conclusion that case-based reasoning cannot be applied to technology-forecasting activities. It cannot therefore be assigned to the category "step IV" of the technology-forecasting dimension. Moreover, taking the requirements of step II and step VIII into account, it is doubtful that case-based reasoning is a useful method with which to support these activities. Both steps need to handle a great amount of new information and need to put this information into context to achieve a clearer perspective of the forecast's scope as well as to collect information with which to monitor the forecast's results. Case-based reasoning is not a method that is intended for the identification of new information. It cannot therefore be assigned to the categories "step II" or "step VIII" of the technology-forecasting dimension.

Nevertheless, it is case-based reasoning's purpose to support decisions and to solve problems. Therefore, it is an appropriate technology for application during step VI. More precisely, case-based reasoning can be used to support planning activities (Lenz, Bartsch-Spörl, Burkhardt & Wess, 1998, p. 14). A company that has a long experience of pursuing and developing innovative technologies might profit from its knowledge when a new technology is about to be developed or integrated.

Information Retrieval

On considering the definitions of each single category of the knowledge management dimension, it seems obvious that information retrieval belongs to the category "information approach'. In general, such a categorization appears to be reasonable since information retrieval targets raw information. Smolnik et al. (2005) argue that although information itself comprises content and context, the context is interwoven with the content and thus difficult to explicate (p. 37). As a result, technologies that do not include additional explicit contextual information only rely on content or its representation within search functionalities. Clearly, this is true of most conceptual information retrieval models.

On the other hand, one can argue that some forms of information retrieval also integrate explicit contextual information into search and retrieval methods. While Smolnik et al. (2005) state that "authors have to provide [explicit contextual] information at the time of creation" (p. 37), the consideration of the concept of aboutness, as introduced by Ingwersen (1992, p. 50), allows an additional perspective. On considering the fact that some information retrieval systems are based on the creation of index terms through document analysis and alignment with a specific domain by individuals, we argue that such indexes represent the indexer's aboutness and therefore also the context of the individual who analyzes the documents and creates the index. Nevertheless, in the same way that indexer aboutness differs from author aboutness, the author and indexer's contexts vary. In general, the characterization of information retrieval by assigning it to the category "information approach" within the knowledge management dimension is a reasonable outcome; however, the exceptions as discussed previously should be taken into account. Information retrieval will therefore be categorized by mainly assigning it to the category "information approach" as well as partially to the category "descriptor approach".

Within technology forecasting, certain process steps include the need to identify information when a large amount of it is available, namely in step II, step IV, and step VIII. The difference between these steps' information need is that the first two steps require a broad range of new information with respect to the selected forecasting scope, while the latter step utilizes specific information that is closely linked with the developed technology forecasts in order to compare them to reality. Therefore, an efficient way to identify and assess relations and derive consequences from specific information objects is more important than the mere retrieval of interesting information from a large amount and variety of information. It is a common assumption among information retrieval researchers that searching within such systems is an iterative process (Salton & McGill, 1983, p. 3). A user starts with some sort of query and evaluates his or her own understanding of the information needed with the help of the first result set. Either the information is sufficient—it results in the retrieval of additional information through references or the like—or a user realizes that the request has to be completely revised. Reasons for this can be found when taking into account that users are only able to describe what they need, which is in turn based on what they already know. These arguments lead to the conclusion that information retrieval is not applicable to step VIII of the technology-forecasting process and, instead, can be characterized as able to support steps with a need for a wide range of new information, thus step II and step IV.

Topic Maps

Topic maps provide methods with which to navigate associatively across large amounts of information in a conscious manner, enabling a systematic identification of information and creation of new knowledge by the user. This is possible by detaching the information source from the context used to find the information, which results in topic maps being "information assets in their own right, irrespective of whether they are actually connected to any information resources or not" (Rath & Pepper, 1999, p. 9). Moreover, topic maps support "managing the meaning of the information, rather than just the information" (Garshol, 2002, p. 2). An explicit context, called metacontext, is used to organize available information in such a way that more efficient search methods can be applied. Hence, the metacontext is the most characterizing aspect when discussing topic maps; they thus clearly belong to the category "metacontext approach" when considering the knowledge management dimension of the context-complexity matrix.

Because a topic map describes certain domain knowledge, it can be very useful when created to represent the forecast's scope. Such a topic map comprises the different technologies and research areas within the focus of the company that conducts the forecast. Associations can be used to link technologies to express their influences and relations. Any information, to which the topic map is applied, can then be categorized with respect to the forecast's scope, facilitating identification of valuable information. Furthermore, once there is a comprehensive information repository, the topic map can be used to relocate information and to relate it to the forecasting activities' results. Hence, topic maps also provide additional value when used within step IV and step VI. Identifying specific information that correlates with the forecasting activities' results is especially important within step VIII. Topic maps' filtering and localization capabilities help to achieve a more precise analysis of available information and, hence, a more efficient monitoring process overall. In general, topic maps have the potential to increase the efficiency of each technology-forecasting step in the context-complexity matrix, because they can be tailored to a forecast's scope and thereby reduce the available information's complexity to a manageable level.

Ontologies

Ontologies are a means to provide a resource that unambiguously determines the meaning of terms and their relations to other terms within a certain domain (Benjamins, Fensel, & Gómez Pérez, 1998, p. 2). This structure is an autonomous construct without links to specific information resources. With respect to the knowledge management dimension of the context-complexity matrix, it is quite obvious that ontologies belong to the category "metacontext approach", as explicit context structures are created that are independent of specific information resources and can themselves be viewed as an information resource. Therefore, relations have to be created between an information resource and ontologies by means of explicit contextual information and specific references that are added to the information resource. This methodology clearly does not fit into any other category on the knowledge management dimension than the metacontext approach.

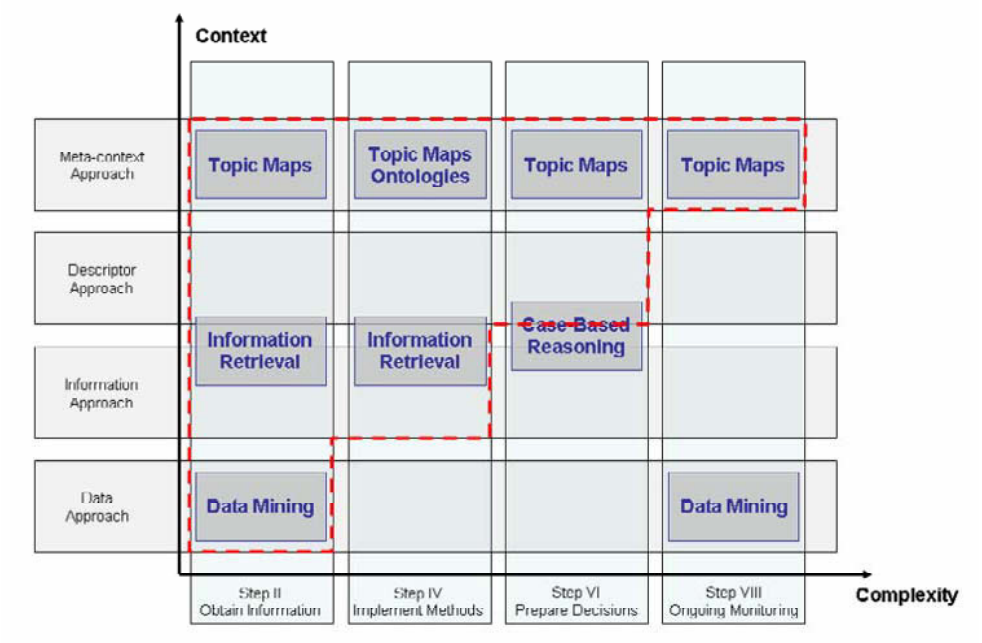
The same reasons that lead to the obvious characterization of ontologies as a metacontext approach hamper categorization with regard to technology forecasting. The question arises: which of the technology-forecasting process's steps and activities benefit from the development and application of an ontology? Following the premises regarding the benefits of ontology application as presented by Zelewski (2001, p. 4), possible applications can be derived for ontologies within technology forecasting. Zelewski (2001) argues that the knowledge intensity of the tasks to be accomplished and the degree to which the knowledge backgrounds of the parties involved in an interaction differ both influence ontologies' importance as a means to improve the considered process tasks' efficiency (p. 4). When conducted for strategic innovation management, many technology-forecasting methods such as, for example, the Delphi method (e.g., Armstrong, 2001; DeLurgio, 1998), are aimed at transforming individuals with different backgrounds' specific knowledge into statements about future technological innovations and developments. Thus, Zelewski's premises are true with regards to technology forecasting. As a result, only the category "step IV" seems to be suitable for ontology application's characterization within technology forecasting for strategic innovation management, but it is limited by the chosen technology-forecasting methods.

DISCUSSIONS

Obviously, some of the technology-forecasting process's steps can be supported by more than one knowledge management technology. Therefore, the question arises: which single technology or which combination appears to be the most promising with which to support and improve this process? To answer this question, it is helpful to consider technology forecasting for strategic innovation management with respect to the type of input each process step requires. We have shown that the complexity of the information structure within the technology-forecasting process increases in the course of the process. We argue that context too becomes more and more important. At the beginning of the process, the importance of context as well as the information structure's complexity is rather modest, but in the end, the degree of complexity and context importance reaches a maximum. As a result, the context-complexity matrix has to be refined to integrate strategic innovation management's focus in such a way that only the upper left triangle represents possible solutions, which are promising ways of supporting technology-forecasting steps through knowledge management technologies as presented in Figure 4.

A striking point of the context-complexity matrix is the fact that topic maps are capable of supporting each process step in a certain way. However, topic maps require some knowledge about the domain and its topics for their generation, while information retrieval provides functionalities that require less prior knowledge and can be used to gather a first broad variety of information. This can be especially helpful during the first phases of technology-forecasting research efforts.

Figure 4. The context-complexity matrix



Such information can then be analyzed to generate the needed topic map, which corresponds with a technology forecast's scope. Later on, the topic map can be used to classify and organize further information and, hence, allows a more systematic way of discovering additional information.

In summary, we can state that a knowledge management system that is based on topic map technologies and integrates information retrieval functionalities as extensions to those provided by the topic map, is the most promising solution with which to support technology forecasting for strategic innovation management. In order to verify the theoretical results, we test them within a real-world scenario.

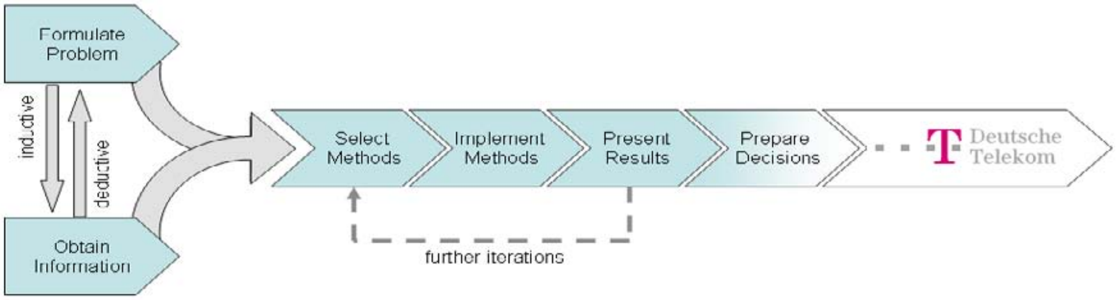
TOWARDS AN EXPLORATORY CASE STUDY

We applied our findings to a project conducted for Deutsche Telekom AG at DETECON Inc., a technology and management consulting company with a focus on innovation engineering. The main objectives of the project were the identification of technology trends and developments that are able to open new opportunities and the assessment of their innovation potential in order to define innovation strategies and achieve company goals. The technology forecasting process at DETECON Inc. differs in two main aspects from the generic process as presented in this chapter. First of all, people at DETECON Inc. distinguish between *inductive* and *deductive* approaches toward innovation and trend identification. This is comparable to what Reger (2001) calls "core technologies" and "white spaces" (p. 539). Inductive methods begin with the identification and formulation of a certain problem setting. In this case, the term *problem* refers to certain needs which emerge from inside Deutsche Telekom and are derived from, for example, internal developments or processes.

After problem formulation, specific information is obtained which is related to the problem and helps finding innovative solutions. In other cases the appearance of information about certain technology developments and innovations precedes the identification of a problem. Emerging trends and innovations are monitored by DETECON Inc. and assessed with respect to their potential influence on Deutsche Telekom AG's business or innovation strategy. An example for technological trends which lead to an innovation need from outside Deutsche Telekom is Voice-over-Internet protocol (VOIP) which, in the long run, can be considered a threat to Telekom's integrated services digital network (ISDN) landline product.

In summary, a forecasting process at DETECON Inc. can be initiated in basically two ways (Figure 5): either problem precedes information or information precedes problem. Furthermore, the technology forecasting process for Deutsche Telekom AG can be considered an iterative process. A first iteration gives a broad overview

Figure 5. Technology-forecasting process at DETECON, Inc. for Deutsche Telekom AG



of potential interesting technologies which are then communicated on a very high level towards Deutsche Telekom AG. On the base of interest, Deutsche Telekom AG requests an additional iteration with an increased analysis depth and a more precise technology scope which results in the development of *technology profile documents*. The process leaves DETECON Inc. in a phase comparable to step VI of the general process of technology forecasting for innovation management. From this point on, Deutsche Telekom AG is responsible for the remaining steps and activities and the integration of the acquired knowledge into its innovation strategy.

In the light of the previous section's results, a system based on the central utilization of topic maps seems most promising to improve technology forecasting's efficiency.

One characterizing aspect of technology forecasting at DETECON Inc. is the flexible scope required by the different steps and activities inside the process. Topic maps can be tailored to suit this flexible use. Regarding the process at DETECON Inc., the development of a single comprehensive topic map that represents the applied domain knowledge's basic structure as, for example, technologies and their relations and influences, could offer a solution. Sophisticated methods, like a topic map concept called scope, can then be used to restrict this topic map to the necessary range for single activities. This is sufficient because all DETECON Inc.'s forecasting activities deal with technology and innovation developments and their influences on Deutsche Telekom's technology and business situation. A topic map that has been built and maintained for the corresponding domain, and which can be tailored to represent only the available information's subparts through the exploitation of topic maps' scope attribute, provides an efficient solution to the flexibility requirement.

Obviously, the nature of a topic map also facilitates the organization and reuse of information, and therefore fulfills another requirement with respect to technology forecasting at DETECON Inc.: information that has been used once can be stored in a repository and can be accessed through the topic map. It is also associated with analyses, contacts, or other related information. Therefore, knowledge structures, once generated, can be represented by the topic map, facilitating the recovery of these structures. In addition, a topic map can be used to categorize new information by determining the topics that occur in the new information. This functionality can be combined with automated information retrieval methods. The information is retrieved from a source (most likely within the WWW); it is analyzed with respect to the occurring topics, and then added to the information repository. This process facilitates the identification of valuable new information without the need to analyze all new information manually. Because the information is available through the topic map, it can be accessed when needed.

Switching control of and responsibility for the process from DETECON Inc. to Deutsche Telekom AG, leads to knowledge transfer being facilitated—another requirement of a system to support technology forecasting at DETECON Inc. Once Deutsche Telekom AG considers a technology interesting and relevant, a more detailed technology profile is created, which is then sent to Deutsche Telekom AG. The integration of the mentioned profile documents into the structure of a topic map, as well as their association with the main topics and further relevant information about the corresponding technologies, facilitates this task. The technology-related knowledge can be transferred with the help of the topic map by allowing access to the profile documents and their related information. Personal meetings can then be used to discuss the technology and business consequences, creating additional knowledge that goes beyond the technology itself.

The challenge of such a system is, however, maintaining the topic map. A fully manual maintenance implies the awareness of new developments. Therefore, methods have to be found that can facilitate this task by suggesting new topics and associations. Statistical methods as applied within automatic indexing can provide a useful starting point to solve this problem.

It is obvious that the intense communication and collaboration between the two organizations cannot only rely on an underlying knowledge management system. Therefore, it can be considered valuable future research to include non-codified knowledge management processes into the analysis of knowledge management support within technology forecasting. One starting point can be to map the socialization, externalization, internalization and combination (SECI) model as presented by Nonaka and Takeuchi of organizational knowledge creation with the technology forecasting process to determine those stages which rely on non-codified knowledge creation to improve the overall forecasting process (Nonaka & Takeuchi, 1995, p. 70).

In summary, topic maps provide the needed degree of flexibility, facilitate information organization and reuse as well as knowledge transfer. Therefore, a system that is based on topic maps will be considered the solution to the increasing difficulties with technology forecasting at DETECON Inc.

CONCLUSION

As shown, knowledge management technologies play an important role in supporting the technology forecasting process as a part of strategic innovation management and overall competitive strategies. As there are several possible knowledge management technologies, the real task for technology forecasting begins with the selection of the appropriate technologies for each process step. We have therefore evaluated several knowledge management technologies, each explained according to its main characteristics, benefits, and constraints, focusing on its support of the technology forecasting process's different steps. We have furthermore aligned them all in the proposed context-complexity matrix. The successful application of our theoretical findings was revealed by the case study, realized at DETECON Inc. and Deutsche Telekom AG.

FUTURE RESEARCH DIRECTIONS

To enrich our proposed context-complexity model, we envisage the following areas of future research:

- First, within innovation management, most forecasting is done via the analysis of information as exemplified by DETECON Inc. and Deutsche Telekom AG. We have to determine whether the integration of other forecasting methods, for example, extrapolation methods, into the supporting system could lead to a higher forecasting quality and decreased uncertainty, with the aim of automating a major part of the forecasting process and achieving improved decision support.
- Second, we have to determine whether knowledge management technologies are also capable of supporting single technology forecasting methods.
- Third, we have to validate and expand our findings in further real-world cases in order to verify the theoretical results and ideas of this chapter and to identify further aspects that could potentially increase technology forecasting efficiency, improve innovation strategy formulation, and thus create and sustain competitive advantage.
- Fourth, efficient knowledge management also depends on organizational issues to a certain extent. While this chapter considers knowledge management technologies to be the focal point for knowledge management support within technology forecasting, we have to determine to what extent organiza-

tional knowledge management concepts influence technology forecasting. We assume that organizational concepts depend on the structure of a forecasting process. Processes which are conducted completely inside a single company might benefit more from organizational knowledge management concepts than processes which a scattered over one, two, or more companies. Further research in this area should discuss which combination of technological and organizational process support results into the highest value for competitive advantage and company success.

- Fifth, the main objective of this chapter is to introduce a technology focused framework for integrating knowledge management into quantitative technology forecasting. However, further research should also focus on the support of qualitative technological forecasting, for example, using methods such as scenarios, as well as on the support by noncodified knowledge management processes like those defined by Nonaka and Takeuchi's SECI model and respective technologies such as collaboration supporting tools.

The development of the context-complexity matrix and its application to selected knowledge management technologies has shown that, within technology forecasting, increasing information structure complexity leads to an increasing need for context explication. Information repositories are less useful without the application of explicit metacontexts that facilitate the discovery of needed information. While technologies like data mining or case-based reasoning provide only a marginal efficiency increase, topic maps possess a broad applicability and have the potential to increase efficiency greatly.

By returning the conclusion to the level of innovation and knowledge strategies, we can state that technology forecasting, which was originally a means of supporting an innovation strategy definition, simultaneously supports a knowledge strategy definition by presenting a basis for knowledge-scope determination. The integration of knowledge management technologies and technology forecasting by applying the proposed framework, can therefore be considered a method with which to support business and knowledge strategy alignment on an operational level.

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Chapter 2.3

A Strategic Framework for City Marketing:

The SSRM Approach

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ABSTRACT

City marketing in the broadest term can be defined as the strategic design of the city to satisfy the various stakeholders of the city who often have conflicting goals. This frequently requires an integrated approach that aligns and addresses the expectation of various stakeholders to create vibrant communities. The current trend in globalization, formation of regional trade blocks, and the shift in importance of location factors have increased the intensity of competition among regions and cities. More than ever, cities need to compete and cooperate with each other to attract companies, investments, talent, tourists, and create markets for their products and services. This entails that cities embrace strategic marketing management tools and practices, and utilize e-services such as electronic customer relationship management. The authors propose a broad approach, called strategic stakeholder relationship management (SSRM), which is enabled by information and communication technologies, including Internet, to help the decision makers succeed in designing the 21st Century city marketing initiatives.

INTRODUCTION

City marketing in broadest term can be defined as the strategic design of the city to satisfy the various stakeholders of the city who often have conflicting needs and aspirations. This frequently requires an integrated approach of thought and action that aligns and addresses the expectation of various stakeholders to create vibrant communities.

The current trend in globalization, formation of regional trade blocks and the shift in importance of location factors have increased the intensity of competition among regions and cities. More than ever cities need to compete and cooperate with each other to attract companies, institutions, investment, talent, and tourists and create markets for their products and services. Without investing in city marketing, cities will become defunct and may perish in the long run as the stakeholders will leave.

A city, in nutshell, is a microcosm of the modern political state in a socio economic sense. There are multiple stakeholders, and sometimes the boundaries between these stakeholders are blurry. Different stakeholders have different needs and aspirations while together they contribute to the overall well-being of the city. Thus, the cities must bring the various stakeholder views into a congruent strategy that benefits all its stakeholders, or at least, does not negatively affect certain stakeholders. Given the multiple stakeholders and their specific needs, it becomes imperative that any strategic approach to city marketing has to address the common as well as the competing needs in a coherent and logical manner.

The Internet, together with other technologies, has helped organizations re-orient their services as to take advantage of the available information and communications technology (ICT). Such services are often termed e-services, as they are based on ICTs (Rust & Lemon, 2001). Most industries have in the recent years seen a push towards more focus on customer relationship management (CRM)—an integral and important part of e-service. Clearly, the Internet and ICTs have helped many organizations interact better with their customers through electronic CRM (e-CRM). As a result, e-service has become a major area of study. However, it has been stated that government organizations have more trouble than the private sector in successfully applying new technology (Dawes et al., 2004). In this paper we therefore propose a framework to help city governments plan their e-service strategically: that is, align the goals of its stakeholders, as well as frame the perceived dimensions of quality inherent in their stakeholder-base. The framework, referred to as strategic stakeholder relationship management tool (SSRM) can aid cities in identifying, addressing, and managing issues that are important to their various stakeholders within the limited resources the city has.

BACKGROUND

A favorable business climate often perceived as a key factor for local economic development (Blume, 2006). Globalization has effects on regions/cities in that there have been observable shifts in intensity of competition, and shifts towards knowledge factors (Blume, 2006). Even though competitive ability of an organization depends primarily on business-related and knowledge factors (cost-efficiency, an ability to innovate, marketing and other internal factors) (Krugman, 1996), it is clear that local economic policies may enhance or inhibit such competitiveness. For example, unwanted side-effects are seen in areas such as the Inland Empire in Southern California region as well as in and China, where an overly focus on transportation and production respectively has had detrimental effects on air quality and congestion. The locational factors traditionally driving economic development in China has been the availability of cheap labor. For Inland Empire, the locational factor has been availability of cheaper land, located centrally to major distribution routes (air, ship, and road).

In the past decade, arguments have been voiced over concerns of economic growth and its potential negative impact on both local and global environments. An example of this is seen in air quality concerns over the 2008 Beijing Olympics (Der Spiegel, 2007). In addressing the air quality issues, noxious factories and power-plants have been relocated, and experiments are under way to limit car traffic (LA Times, 2007). The recent implementation of variable toll rates and congestion fees (as in Manhattan, NY), are a step in the same direction. Clearly, local economic policies related to the control of pollution drive these concerns. The immediate negative effects, in the case of the Beijing Olympics, are related to image and tourism in China as well as the poor air quality for local residents. What is clear is that there is a strong link between the marketing of Beijing as a city, and local policies for pollution control. One could clearly argue that in these areas, the local governments have not been aware of some of the issues that are important to many of its stakeholders (for example, the residents). At best, the local government has not been cognizant of one stakeholder view: the quality of life factor. Indeed, Wong (2001) found that when traditional economic factors already are in place (such as infrastructure and workforce), quality of life issues become crucial in the competitive process between cities. That is, as competition matures, the notion of being in touch with ones customers becomes even more important.

The concept of customer relationship management (CRM) is based on value maximization for the organization. The core concept of CRM is that value creation between the firm and the customer is related in such a way that an increase in customer value leads to an increase in firm value (Mithas, Krishnan & Fornell, 2005). In the words of Payne and Frow (2005):

> *CRM is a strategic approach that is concerned with creating improved shareholder value through the development of appropriate relationships with key customers and customer segments. CRM unites the potential of relationship marketing strategies and IT to create profitable, long-term relationships with customers and other key stakeholders. CRM provides enhanced opportunities to use data and information to both understand customers and co-create value with them. This requires a cross-functional integration of processes, people, operations, and marketing capabilities that is enabled through information, technology, and applications.*

The customer, in the city government setting, is a stakeholder: such as a resident, a business, a visitor, etc. It is clear from the discussion above that one should go to great efforts to clearly identify and understand the needs of the stakeholders (or the customers, as they might be). Once these issues are known, one must then align the stakeholder goals as to create a congruent plan for marketing the city. The framework proposed below provides a semi-structured way of identifying, understanding, and aligning stakeholder goals within a resource-based, e-service context.

THE FRAMEWORK

The resource-based view of the firm (RBV) argues that an above average return may be generated when the firm develops or obtains a resource that—when successfully applied in a business strategy—provides competitive advantage. The competitive advantage typically comes about after the firm discovers opportunities for change, executes on its strategy paradigms, and implements its strategy (see for ex. Barney & Hesterly, 2006). Since cities compete for customers—employers, residents, and visitors—it is clear that they must take an approach to competing similar to that of the RBV, but where the returns are to be defined by their stakeholders. In section 3.1, we will illustrate a framework for achieving this, and outline the illustration with a specific example in section 3.2.

Construction of the Framework

A city's resources are similar to most organizations' resources, yet perhaps more encompassing. Organizational theorists typically categorize the assets of the organization into logical groupings (Schermerhorn, 1999). These groupings include personnel, facilities and operational resources, and organizational knowledge as reflected in operational processes. The city's customers and specific external environmental elements should be included with the other organizational assets from the perspective of an extended resource-based view of the organization. This extended classification is often apparent in service industries where the customer has an extensive relationship with the firm—much like that of a city and its customers. The city's stakeholders should be viewed as its customers. Thus, in the discussions below, we use the term stakeholder and customer interchangeably.

Rolland, Patterson and Ward (2008) proposed a 2-dimensional framework for linking organizational resources with the customers' perception of quality (in other words, the things customers may care about). In the spirit of their suggestions, and based on the above discussion, we propose that a city possess organizational assets that can be broadly categorized into:

1. **Personnel:** this organizational asset includes all city employees with whom the stakeholders may interact.
2. **Operational Processes:** this asset includes all major organizational processes, such as city planning, issuing permits, infrastructure development, etc.
3. **Facilities and Operational Assets:** this asset includes infrastructure, land, buildings, parks, equipment, and all other non-personnel related resources.
4. **Customers:** this asset includes the stakeholder, and his/her abilities, restrictions, etc.
5. **External (or environmental) components:** this asset includes regulation, media, competition, and other external factors that may impact the customer/stakeholder.

The first three categories of organizational assets are those that are under very direct control of the city government.

In a CRM system, we are seeking opportunities to understand and improve any interaction (or potential interaction) that takes place between the organization and its customers. Burr, Patterson, Rolland and Ward (2007) as well as Rolland, Patterson and Ward (2008) proposed that such interactions be categorized into a set of "quality dimensions". These quality dimensions are related collections of factors that express (or explain) what customers care about—similar to customer satisfaction factors from studies such as ServQual (Parasuraman, Zeithaml & Berry, 1988). For city marketing, we hypothesize that a reasonable set of example stakeholders would be:

1. **Residents:** This group includes current and potential residents.
2. **Employers/Local businesses:** This group also includes current and potential businesses.
3. **Employees:** includes both people who are residents, and those work, but who do not live, in the city.
4. **Visitors:** This group primarily includes tourists and conference attendees.

Clearly, the stakeholders may have incongruent views as to their own "quality dimensions" that they care about. For example, the resident would typically value low traffic congestion and good air quality, whereas the local businesses would value lower taxes and availability of an appropriate workforce. These quality dimensions could be congruent, but typically will not be as (for example) higher taxes might be needed to reduce traffic congestion.

The dimensions of perceived quality (benefits) are typically determined through in-depth knowledge about the stakeholders, and are measured through the use of surveys (see for example Parasuraman, Zeithaml & Berry, 1988; Ward, Rolland & Patterson, 2005; or Burr et al., 2007, Rolland, Patterson & Ward, 2008). Indeed, from a quality of life and business perspective, such surveys are often found in the public domain already. For example, CNNMoney.com (Fortune, Money, and Business 2.0 magazine) publishes annual ratings for best cities for both living and business (CNNMoney, 2007; Forbes, 2007)—effectively addressing 2 of the city stakeholders: residents and businesses. Although the "quality dimensions" used in such articles sometimes are rather vague, the variables for best places to live are typically centered on variables such as job, income and cost-of-living data; housing affordability; school quality and education scores; crime rates; arts and leisure opportunities; ease of living; access to airports or teaching hospitals, and others. For best places for business, the variables often used are business costs, living costs, education, crime rates, job growth, and income growth. It should be noted that these quality dimensions differ from those often proposed in the literature. For example, ServQual (Parasuraman, Zeithaml & Berry, 1988) proposes 10 original quality dimensions for evaluating service quality: Access, Communication, Competence, Courtesy, Credibility, Reliability, Responsiveness, Security, Tangibles, and Understanding/Knowing the Customer. Sullivan and Estes (2007) implemented ServQual for local governments, and used all the 10 quality dimensions proposed in the original ServQual instrument, albeit many studies of applications of ServQual across various industries do not find support for all 10 quality dimensions. Indeed, a smaller subset of 5 ServQual dimensions is often used: Tangibles, Reliability, Responsiveness, Assurance, and Empathy. Ward, Rolland and Patterson (2005) found 4 quality dimensions to be dominant for healthcare organizations: Interaction & Communication, Access, Tangibles, and Outcome. The dimensions were found by analyzing more than 60,000 surveys of healthcare patients over a seven-year period. It would be expected that perceived service quality dimensions for cities would most likely show 3-10 dominant dimensions, where the variables listed for popular domain surveys would group into several more generic service quality variables. For the sake of the examples in this paper, we will use the following sample quality dimensions:

1. **Interaction and Communication:** This includes all interaction and communication with city resources.
2. **Access:** This could include access to city facilities and systems, schools, hospitals, airports, and others.
3. **Tangibles:** This includes cost of doing business/living, school performance scores, quality of life, quality of labor, crime rates, and other things that can be measured or observed, such as city equipment, personnel, and communication materials.
4. **Reliability:** A city's ability to perform the promised services dependably and accurately.

Once the stakeholders' perceived quality dimensions are known, we need to construct an interaction-space matrix to relate the quality dimensions to the organization resources that the city controls. Thus, for each stakeholder, we generate interaction-space matrices as shown in the examples in Figures 1 and 2. For each interaction between an organizational asset and a quality dimension, we find an interaction-space. Each interaction-space can hold zero or more interaction-points. These interaction-points constitute an opportunity for the city to interact with the stakeholder in a manner that matters positively to the stakeholder. Particularly, each interaction-point may constitute an opportunity for the city to interact with the stakeholder using electronic means (such as the internet). By definition, the interaction-points may constitute a crucial part of a CRM system, since such systems are seeking opportunities to understand and improve any interaction (or potential interaction) that takes place between the organization and its customers. Figure 3 shows the collection of interaction point matrices for 3 city stakeholders: Residents, Employers, and Visitors.

The measurement and analysis of the interaction-points can be done by surveying the customers. Survey instruments need to be developed for

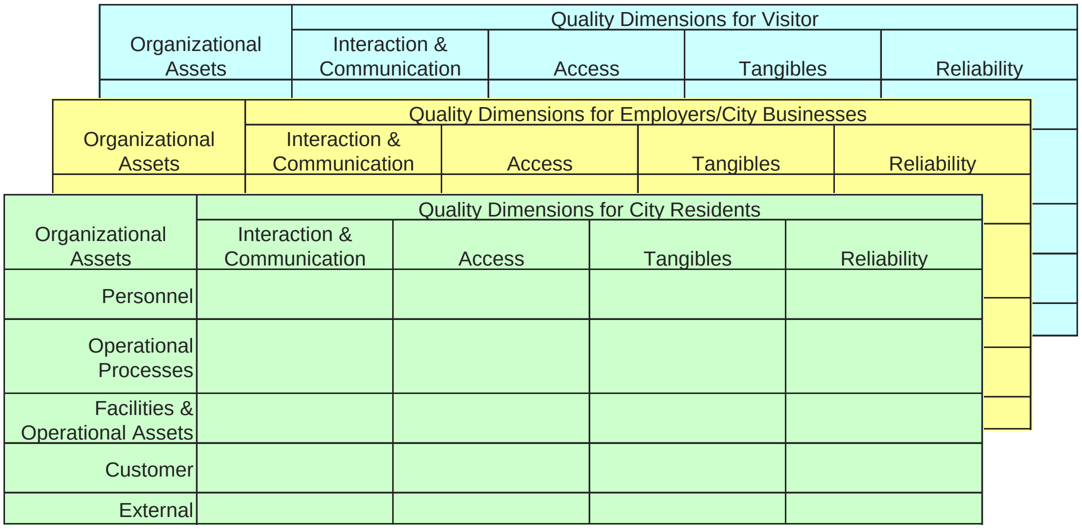
Figure 1. The SSRM framework for city residents

Organizational Assets	Quality Dimensions for City Residents			
	Interaction & Communication	Access	Tangibles	Reliability
Personnel	Interaction point Interaction point	Interaction point Interaction point	Interaction point Interaction point	Interaction point Interaction point
Operational Processes	Interaction point Interaction point Interaction point	Interaction point Interaction point Interaction point	Interaction point Interaction point Interaction point	Interaction point Interaction point Interaction point
Facilities & Operational Assets	Interaction point Interaction point	Interaction point Interaction point	Interaction point Interaction point	Interaction point Interaction point
Customer	Interaction point Interaction point	Interaction point Interaction point	Interaction point Interaction point	Interaction point Interaction point
External	Interaction point Interaction point	Interaction point Interaction point	Interaction point Interaction point	Interaction point Interaction point

Figure 2. The SSRM Framework for city businesses

Organizational Assets	Quality Dimensions for Employers/City Businesses			
	Interaction & Communication	Access	Tangibles	Reliability
Personnel	Interaction point Interaction point	Interaction point Interaction point	Interaction point Interaction point	Interaction point Interaction point
Operational Processes	Interaction point Interaction point Interaction point	Interaction point Interaction point Interaction point	Interaction point Interaction point Interaction point	Interaction point Interaction point Interaction point
Facilities & Operational Assets	Interaction point Interaction point	Interaction point Interaction point	Interaction point Interaction point	Interaction point Interaction point
Customer	Interaction point Interaction point	Interaction point Interaction point	Interaction point Interaction point	Interaction point Interaction point
External	Interaction point Interaction point	Interaction point Interaction point	Interaction point Interaction point	Interaction point Interaction point

Figure 3. The SSRM framework showing 3 stakeholders



Organizational Assets	Quality Dimensions for Visitor			
	Interaction & Communication	Access	Tangibles	Reliability

Organizational Assets	Quality Dimensions for Employers/City Businesses			
	Interaction & Communication	Access	Tangibles	Reliability

Organizational Assets	Quality Dimensions for City Residents			
	Interaction & Communication	Access	Tangibles	Reliability
Personnel				
Operational Processes				
Facilities & Operational Assets				
Customer				
External				

each stakeholder, and data collected on a regular basis to monitor and analyze interaction-points. For example, a survey instrument should be developed that measures the customers' perceptions of the e-services. That is, the surveys are measuring the stakeholders' perceived value and their priority in relation to the organizational assets. A collection of statistically significant questions would be needed to assess each interaction-point. Such surveys typically consist of 5 point, Likert-scale questions, and must be tested and statistically validated for the survey to be deemed useful. City management can use these surveys as a basis for allocation of resources to different interaction points based on their priority and perceived value to stake holder so as to get the best return on their resources. For example, in the healthcare industry medical providers and hospitals conduct annual surveys that may be very useful in the context of healthcare; in the US these surveys are often mandated by national quality organizations such as the Agency for Healthcare Research and Quality (AHRQ). AHRQ has an online site with copies of their questions and surveys used for an annual survey where consumers assess their healthcare providers (AHRQ, 2008). J.D. Power uses similar surveys in their highly publicized annual quality measures (J.D. Power, 2008). For a brief introduction to survey use in government planning, complete with resource links, see Dawes et al. (2004)

Provided that cities regularly use and measure the performance of their interaction-points through such surveys, the organizational assets can then in turn be changed/removed/improved to promote necessary improvements in the interaction-point measures as needed. The relative importance of the interaction-points can be measured by factor analysis (Burr et al., 2007; Rolland et al., 2008), or by administrating direct questionnaires as to what the stakeholder opinions are regarding importance of interaction-points.

One major task in making the framework functional is to align stakeholder goals: that is, ensure congruency in the stakeholders' perceived quality views of the city. Rolland and Maghroori (1997) proposed that efficient organizations must be responsive to all its stakeholders. They propose a set of actions (mission realignment strategies) to correct for situations where this is not the case. The interesting thing to note about this, is that the when the stakeholder goals are aligned with the organization's mission, there is by definition congruency in the stakeholder views (Rolland & Maghroori, 1997). Thus, aligning stakeholder views may entail some tuning of the organization's mission. That is, the exercise of identifying stakeholders, perceived quality dimensions for the stakeholders, and interaction-points for the stakeholders vis-à-vis organizational assets may indeed help define or improve the goals of the city.

An Illustrative Example

In our example, we will develop the some interaction-points related to the 3 stakeholder views found in Figure 3 above. For the sake of this example, we assume that the city managers will be addressing 3 stakeholders: city residents, city businesses, and visitors. We further assume, based on surveys of the stakeholders as well as on findings from the research literature, that the 4 perceived quality dimensions dominant for servicing the 3 stakeholder groups are: Interaction & Communications, Access, Tangibles, and Reliability.

Figure 4 shows potential interaction-points for city residents. Under the *Interaction & Communication* column we see that potential interaction points between residents and city employees are through phone and online chat systems (other possibilities do of course exist). The operational processes that the city residents seeks to interact with are billing systems, appointment systems, a reminder systems (for appointments and bills due etc.) They also seek to communicate with a reservation system for use of public space/facilities.

Figure 4. Potential interaction-points for city residents

Organizational Assets	Quality Dimensions for City Residents			
	Interaction & Communication	Access	Tangibles	Reliability
Personnel	1. Phone system, including live operator 2. Live chat system	1. Live phone operator 2. Live chat with qualified employees	1. Information about employee qualification	1. Live person available 24 hours 2. Adequate police/fire staffing
Operational Processes	1. Billing system 2. Appointment system 3. Reminders - status reports	1. Appointment scheduling 2. Maps and directions 3. Status of permits/licenese/.. Applications 4. Utility services (electric, water, trash, gas) 5. Pet licensing	1. School rankings 2. Crime rates 3. Water and air quality 4. Tax rates, property taxes	1. Automated phone system available 24/7 2. Web system available 24/7 3. Provide information during non-working hours 4. IT security
Facilities & Operational Assets	1. Reservation system for use of public space	1. Available web services for all city issues 2. Emergency room services	1. Pools, parks, tennis courts, golf courses	1. Statistics of faciltities
Customer		1. Training for use of city e-Services		
External			1. Telecommunications infrastructure for the residents 2. Free wireless web access	

Under the *Access* column, we see that city residents seek to have access to the systems by which they sought to communicate (in the previous column), as well as have access to other systems, such as pet licensing and emergency room services. Access to emergency room services could for example be via live chat or telephone, or web scheduling, etc. We also note that the residents want access to training as to how to use the city's e-service systems.

The *Tangibles* dimension primarily lists factual information about issues related to the city's organizational assets. For example, information about: the city employees' qualifications, school rankings, crime rates, water and air quality, and tax issues. Additionally, the residents seek to know about the telecommunications infrastructure (for example, what broadband options are available), and if a free wireless network is available. The latter two issues are related to resources external to the city's organizational assets, but show that it may be important for cities to attract such services from the external industry.

Reliability would include adequate city staffing around the clock—particularly of police services and other emergency services. It also would include access to city e-service 24 hours per day, including holidays, and also may include statistics of city-operated facilities (police, fire, electric, water, etc.) in terms of service reliability. Of course, residents expect that all city services that are conducted electronically can be performed securely (IT security).

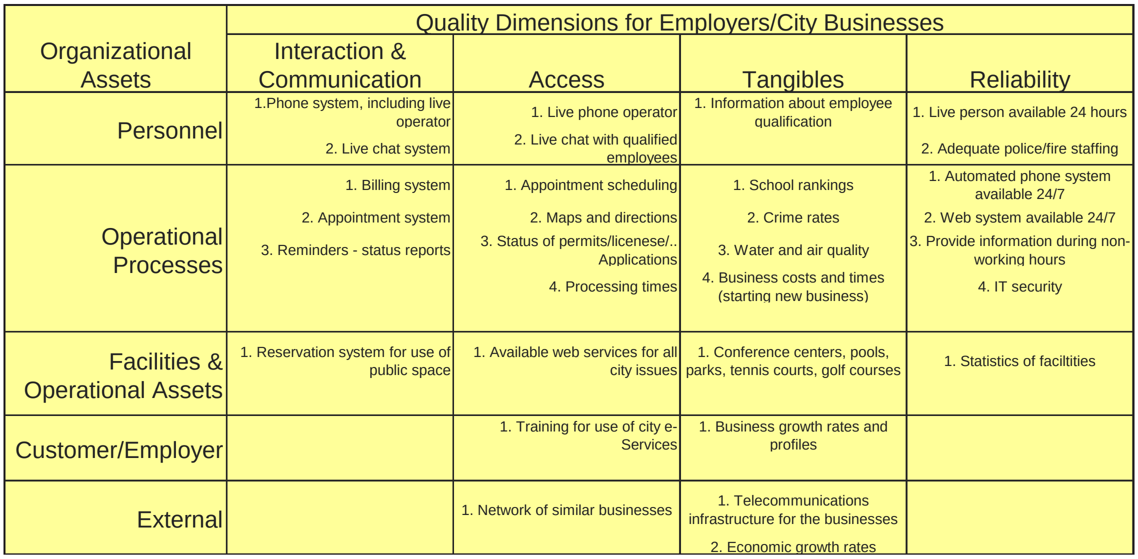
In Figure 5, we list some potential interaction-points for the employers/city businesses. This interaction-space matrix differs only slightly from the resident's matrix. For example, an important *tangible* related to city facilities could be the existence and size of conference centers for business conferences. Also, businesses would be interested in business growth rates, and profiles of local industry (both variables related to the employers themselves), as well as economic growth rates for the region/state (an issue external to the city). Of course, businesses would like to have access to processing times for business license issues, but they normally would not care about pet licensing as residents do. Also, businesses may care about access to a network of similar businesses for purposes of professional exchange (for a Silicon Valley-like environment), skilled labor pool, university and vocational institutes.

Figure 6 shows some potential interaction-points that visitors may deem as important. For example, potential visitors may want to have access to and interact with city personnel who are dedicated to tourist services. They also want access to maps and directions, as well as purchasing tickets for public transportation systems (all access issues). Visitors are also interested in tangibles (mostly information) related to air quality, weather, hotels, airports, beaches, mountains, and other recreational areas. On the *reliability* side, visitors would be interested in the reliability and interoperability of public transit systems, police staffing in the city, and perhaps reliable availability of city tourism experts even on holidays and nights.

Links to Organizational Strategy

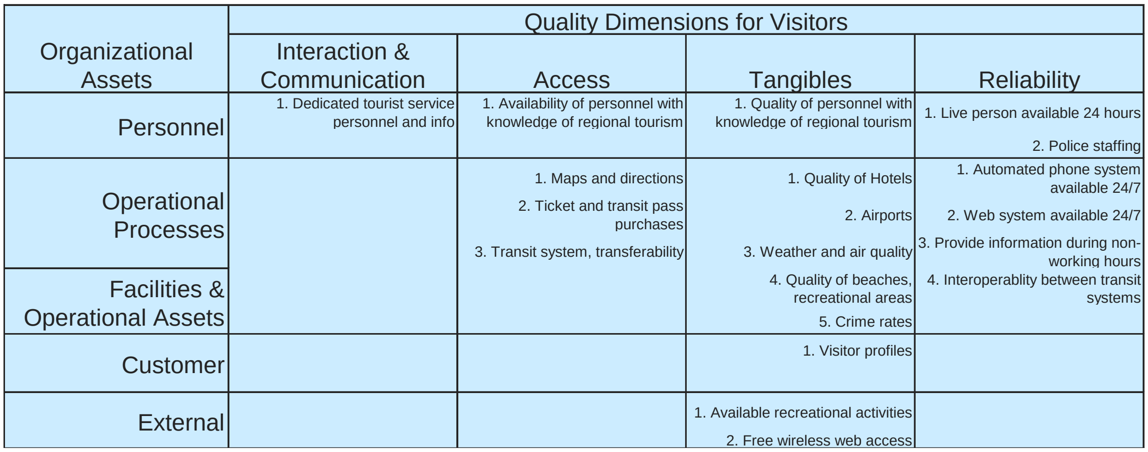
Strategic planning in an organization must take into consideration an assessment of the firm, planning for the future, and implementation of the plan (see Figure 7). Bryson et al. (2007) proposed a resource-based approach to strategy formula-

Figure 5. Potential interaction-points for city businesses/employers



Organizational Assets	Quality Dimensions for Employers/City Businesses			
	Interaction & Communication	Access	Tangibles	Reliability
Personnel	1.Phone system, including live operator 2. Live chat system	1. Live phone operator 2. Live chat with qualified employees	1. Information about employee qualification	1. Live person available 24 hours 2. Adequate police/fire staffing
Operational Processes	1. Billing system 2. Appointment system 3. Reminders - status reports	1. Appointment scheduling 2. Maps and directions 3. Status of permits/licenese/.. Applications 4. Processing times	1. School rankings 2. Crime rates 3. Water and air quality 4. Business costs and times (starting new business)	1. Automated phone system available 24/7 2. Web system available 24/7 3. Provide information during non-working hours 4. IT security
Facilities & Operational Assets	1. Reservation system for use of public space	1. Available web services for all city issues	1. Conference centers, pools, parks, tennis courts, golf courses	1. Statistics of faciltities
Customer/Employer		1. Training for use of city e-Services	1. Business growth rates and profiles	
External		1. Network of similar businesses	1. Telecommunications infrastructure for the businesses 2. Economic growth rates	

Figure 6. Potential interaction-points for visitors



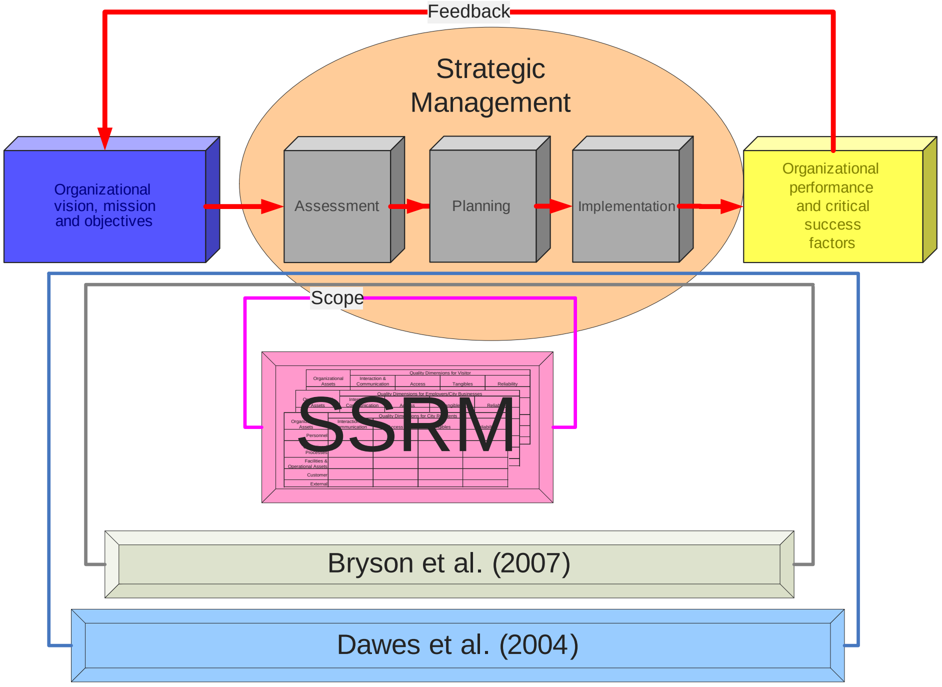
Organizational Assets	Quality Dimensions for Visitors			
	Interaction & Communication	Access	Tangibles	Reliability
Personnel	1. Dedicated tourist service personnel and info	1. Availability of personnel with knowledge of regional tourism	1. Quality of personnel with knowledge of regional tourism	1. Live person available 24 hours 2. Police staffing
Operational Processes		1. Maps and directions 2. Ticket and transit pass purchases 3. Transit system, transferability	1. Quality of Hotels 2. Airports 3. Weather and air quality 4. Quality of beaches, recreational areas 5. Crime rates	1. Automated phone system available 24/7 2. Web system available 24/7 3. Provide information during non-working hours 4. Interoperablity between transit systems
Facilities & Operational Assets				
Customer			1. Visitor profiles	
External			1. Available recreational activities 2. Free wireless web access	

tion and implementation that is relevant to the framework proposed in this paper. In their paper, Bryson, Ackermann and Eden (2007) presented mapping methods for identifying distinctive organizational competencies, as well as a livelihood scheme that shows what the organization desires, as supported by the organizational competencies (Eden & Ackermann, 2001).

The SSRM method, as proposed in this paper, can certainly build upon (and is informed by) the approach by Bryson et al. (2007), but also is more specific in its treatment and identification of interaction-points—the latter being crucial in an e-service context. For example, Bryson, Ackermann and Eden (2007) identify distinct organizational competencies. These competencies are typically thought of as things the organization do especially well in comparison with other organizations. Such items may be thought of as subsets of the organizational resources, and would typically fall under Operational Processes in the SSRM framework. Thus, the e-service relevant capabilities found by using the method proposed by Bryson et al. (2007) can be thought of as various Operational Processes in the SSRM framework.

The SSRM framework discussed above is designed to allow for some guidance in the strategic planning process, without limiting the creativity of the city managers. That is, the goal is to generate e-service interaction-points that tie firm resources to customer-perceived issues. This planning process is clearly a creative one, and it would be counter-productive to specify in detail what must take place in such a process. However, one could clearly integrate the SSRM with existing planning methods, such as the one suggested by Bryson, Ackermann and Eden (2007). The SSRM framework by itself simply enables the managers' creative planning to take place within the context of firm resources and customer-perceived quality issues.

Figure 7. SSRM and organizational strategy



FUTURE TRENDS

It is clear that the development of e-services for cities is progressing rapidly. A large number of cities have implemented many of the services discussed in the examples above. However, it is not clear what tools have been available to city managers to conduct studies to frame proper analyses of stakeholders and interaction-points between organizational assets and perceived quality in the e-service context. Dawes et al. (2004) have presented and summarized an excellent collection of general tools and tips for improved use of ICT in government organizations, and these tools and tips are applicable across the strategic management processes. Bryson, Ackermann and Eden (2007) have proposed specific and important methods to better help government organizations to plan strategically. The SSRM method complements this prior work by specifically aiding the development of e-services in the strategic planning process. The potential strategic management scope of the research by Dawes et al. (2004), Bryson, Ackermann and Eden (2007) are shown in relationship to the SSRM in Figure 7. The rectangles emanating from each method shows the potential use of the method in strategic management. We assume that the proposed SSRM framework, along with the works of Bryson, Ackermann and Eden (2007) and Dawes et al. (2004) should be both useful and of crucial importance to city managers. This should be true whether or not one believes that cities compete with one another: at any rate, all cities are charged with providing its stakeholders with the best services in the most cost efficient manner.

Numerous future research opportunities exist in fine-tuning the organizational assets in the light of the perceived quality dimensions. That is, organizational assets can perhaps be broken into smaller chunks in order to see a finer picture of how the organization (the city) should relate its resources to the perceived quality dimensions. For example, one might want to identify the actual organizational processes, and compare those to existing or new processes that might serve the stakeholders' perceived quality better.

One limitation of this proposed method is clearly that while parts of the framework have been well tested in the healthcare setting (Burr et al., 2007; Rolland, Patterson & Ward, 2008), it is otherwise unproven in the city setting. That is, the perceived quality dimensions used herein must be proven significant for the purposes of city marketing in its e-service context. As such, another fruitful avenue for future research lies in verifying or finding the perceived quality dimensions for city marketing. Even with such a limitation, this framework constitutes the first attempt to align city stakeholders and their perceived quality dimensions to organizational assets through identifying and measuring/monitoring interaction-points in order to improve a city's e-service efforts.

CONCLUSION

In this paper we have proposed a framework to help cities plan their e-service strategically. The approach includes identifying the city stakeholders, aligning the goals of these stakeholders, as well as framing the perceived dimensions of quality inherent to each stakeholder. Each stakeholder's perceived dimension of quality can now be linked to the city organizational assets by identifying one or more interaction-point between the city's organizational asset and the stakeholder's perceived quality dimension. These interaction-points are touch-points between the city and its stakeholders.

By measuring and monitoring the interaction-points on a regular basis, using for example annual stakeholder surveys, the city can adjust the "functionality" of its organizational assets, or adjust the use of interaction points, in manners which lead to higher stakeholder-perceived service quality. For example, the city can change its assets by changing its operational processes, training its personnel, acquire or improve its facilities and operational assets, or influence the stakeholders or external entities to cooperate with the city. Also, the framework enables the city to monitor the importance of the interaction-points (by using statistical techniques - factor analysis and regression) in order to de/emphasize or delete/change interaction points. The framework also allows city managers to think about potential new interaction-points that their stakeholders may value highly—particularly such interaction points that may already be in use at "competing" cities.

The impacts of using the framework are in improved service to all of the city's stakeholders. From a management perspective, the application of the method proposed herein requires deep local knowledge along several dimensions: First, the managers must clearly understand who the stakeholders are, and what these stakeholders care about in terms of perceived quality. The strength of the proposed method is that the final interaction-points outline a broad map for the design of the city's e-services (that is, direct things to put into the web site design related to the interface for each stakeholder). Further, the framework allows city managers to think about interaction points in a semi-structured way, which does not inhibit creative thinking or discussion about the interaction-points. Use of the framework for strategic purposes (setting direction both for goals and processes) may contribute strongly to the city's dynamic capabilities, and in turn their competitiveness as a city (Rolland et al., 2008). While it has been shown that increases in the customers' perceived service quality leads to an increase in firm value (Mithas et al., 2005), we argue that this relationship should persist even if, as is normally the case, the city is a non-profit entity.

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Chapter 2.4

Dynamics in IS Development: A Multi-Method Experiment to Measure the Effects of Disruptions during the Development Process

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ABSTRACT

The failure of many IS development efforts suggests that the development process, in particular the role that key antecedents play in ensuring success, is poorly understood. Information systems are based on a series of highly complex interrelated tasks that can be significantly affected by organizational (e.g., management attention), project (e.g., resources), and technical (e.g., tools) drivers. Changes or disruptions in these can have severe and, in many cases, unanticipated consequences for IS development efforts. To help understand how disruptions during the IS development initiative affect the quality of the system, we employ the system dynamics methodology to capture feedback from non-linear activities, viz., those that define a systems development effort. The results from the simulation lead to some tangible and timely recommendations to manage an IS development initiative. [Article copies are available for purchase from InfoSci-on-Demand.com]

INTRODUCTION AND MOTIVATION

Developing an information system is a difficult task often plagued by cost overruns, delays and cancellations. Disruptions arise from a number of factors including technical difficulties, lack of managerial attention, lack of strategic or process alignment, or lack of user involvement. Models intended to explain factors critical to successful IS development (cf., Arnold, 1995; DeLone and McLean, 1992; Seddon, 1997) address important deployment (e.g., system quality) and usage (e.g., user satisfaction) drivers but fail to adequately explain the impact of relationships between these factors.

Research suggests that because managers have difficulty understanding the interactions among factors in complex systems, they fail to adequately account for the time delay between a control action and its effect (Simon, 1979; Sterman, 1989). They may also fail to understand the feedback between their own decisions and changes in the environment, which, as Sterman (1989) notes, can cause instability. In many cases, we assume conditions to be stable during IS development. Unfortunately, both external and internal disturbances that accompany systems development efforts can cause conditions to become unstable, and systems to become unpredictable or uncontrollable (Cambel, 1993).

The literature suggests that the most common sources of instability are changes in schedule, user requirements, staffing/leadership, and design (Rebentisch, 1996); a number of researchers have attempted to explain the impact of these factors on system development efforts (cf., Schmitt and Kozar, 1978; Necco et al., 1988; Davis et al., 1992; Pollalis et al., 1993).

IS projects fail not only because of instability but also because of management's inability to anticipate the delay that inevitably occurs before problem resolution takes full effect (Keil and Robey, 1999). Traditional IS development models (cf., DeLone and McLean, 1992; Seddon, 1997) sequentially arrange deployment and usage drivers or apply linear methods (e.g., regression) in which independent variables are used to make predictions about system behavior (Svyantek and Brown, 2000). A better understanding of the dynamic interactions that affect IS use and, subsequently, IS success can be achieved using non-linear methods.

Abdel-Hamid et al. (1989, 1990, 1992 and 1999) have applied non-linear modeling to investigate how staff turnover, resource allocation, and managerial turnover affect software development and cost. While this research stream addresses a number of important questions in regard to schedule changes and cost overruns in software development, it has focused primarily on the human resource dimension of software project management. Our study aims to extend the work of Abdel-Hamid et al. by (a) including the qualitative dimensions of the skill and knowledge of IS development teams and (b) measuring the expected outcome of IS development projects from the user's perspective. We contend, that by quantifying the different effects of instability during IS development and viewing the results from a user's perspective we are better able to measure the anticipated use of the information system and, subsequently, IS success.

The next section describes IS development characteristics with reference to DeLone and McLean's original IS success model. In the methodology section, we conceptualize the simulation model, explain our research methodology and discuss key variables and interactions between them. In the section entitled "Model Characteristics" we show how, under certain conditions, imbalances between desired and available resources and changes in project scope can have a profound impact on the development of an information system. The article concludes with a discussion of limitations and possible extensions of the model.

IS DEVELOPMENT CHARACTERISTICS

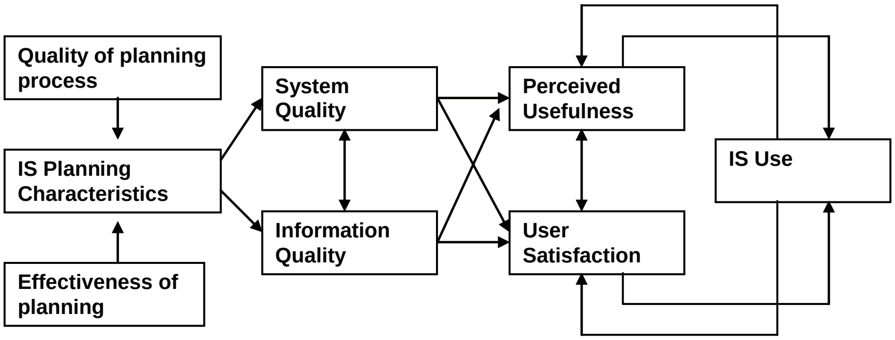
Over the last twenty-five years or so, numerous studies have been conducted to determine strategies to help improve the chances of developing successful information systems (Lucas, 1981; Bailey and Pearson, 1983; Ives et. al., 1983; Davis, 1989; Melone, 1990). The authors of one of the more widely cited models (DeLone and McLean, 1993) contend that use of the system, and user satisfaction, are highly correlated with the system's impact on the user and the organization. Rai, Land and Welker (2002) contend that there is empirical evidence to support the explanatory power of the DeLone and McLean model. In a ten year update, DeLone and McLean (2003) discuss a decade's worth of attempts to apply and validate their model.

Although DeLone and McLean (2003) suggested minor refinements to their original model and proposed an updated IS Success Model that incorporates the notion of service quality, we have chosen to focus on their original model in order to build on and extend the rich body of research that has validated this model. While DeLone and McLean suggest that system quality (e.g., consistency of the interface) and information quality (e.g., timeliness, accuracy, etc.) lead to intention to use, user satisfaction, and, ultimately, net benefits, they do not specify what determines system quality or information quality. They argue that organizational (e.g., managerial support), project (e.g., project management) and technical (e.g., standards) factors are critical to ensuring system and information quality. We contend that one of the most important of these factors is planning. A survey of senior managers confirms our contention (Luftman and McLean, 2004). This survey of CIOs and senior IS managers cited planning along with IT and business alignment as their top two concerns. Unfortunately, most of the research on planning has focused on more strategic issues such as alignment of IS planning with business strategy, the role of IS and IT in helping the firm gain and maintain competitive advantage, or understanding patterns of information use in organizations (Segars and Grover, 1998).

We agree with Premkumar and King (1994) who contend that the quality of IS planning derives from the quality of the planning process and planning effectiveness. Unfortunately, studies assessing the effectiveness of IS planning efforts generally lack consistency and have prevented researchers from making relevant conclusions about the effectiveness of information systems and practices associated with their management (Segars and Grover, 1998). Given the broader scope of our research, we have selected the characteristics "quality of planning process" and "effectiveness of planning" as the theoretical bases for conceptualizing IS planning. Collectively, these constructs represent the criteria used to assess information quality and system quality. While many aspects of effectiveness with respect to IS and IS management are complex (DeLone and McLean, 1992), with multiple interrelated success dimensions measured by multiple indicators (Segars and Grove, 1998), this study frames an aggregated theoretical and operational dimension of IS planning. Working within these parameters, the following theoretical and operational construct is developed.

The proposed study framework, as shown on Figure 1, encapsulates IS development from an aggregated perspective, integrating IS planning concepts (Premkumar and King, 1994), the technology acceptance model (Davis, 1989), and the DeLone and McLean IS Success Model (2003). DeLone and McLean suggest that their

Figure 1. Characteristics of IS development and framework for study



revised model is still constructed in a process sense, given that "the nature of these associations should be hypothesized within the context of a particular study" (DeLone and McLean, 2003). Our study framework, thus, links attitudes and beliefs (perceived usefulness and expected use of system) with the system characteristics suggested by DeLone and McLean (2003) and Premkumar and King (1994) to capture the expected use of the information system through design and implementation.

While the proposed framework shown on Figure 1 links together the major elements in IS development, it implies linear or sequential characteristics of the different measures that influence IS success. To address this deficiency, we employ a dynamic non-linear systems methodology. Even though the fundamental structure of the proposed study framework is developed by referring to a number of existing theories in the area of management information systems, our study is aimed at making policy recommendations rather than providing theory. A dynamic feedback perspective, we contend, is important because it can help policy makers better understand the impact that delay between a control action and its desired effect has on IS development (Adbel-Hamid, 1993).

In the following section we develop a basic simulation model, designed to capture the dynamic nature of an IS development initiative using the structural components shown on Figure 1. Our study is aimed at capturing key interactions in an IS development project, thus, some structural components in our model are represented in aggregated form. Nevertheless, our dynamic non-linear model provides the following advantages over traditional linear models. *First*, the simulation model captures the dynamic characteristics of disruptions that cause disequilibrium during information system development. Although the representation of the system, along with the causes of instability is highly aggregated, the model provides insight into the dynamic behavior of organizations with respect to information system development efforts. *Second*, the model can be used to simulate and test different policies that might influence the expected use of the information system and, thus, the success of the development effort.

METHODOLOGY

The main objective of this study is to conceptualize a system dynamics model to gain insight into how changes in the important deployment factor, IS planning, affects IS development efforts keeping in mind the utility function of IS users. The model is designed to test different managerial policies in order to understand interactions among various factors in a systems development effort and their impact on IS planning and ultimately on IS use and IS development success.

As Zuboff (1988) concluded, "behind every method is a belief." Our belief is that system dynamics is well suited not only to theory development but also to understanding complex behavior associated with information systems development projects. Our belief is based upon the following assumptions: (1) time is an important element in constructing a conceptual framework for capturing the social interactions and interventions between teams during IS development (Sawyer, 2002); (2) longitudinal process models employed in research often provide a limited (linear) perspective on time (Abbot, 1995); non-linear methods such as system dynamics consists of multiple measurements of both independent and dependent variables that provide graphs of the resulting data over time; (3) policy predictions are more qualitative than the predictions made using traditional approaches (Svyantek and Brown, 2000); (4) an actor's interpretation of an action and its effect is part of a larger dynamic context (Sterman, 1989); (5) system dynamics models have long been associated with the notion that complex systems are counterintuitive (Forrester, 1961).

As Figure 1 indicates, an important measure of IS development success is whether or not the system is used. It is reasonable to assume that if the system is used, it will lead to improved individual and organizational performance. While previous studies by Abdel-Hamid (1989 and 1992) focused on how resource allocation and staff turnover affect software development cost and schedule, subsequent works have applied a project management perspective. Our aim is to measure how changes in project drivers or disruptions (e.g., level of staff experience, level of organizational stress, or management attention) affect planning and ultimately IS use.

The current user satisfaction literature (cf. Bailey and Pearson, 1983; Baroudi and Orlikowski, 1988; Doll and Torkzadeh, 1988; Ives at al., 1983) provides the basis for our survey. However, instead a measuring the variables independently, we conducted conjoint analysis to measure how IT users make trade-off decisions when faced with a set of attributes. Conjoint analysis is a statistical technique normally applied to product development and positioning strategies. In our study, we employed conjoint analysis as a complementary tool in tandem with system dynamics. In this way, we were able to identify attributes and relationships among those attributes considered important by IS users.

Conjoint analysis examines the trade-offs IS users make when selecting certain IS attributes. In using the technique, we assume that an information system is a bundle of attributes, such as timeliness, ease of use, accuracy, and output--each of which consists of several hypothetical functional dimensions (discussed below). Our conjoint analysis design consists of four attributes on two levels, resulting in 32 (4x4x2) combinations. The number of relevant combinations was reduced, without invalidating the conjoint analysis technique, through the use of an orthogonal array experimental design (Green, 1974). We used SPSS conjoint analysis design, which selects the test combinations so that the independent contributions of the selected attributes are balanced and each attribute weight is retained.

Data Collection

Data was collected using a structured questionnaire and score cards representing hypothetical functional dimensions of an information system. Participants were asked to rank the score cards to indicate the combination of attributes they found most desirable. The study sample consisted of 75 executive MBA students; 68 of the 75 returned questionnaires were suitable for data analysis. The product attribute selection for conjoint analysis is based on Doll and Torkzadeh's (1988) construct for measuring end-user computing satisfaction. The following attributes were used:

Timeliness: *System is ready when needed*
System provides up-to-date information
Ease of use: *System is user-friendly*
System is easy to operate
Accuracy: *System is accurate*
System content meets my needs
Output: *System output is presented in a useful format*
System provides clear information

Using the orthogonal array experimental design technique, the original set of 32 (4x4x2) IS configurations was reduced to a parsimonious set of 8, in which the independent contributions of all 4 attributes were balanced. This reduced set of combinations representing hypothetical information system characteristics was then presented to the study participants who were asked to rank the cards, on a scale from 1 to 7, according to individual preferences. The conjoint analysis program then derived estimates of the utility function for each participating IS user, based on their evaluations of the hypothetical IS characteristics. The utility functions, which are used as input for the simulation model described below, quantify the relationship between each participant's evaluation of the hypothetical information system and the individual attributes of the information system. Thus, conjoint analysis can be used to determine the most desirable attribute configuration for a product (Green and Wind, 1975) or, in our case, the desired features and functionality of a hypothetical information system. The results of our conjoint analysis reflect the perceived usefulness of an information system as seen from the user's perspective. As will be demonstrated below, in the section entitled "Sector View: Expected Use of System", perceived usefulness is required to assess expected use of the system.

Results

The conjoint analysis output, i.e., the utility functions of the individual participants for the attributes and related levels, is used as input in the simulation model described below.

In conjoint analysis, all utility scales are expressed in a common unit of measurement. This allows for a meaningful comparison of attributes (Green and Wind, 1975). As can be seen in the importance summary (Table 1), "timeliness" had the most utility for study participants. The least important attribute was "ease of use", which may appear counter-intuitive if the implicit trade-off is not considered. In relation to "timeliness", the attributes "accuracy" and "output" are less important, though only marginally so. Given our sample size, we may not be able to project our findings onto a larger population of IS users. Yet, it was never our intention to generalize our results but, rather, to use the utility functions as input for a simulation model in order to test our theories in the context of an IS development project.

MODEL CHARACTERISTICS

As previously stated, we use system dynamics to capture the complex interrelations among factors germane to IS success. System dynamics has its roots in engineering control systems and in the theory of information feedback systems (Morecroft, 1987). In 1956, Jay Forrester reshaped a mathematical, engineering control systems approach into an analysis method for the visualization and simulation of feedback dynamics. Richardson (1996) defines modern system dynamics as "a computer-aided approach to policy analysis and design".

Figure 2 shows the major structural components, the five subsystems and feedback effects of the model. The five subsystems consists of (1)

Table 1. Relative importance of conjoint analysis factors

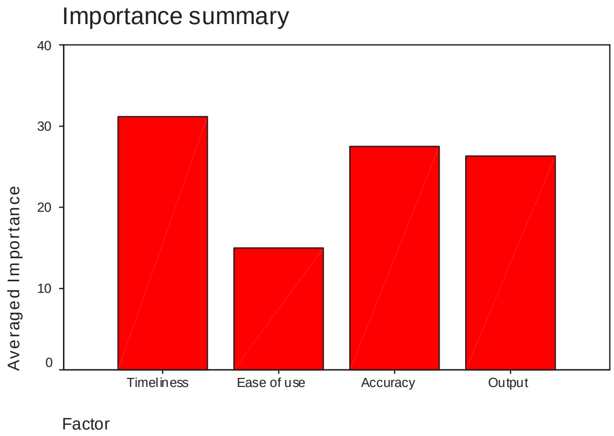
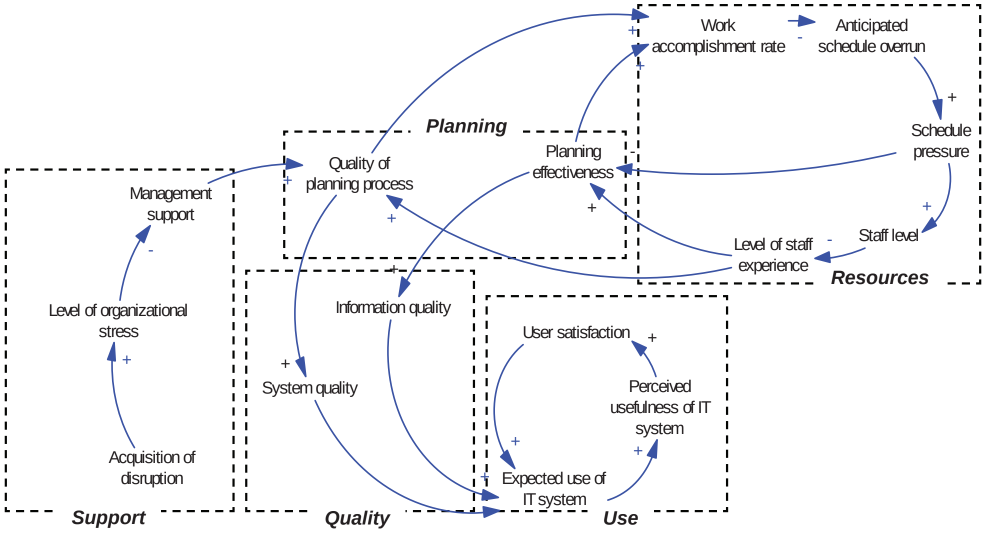


Figure 2. Aggregated overview of model structure. The polarity of the information feedbacks denotes the sign of the relationship between independent and depend variables, e.g., $X \rightarrow +Y \Rightarrow (\partial Y / \partial X) > 0$.



Management Support; (2) Information and System Quality; (3) Expected use of System; (4) IS Planning; and (5) the Resource Subsystem.

The actual simulation model is more detailed, containing more than 180 causal links; a detailed discussion of the model would exceed the scope of this article. Those interested in seeing the detailed model can download a free version (Vensim PLE) of the simulation software used to conceptualize the model (http://www.vensim.com) and contact one of the authors for a copy a the simulation model.

The Management Support Subsystem

A sizable body of literature attests to the fact that lack of managerial attention will either delay or undermine IS development efforts (cf., Ein-Dor and Segev, 1978; Lucas, 1975; Kaye, 1990; Keil and Robey, 1999). We assume that management has a certain capacity to respond to organizational disruptions; this influences the level of attention management can provide to IS development. The level of management attention is determined by performance ability, which is influenced by the stress level to which management is exposed. By combining the interruption theory of stress (Mandler, 1982) with the structural formulations found in Rudolph and Repenning's (2002) conceptualization of disaster dynamics, we are able to predict the level of management attention to IS development when unexpected disruptions occur. This structural formulation is based on the assumption that organizations are faced with a continual stream of incoming disturbances, which they are able to process until the influx reaches a critical threshold. At that point, management's processing capability decreases while stress levels continue to increase. The rate of disturbance is an artificial numerical value not grounded in empirical research. Nevertheless, we are able to capture stress level thresholds, i.e., the point at which management can no longer effectively respond to disruptions or provide the attention required to manage an IS development project.

To simulate the perturbation rate of incoming disruptions (acquisition of disruption) we have used Sterman's (2000) formulation of "pink noise" to capture a randomness that allows us to specify the degree of persistence or the amplitude of each frequency. We have used this formulation to simulate a certain variation in disruptions because it is assumed that instability is not a constant variable to which an organization is exposed.

The Planning Subsystem

The IS planning concept, as suggested by Premkumar and King (1994), consists of organizational and project drivers which we contend are surrogates for the quality of the planning process and planning effectiveness, respectively. The construct "quality of planning process" is operationalized in terms of the extent of detailed analysis in the three major areas of the planning process: internal, external, and technological (McLean, 1977; Boynton and Zmud, 1987; Karimi, 1988). Because our emphasis is on capturing key interactions in IS development, we aggregate the three major areas of the planning process and simplify these concepts. Improving the quality of the planning process is a function of staff experience and management attention. The level of staff experience is derived from the skill set of people assigned to the project; management attention is linked to the level of guidance provided during development. Degrading quality (of the planning process) is a function of schedule pressure and a fractional time constant, which captures a normal decay of planning quality over time. Planning effectiveness is a performance measure used to discern team effectiveness and efficiency, two important dimensions for knowledge teams (Ancona and Caldwell, 1992; Henderson and Lee, 1992; Leonard-Barton and Sinha, 1993). Because objective measures of performance are problematic in the IS field (Henderson and Lee, 1992; Kemerer, 1989) we aggregate planning effectiveness as a function of the productivity rate of experienced and new staff assigned to the team, controlled by schedule pressures, which occur when there is an anticipated schedule overrun.

The Quality Subsystem

As noted in the foregoing discussion of the DeLone-McLean model, system quality is linked to information quality, perceived usefulness and user satisfaction. We do not explicitly capture system quality and information quality in our model but, rather, the underlying measurements that influence these two constructs: "output" and "accuracy". It has been shown that output and accuracy can be employed to determine system quality, whereas ease of use and timeliness determine information quality (Doll, 1988). Since we are interested in an outcome assessment of IS development as perceived by IS users, we use this aggregated view.

The Resource Subsystem

We contend that the task of developing and implementing an information system follows a number of predefined steps. Thus, in our simulation model, development is a function of "work to do" (e.g., business process analysis or deployment of the information system) determined by a task accomplishment rate. The rate at which individual tasks are fulfilled is based on the quality of the planning process and planning effectiveness, which, in turn, are influenced by staffing decisions, team skills or management attention levels. The structural components in our model that simulate project dynamics are based on well established system dynamics concepts (e.g., Abdel-Hamid and Madnick, 1990; Richardson, 1996; Lyneis, 1999).

The IS Use Subsystem

As mentioned earlier, we conducted conjoint analysis in order to provide empirical grounding for the conceptualization of IS success and to assess its impact on IS use in the simulation model. The resulting conjoint importance summary (see Table 1) provides input variables in order to measure end-user expectations of the hypothetical information system. In order to compute the value of perceived usefulness of the information system, we apply the Multi-Attribute Utility Theory (MAUT)--an approach grounded in the utility theory of von Neumann and Morgenstern (1947) and the specific assessment techniques developed by Kenney and Raiffa (1976). MAUT allows users to: (1) determine the relative importance of attributes deemed essential to a decision or preference; (2) assess the worth (utility) of each choice regarding qualities deemed important in a decision situation; (3) aggregate individuals' preferences for the choices available, given the utility of each choice (Klersey, 1988). According to Keeney and Raiffa (1976), the utility (U) of a decision alternative with multiple attributes, x_1, x_2, …..,x_n, can be expressed as U(x_1, x_2, …..,x_n). We calculate the aggregated utility for the perceived usefulness of an information system as follows:

Perceived usefulness of system =

$$\sum_{i=1}^{4}(Wt_i \times A_i)$$

(where Wt_i is the user weight, or importance summary of conjoint analysis for an individual attribute, and A_i is the respective attribute.)

The variable "expected use of system" is directly related to the perceived usefulness of the system. Seddon (1997) argues that use precedes impact and benefit but does not cause them. We simplify the construct of user satisfaction and IS use for two reasons: first, because we cannot capture user satisfaction unless the system is already in place; second, because we contend that expected use of the system is equivalent to user satisfaction, which is traditionally conflated with IS success (Bailey, 1983). The next section discusses a number of simulation experiments designed to explore a variety of conditions that cause instability in IS development.

EXERCISING THE SIMULATION MODEL

This section describes how the system dynamics model is used to simulate different conditions and to identify potential remedies for instability in information systems development. The managerial interventions cited do not constitute all possible interventions yet they are adequate, we believe, to help develop a model robust enough to capture management's ability to successfully control an information systems development project.

Time delays influence interventions in at least two ways. First, a delay may cause managers to hire more staff in order to reduce schedule slips. Second, schedule slips can impede management's ability to initiate the required project management response, thus causing further delays. Brooks (1974) illustrates how traditional conceptions of time--linear and additive--may lead to inaccurate hypotheses within a complex social context. He argues that one might hasten to complete a project by assigning more people only to produce counterintuitive effects, i.e., slowing down the process.

Base Line: Reference Mode Behavior

The preceding sections provided the structural details of the model together with the different sectors, characterizing the problem domain for an IS development project. We contend that in applying well established and empirically grounded IS taxonomies, the structural components of the simulation model are consistent and valid. However, because most of the variables used in the model are hard to measure, the model cannot be calibrated against real data. Thus, testing the validity of the model is not an easy task.

The goal of model validation in system dynamics is to determine whether a model is appropriate for a given purpose and whether model users can have confidence in it. This is accomplished through testing and calibration. Forrester and Senge (1980) describe 17 tests for building confidence in a system dynamics model. Sterman (2000) offers 12 tests, examining models on both structural and behavioral grounds. Other tests focus on collaborative model building projects that include both modelers and model users. Richardson and Pugh (1981) divide confidence-building tests into those that test for suitability and those that test for consistency. Suitability tests determine whether the model is appropriate for the problem it addresses, while consistency tests examine whether the model is consistent with the particular aspect of reality it attempts to capture. The reality we aim to capture with the model is shown as a reference mode on Figure 3. This reference mode identifies hypothetical behavior for an information system development project over time.

The theoretical reference mode behavior depicts a successful IS development project, in which effective management of resources, appropriate team skills and the absence of disruptions lead to perfect project completion. While this reference mode is highly simplified, it captures possible behavior of an IS development initiative under perfect conditions. The assumptions upon which this reference mode is based are a desired project completion time of 100 weeks and a team consisting of experienced people. Thus, the initial value for the expected use of the system is relatively high.

The graph on Figure 4 captures the simulation model's base line, characterizing the dynamics of a hypothetical IS development initiative under perfect conditions. We contend that the model is able to replicate the reference mode behavior with regard to the expected outcome of the project. We did not attempt to calibrate the slope of the line against the reference mode. The reference mode only characterizes the expected behavior of IS development, which implies that system quality and information quality increase over time, leading to a perfect result. Richardson and Pugh (1981) contend that one can have increased confidence in the insights that derive from the model if the reference environment can be replicated.

The input conditions for the base line of the model are as follows: the project team consists of four experienced and two new staff members (with initial levels of relative quality and relative productivity of 0.5); management attention is sufficient to support the project; the initial work consists of 400 tasks. The input value for expected use of system is 0.5 at t=0 because we assume that a relatively high level of staff experience shapes the outcome of a project. The number of tasks (400) used as the initial input is arbitrarily chosen. While, in the real world, the process rate for individual tasks would vary, the model processes each task in the same unit of time.

Figure 3. Reference mode for IS success

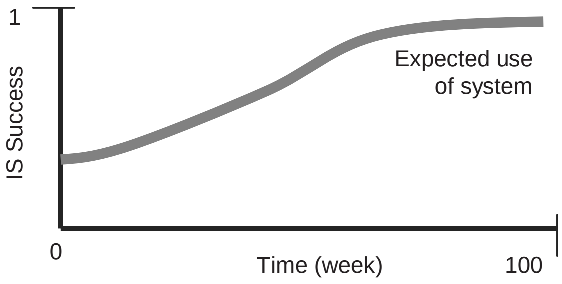
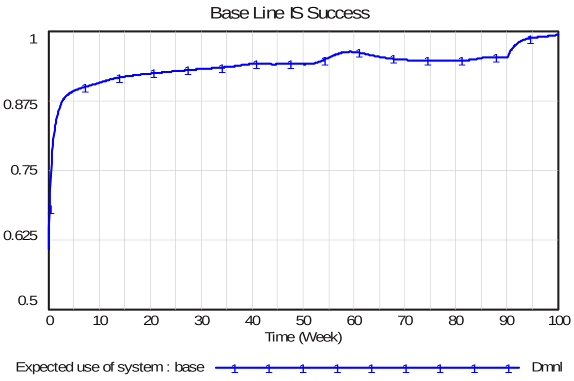


Figure 4. Base line of simulation model



Variability of Disruptions

Aside from external organizational instability, internal disturbances can also affect IS development. Sources of internal instability leading to insufficient management attention include: lack of business process alignment; changes in corporate culture; and stakeholder involvement. We can simulate these disturbances as shocks with variable strengths, depending on the cause of the disruption. As noted earlier, the variability of perturbations captures the notion that disruptions can be quite diverse, ranging from incoming customer requests to relocation of key people to structural changes in business units. When external and internal disturbances occur, organizational resources, e.g., structure and people, can be mustered to help re-stabilize the organization. This will occur because stability is a property of non-linear systems and a complex system, even after drastic disturbances to its environment, tends to return to its original state (Bak, 1996).

Effects of Disruptions on Management Attention: Earlier in this article we discussed the role of management in IS development. In this subsection, we simulate the effect of disruptions on the management attention levels, which, in turn, affect the outcome of IS development projects. We simplify disruptions as unexpected events requiring resolution by management.

The graph on Figure 5 shows simulation runs with unexpected disruptions plotted against the base run (line 1 in the graph). In the first simulation, we increase the perturbation rate by 30 percent, beginning at t=20 and ending at t=40 (line 1); the arbitrarily chosen rate of increase is designed to capture the effect of an unexpected exogenous event on IS development. In the second simulation, the same perturbation rate begins to increase at t=60, ending at t=80 (line 2). The short increase in the slope at the beginning of the disruption corresponds to a positive stress level; management is not yet overwhelmed by the unresolved disruption or trapped by negative stress. The results of this simulation suggest that an early disruption in the form of lack of management attention has a greater negative impact on the outcome of the project than a later disruption.

This may be the result of project resource dynamics. When management attention decreases early in the process, the team needs more resources to complete the project on schedule. When inexperienced staff are added (see Figure 6a) the overall level of staff experience decreases (see Figure 6b). Once staff experience decreases, planning effectiveness also decreases.

While the literature suggests that IS development fails or is delayed because of lack of attention by management (cf. Ein-Dor and Segev, 1978; Lucas, 1975; Kaye, 1990; Keil and Robey,

Figure 5. Effects of disruptions on expected use of system

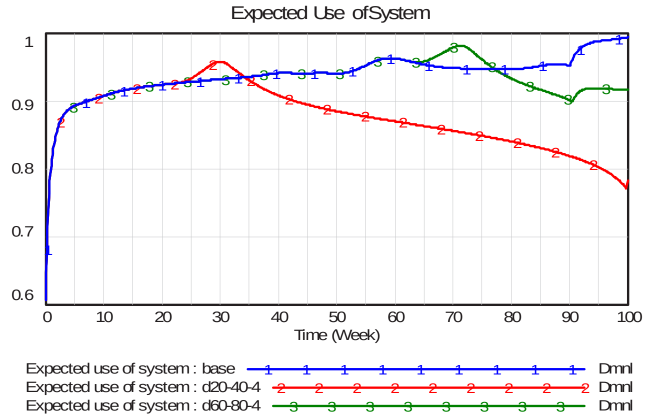
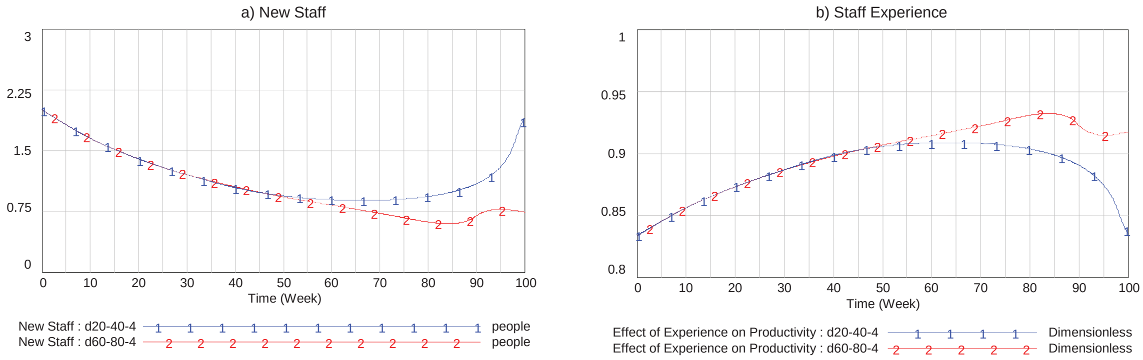


Figure 6. Resource dynamics with increased perturbation rate



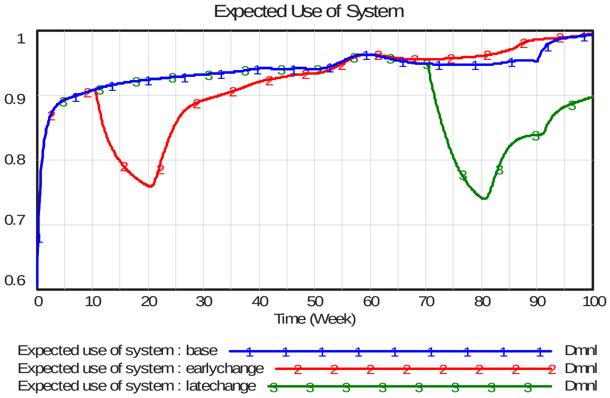
1999), the results of our simulation suggest that management's influence on the outcome of an IS development project differs greatly over time. The point at which disruption occurs directly affects patterns of resource allocation. Earlier studies designed to measure IS project dynamics (Abdel-Hamid, 1989; 1992; Abdel-Hamid and Madnick, 1990) do not include the escalating effect which occurs when management attention decreases during IS development.

Effects of Changes in User Requirement

It is well known that changes in user requirements influence the outcome of IS development. In this subsection we simulate the effect of changes in user requirements on the expected use of the system and, subsequently, IS success. For model simulation purposes, we operationalize changes in user requirements by increasing the number of tasks at to be performed at specific points.

Figure 7 indicates the results of early and late changes in user requirements. For both simulations we use a pulse (increase) of 120 tasks between t=10 and t=20 for the early change and between t=70 and t=80 for the late change. This means that over a period of 10 weeks the team has additional tasks to process because of changes in user requirements. In response to this increase, the system adds resources to complete the project on time. It is interesting to note that a late change in user requirements has a more profound impact on the outcome of an IS development project than does

Figure 7. Dynamics of changes in user requirements



an early change in user requirements. The cause of this behavior can be found in the dynamics of the resource sector shown on Figure 8a & b.

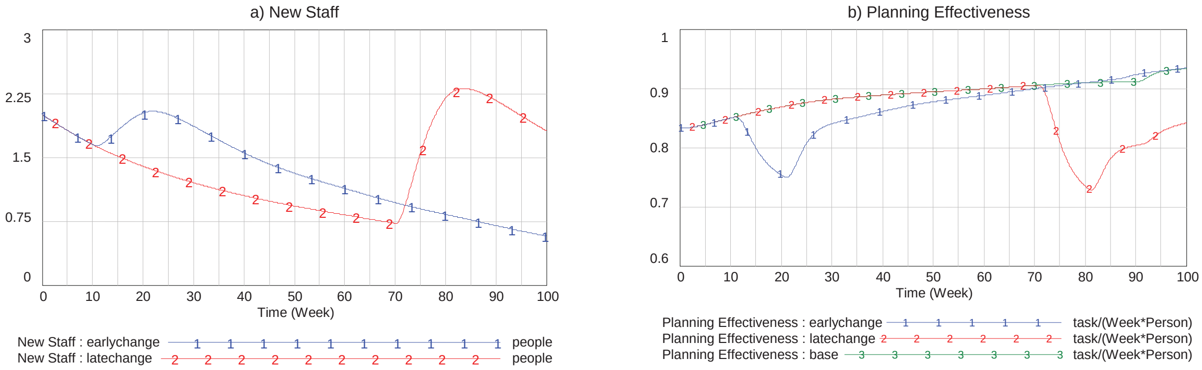
A late change in user requirements is much more disruptive than an early change; as previously noted, when new staff is added staff experience and planning effectiveness levels decline. While both early and late changes require adjustments, new staff that is added early on is able to gain experience, allowing the team to achieve the same performance measures (curve 1 on Figure 8b) for planning effectiveness as the base line. Waltz et al. (1993) conclude that team coordination breakdowns and difficulties in knowledge sharing and integration were identified as key factors hindering project outcomes. Thus, the time to train and integrate new people must be considered as important factors influencing the outcome of an IS development project. Our results support Brooks' (1974) findings that one might hasten to complete a project by assigning more people only to produce counterintuitive effects, especially during the later stages of development.

While Brooks's law – adding manpower during the later stages of a software project only delays it further – is intuitive, the use of a simulation model enables us to understand and respond to changes in user requirements in information system development projects. Abdel-Hamid and Madnik (1990) used a system dynamics model to test the applicability of Brooks's law to the DE-A project (Abdel-Hamid, 1989). The results indicated that, while adding people late in the lifecycle did increase the project cost, it did not delay the project. We do not consider costs in our simulation model; however, we measure planning effectiveness, which determines expected use of the system. Our experiment indicates that adding staff at a late project stage delays it further. While Abdel-Hamid (1990) concludes *"Obviously, the earlier in the lifecycle that people are added and the shorter the training period, the more likely the cumulative contribution will turn positive"* the results from our simulation indicate that a late change in project scope will negatively influence the expected outcome of the IS development initiative.

Effects of Varying Resources

Successfully building information systems requires not only technical skills but also effective management of staff skills and knowledge. The simulation in this subsection provides insight into team structure with regard to skills and knowledge. The initial value for new staff of 0.5 for relative quality and productivity (on a scale from 0 to 1) suggests moderate levels. In the model, the time for new staff to gain experience is 80 weeks--a value based on market observations. The following graphs summarize the results of a simulation in which the size and experience of the team structure is changed.

Figure 8. Resource dynamics under changing user requirements



The initial input for the simulation model is 4 experienced people and 2 new staff (see curve 1 on Figure 9). Curve 2 on Figure 9 shows the expected use of the system with 8 new staff and only 2 experienced people. Even though we add resources, the outcome of this change is a lower than expected use of the system. This behavior can be explained with the following graphs (Figure 10a & b).

By adding more people to the team, the feasible work rate increases, which results in an earlier completion time of the project (see curve 1 Figure 10a). However, due to the lower skill and knowledge levels of the team, planning effectiveness does not reach the desired value needed to achieve the expected outcome of the project. Research on software development teams suggests that team performance is linked to the effectiveness of team coordination (Kraut and Streeter, 1995; Nidumolu, 1995). Evaluating the effect of team coordination within a large, complex, and dynamic social system such as an IS development project can be exceedingly difficult (Wholey et al., 1996). Simulation modeling provides a viable alternative over traditional regression models (Abdel-Hamid and Madnick, 1990).

DISCUSSION

The model described in this article is aimed at extending current IS success models. We do this

Figure 9. Dynamics of changing team structure

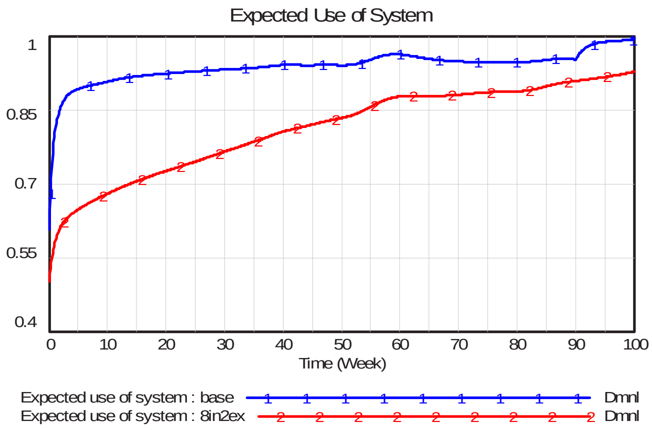
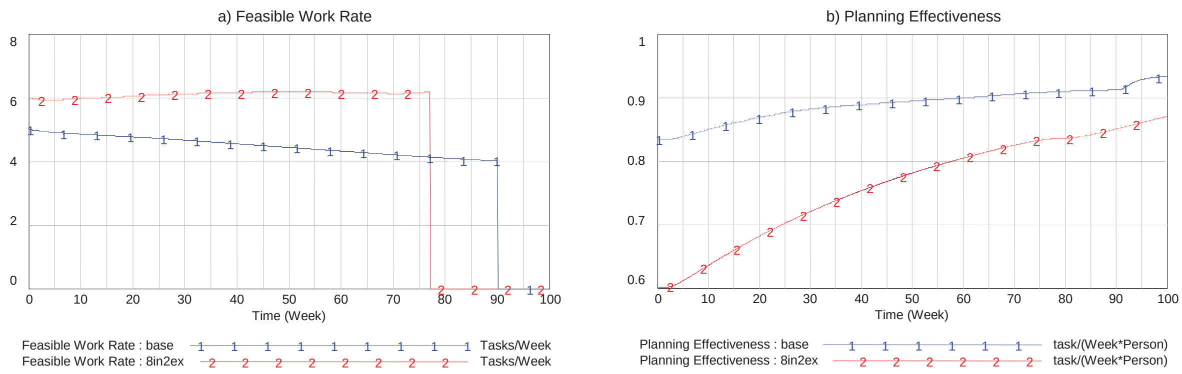


Figure 10. Work rate and effectiveness under changing team structure



by employing a dynamic perspective involving factors that influence anticipated use of an information system as determined by utilities considered important for IS users. Using a nonlinear methodology such as system dynamics captures interactions and feedback effects and allows us to draw qualitative insights into behavior characterizing dynamics in systems development. A number of tangible and timely recommendations emerge from the simulation experiments that evaluate policy options. For example, the results of this simulation suggest that managing resources has not only a quantitative (e.g., number of people in the team) but also a qualitative (e.g., knowledge and experience) dimension. Consequently, using a simulation model provides insights for an optimal team structure that may help management reduce costs and achieve the desired outcome of an IS development project. As such, the article provides management with a tool to explore various scenarios and assess the impact that different assumptions have on the success of system development efforts.

While sufficient data was not available to quantify the parameters in our model, we contend that the validity of the model can be assumed due to the following arguments: that the causal structure is supported by logic and previous research; the resulting dynamic behavior mirrors real-world observations; the parameters used in the model match real data points to some extent.

However, the simulation model presented in this article has limitations and can be enhanced in several ways. First, the concepts “quality of planning process” and “planning effectiveness” can be decomposed and represented in more detail to capture the multifaceted activities of IS planning, e.g., linking application of IS to business goals, and determining information requirements to meet an organization’s short and long term business goals (Earl, 1989; Wiesman, 1988). Second, the linkage between IS planning characteristics and system quality and information quality can be refined to encompass a variety of context-related attributes, such as the commitment and involvement of organizational members or the influence of different stakeholders. Modeling these details introduces additional complexity and may not change the basic behavior described in the preceding sections. Moreover, interrelationships between IS planning characteristics and system quality and information quality are poorly understood. Thus, adding complexity to the model may not provide any more insight into the fundamental dynamics determining IS success.

The results of this multi-method study lead to future avenues of investigation. One area would be a longitudinal perspective on IS success with the objective of measuring changing attitudes of IS users on the perceived usefulness of an information system. It is suggested that comparing the results of a longitudinal study against the base line of expected use of the system would provide further insights into how organizational dynamics determine IS use and, subsequently, IS success.

While the simulation model presented in this article is aimed at providing an effective tool for gaining insight into the interrelated nature of key drivers affecting system development efforts, it is important to emphasize that such a model focuses on understanding the dynamics of complex systems and, thus, is a powerful methodology to complement quantitative research.

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Chapter 2.5

Design Science:
A Case Study in Information Systems Re-Engineering

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ABSTRACT

Recently, many organisations have become aware of the limitations of their legacy systems to adapt to new technical requirements. Trends towards e-commerce applications, platform independence, reusability of prebuilt components, capacity for reconfiguration, and higher reliability have contributed to the need to update current systems. Consequently, legacy systems need to be re-engineered into new component-based systems. This chapter shows the use of the design science approach in information systems re-engineering research. In this study, design science and the Bunge-Wand-Weber (BWW) model are used as the main research frameworks to build and evaluate conceptual models generated by the component-based and traditional approaches in re-engineering a legacy system into a component-based information system. The objective of this evaluation is to verify that the re-engineered component-based model is capable of representing the same business requirements as the legacy system.

INTRODUCTION

The objective of this chapter is to show how the design science research approach can be used for applied information systems (IS) research. Design science in information systems is defined by March and Smith (1995) as an attempt to create things that serve human purposes, as opposed to natural and social sciences, which try to understand reality.

The IS research problem chosen to demonstrate the use of design science is the re-engineering of a legacy system in a financial institution. The vast majority of legacy information systems were implemented using the traditional paradigm. The traditional paradigm consists of modeling techniques used by system analysts including system flow charts and data flow diagrams (DFD) to capture, during the analysis phase, the activities within a system. However, with recent developments, particularly trends towards e-commerce applications, platform independence, reusability of prebuilt components, capacity for reconfiguration, and higher reliability, many organizations are realizing they need to re-engineer their systems. Given the limitations of legacy systems to adapt to these new technical requirements, new component-based systems are required to meet these trends; however, there is a high degree of interest and concern in establishing whether or not a full migration to a more portable and scalable component-based architecture will be able to represent the legacy business requirements in the underlying conceptual model of re-engineered information systems.

To address this concern, the research project re-engineered a sample process to derive a component model from the legacy system and posed the question: Is the resulting component-based model equivalent to the legacy conceptual model?

In order to answer the research question, the project evaluated the conceptual models generated by the component-based and traditional approaches in the re-engineering process in order to verify that the re-engineered component-based model was capable of representing the same business requirements of the legacy system. Design science is used as the central research approach for this project.

The first section provides the background for this chapter. Then, the application of design science in information systems re-engineering is demonstrated by using a case study. Finally, directions of future research are suggested.

DESIGN SCIENCE BACKGROUND

Design Science as an Information Systems Research Approach

The design science approach has a history of providing useful results in the evaluation of constructs and models in information systems (Hevner, March, Park, & Ram, 2004). This is in line with Nunamaker and Chen (1990) who classify design science in IS as applied research that applies knowledge to solve practical problems. March and Smith (1995) define design science as an attempt to create artifacts that serve human purposes, as opposed to natural and social sciences, which try to understand reality (Au, 2001).

Fundamental Concepts of Design Science

March and Smith (1995) outline a design science framework with two axes, namely research activities and research outputs. Research outputs cover constructs, models, methods, and instantiations. Research activities comprise building, evaluating, theorizing on, and justifying artifacts.

Constructs or concepts form the vocabulary of a domain. They constitute a conceptualization used to describe problems within a domain. A *model* is a set of propositions or statements expressing relationships among constructs. In design activities, models represent situations as problem and solution statements. A *method* is a set of steps (an algorithm or guideline) used to perform a task. Methods are based on a set of underlying constructs (language) and a representation (model) of the solution space. An *instantiation* is the realization of an artifact in its environment. Instantiations operationalize constructs, models, and methods.

Concerning research activities, March and Smith (1995) identify *build* and *evaluate* as the two main issues in design science. *Build* refers to the construction of constructs, models, methods, and artifacts demonstrating that they can be constructed. *Evaluate* refers to the development of criteria and the assessment of the output's performance against those criteria. Parallel to these two research activities in design science, March and Smith (1995) add the natural and social science couple, which are *theorize* and *justify. Theorise* refers to the construction of theories that explain how or why something happens. In the case of IT and IS research this is often an explanation of how or why an artifact works within its environment. *Justify* refers to theory-proving and requires the gathering of scientific evidence that supports or refutes the theory (March & Smith, 1995).

The use of the design science research framework is justified on three grounds for the chosen research project. First, it provides a framework that can be used for Information Systems applied research. This is in line with Nunamaker and Chen (1990) who classify design science in IS as applied research that uses knowledge to solve practical problems. Second, design science provides a framework for evaluation of models. The objective of this research project is the evaluation of the capacity of component-based models to represent business requirements of legacy conceptual models. This framework seems to be aligned with this objective. Finally, the framework can be used to extend the scope of this research. Although the objective of this research is not to create new theory based on the findings, the framework provides that possibility and could be used for future research.

The objective of the project chosen to demonstrate the design science approach is to use component-based constructs to compare the representation of the same requirements in component-based models with legacy systems modeled with traditional constructs. Very few research frameworks for applied research in information systems have been developed in the past. However, design science is a scientific research method that can be used in developing an evaluation of conceptual models' frameworks (March & Smith, 1995).

For the chosen research problem, the design science approach is used to design an evaluation of conceptual models' frameworks to help IS specialists in the verification of representation of the business requirements in re-engineered component-based models originally represented in legacy conceptual models.

The *building* part of the research uses re-engineering methodologies to generate the conceptual models required for the research. There are many re-engineering methodologies that help to cope with the problem of transforming legacy systems originally developed with traditional methodologies into component-based systems.

APPLICATION OF DESIGN SCIENCE APPROACH

Research Outline

The research project chosen to demonstrate the design science framework covers the *build* and *evaluate* research activities and has a research output of *constructs* and *models. Instantiations* are not covered as the scope of this research is limited to conceptual models. Conceptual models do not include any implementation details that can be used for instantiation.

March and Smith (1995) propose a 4 by 4 framework that produces 16 cells describing viable research efforts. The different cells have different objectives with different appropriate research methods. A research project can cover multiple cells, but does not necessarily have to cover them all.

The *build* part of the framework will be used as part of this research since conceptual models need to be created for ontological evaluation. The main activity of the research project will be the *evaluation* phase, as it will allow identification of metrics to compare the performance of constructs and models.

Table 1 illustrates the cells at the intersection of research activities and research outputs of March and Smith's (1995) framework which are discussed in this chapter. Each cell/intersection contains a specific research objective of the overall research. The *build* column covers the recovery of a conceptual model for a legacy system and the generation of a re-engineered component-based model. Construct building is not required as existing constructs for both traditional and component-based are used.

The *evaluate* column in Table 1 includes evaluating the completeness of the component-based constructs (UML) in terms of ontological deficiencies that the constructs could have when modeling traditional constructs. Conceptual models need to be evaluated in order to measure the capacity of the component-based model to represent the same requirements as the legacy model.

Selection of Methodologies Applied to the Design Science Approach

In the previous section we explained the research objectives in the different cells of March and Smith's framework (1995) covered by the research study. However, as March and Smith explain, every cell and research objective may call for a different methodology. This makes it necessary to identify an adequate method for each specific research objective, resulting in an overall method mix. To achieve this, several methodologies were identified as part of the literature review. These methods are listed in Table 2.

The IS research problem chosen to demonstrate the use of design science involves three main parts: conceptual model recovery, system re-engineering, and ontological evaluation.

Methodologies Selected for Conceptual Model Recovery

The conceptual model recovery of the case study is one of the major challenges in the research since most of the legacy systems have very poor documentation in terms of models and technical design. In order to address this problem, the researcher captured the conceptual model of the legacy system by applying a reverse engineering approach as specified in the Jacobson and Lindstrom (1991) methodology. There are many re-engineering methodologies that help to cope with the problem of transforming legacy systems originally developed with traditional methodologies into component-based systems. The Jacobson and Lindstrom (1991) approach for re-engineering of legacy systems was chosen for the following reasons:

- It contemplates cases of a complete change of implementation technique and no change in the functionality, which is the case of this research;

Table 1. Research activities based on design science approach (adapted from March & Smith, 1995)

	Build	**Evaluate**
Constructs	Not required	Identifying ontological modeling deficiencies of component-based constructs in terms of traditional construct representation
Model	Recovering the legacy conceptual model of the case study Generating the re-engineered component-based model for the legacy system	Evaluating the capacity of the re-engineered component-based for representing the same business requirements embedded in the legacy model

Table 2. Methodologies selected for research project

Methodology	Definition
Case Study	Study of a single phenomenon (e.g., an application, a technology, a decision) in an organization over a logical time frame
Jacobson & Linstrom (1991)	Methodology for information systems re-engineering and legacy system conceptual model recovery
Fettke & Loos (2003)	Methodology for ontological evaluation of conceptual models
Interviews	Research in which information is obtained by asking respondents questions directly
Direct observation	This occurs when a field visit is conducted during the case study
Secondary Data	A study that utilizes existing organizational and business data, that is, document, diagrams, and so forth.
Rosemann & Green (2002)	Meta Models methodology for Normalized Reference Models generation and comparison

- It does not require the use of source code. In the case study used for this research there is no access to the source code used to develop the system;
- It also covers reverse engineering. This is useful for this research given the need to capture the original conceptual model for the legacy system;
- It is relatively simple to use.

Although Jacobson and Lindstrom's (1991) original methodology was proposed for object-oriented systems, it can be easily adapted for component-based systems since components can be viewed as a higher level of abstraction based on object-oriented methodology. The methodology for this project uses data collection methods including interviews, direct observation and secondary data.

Methodologies Selected for System Re-engineering

Once the conceptual models from the legacy system are recovered, the system is re-engineered using the Jacobson and Lindstrom (1991) approach for re-engineering of legacy systems. The output of this step is the re-engineered component-based model as detailed in Valverde and Toleman (2007).

Methodologies Selected for Ontological evaluation

The legacy system and re-engineered models generated as part of the building part of the research are then evaluated based on the ontological evaluation of grammars (Wand & Weber, 1993). As part of the evaluation research, an analysis is done using the Bunge-Wand-Weber (BWW) model. The BWW model is an ontological theory initially developed by Bunge (1977, 1979) and adapted and extended by Wand and Weber (Wand & Weber, 1989, 1995; Weber, 1997).

The BWW model is well founded on mathematical concepts. Prior research on the evaluation of grammars has shown it has been used successfully in information systems research (Evermann & Wand, 2001; Green & Rosemann, 2000; Opdahl & Henderson-Sellers, 2002; Weber & Zhang, 1996).

After developing the re-engineered model, it is necessary to compare both legacy and re-engineered models for equivalency of representation of business requirements. An ontological normalization methodology developed by Fettke and Loos (2003) is used for this activity. The Fettke and Loos (2003) methodology is considered appropriate as it provides a mechanism for the comparison of conceptual models; models can be compared based of their normalized referenced models; and it is simple to use.

In order to generate these normalized reference models in BWW terms, the Rosemann and Green (2002) BWW meta-model is used. This meta-model is based on the original entity relationship specification from Chen (1976) with extensions made by Scheer (1998). Scheer's version is called the extended ER model (eERM).

Once the legacy system and re-engineered models are generated, they can be evaluated based on an ontological evaluation of grammars (Wand & Weber, 1993). An ontological normalization for the original and re-engineered models is generated. The two models are evaluated using the Fettke and Loos (2003) methodology based on their ontologically normalized models generated by the Rosemann and Green (2002) methodology. The result of the comparison reveals that the compared models are equivalent, complementary or in conflict (Fettke & Loos, 2003). Table 3 displays the mapping of the retained methodologies to the activities.

Research Project Procedures

The case study methodology is chosen to evaluate the capacity of the re-engineered component model to represent the same requirements as the legacy traditional model (Benbasat, Goldstein, & Mead, 1987). The case-study system selected is a *Home Loan* information system developed by a consultant company in the Netherlands. The system was customized for a mid-sized home loan bank that specializes in the marketing, sales, and administration of its own home loan products. The information system was designed for use on Unisys A-Series mainframes.

In this chapter, the focus is not on reporting the outputs of the re-engineered business process but on the procedures and frameworks used by the researcher in adopting a design science research approach. Research procedures are divided into build and evaluation procedures. Build procedures are required to accomplish the build objectives of the design science approach while the evaluation procedures accomplish the evaluation objectives.

Data Collection (Build)

Data gathering is an important part of this research as it is required to commence the building part of the research. For this research, observation techniques, interviews, and review of physical artifacts and system documents were used as the sources for data gathering. The most common methods of collecting data within the case study approach are through observation and interviews (Bell, 1992).

The use of observation as a method of data collection is well documented (Bell, 1992; Benbasat

Table 3. Research methodologies selected for the design science approach

	Build	**Evaluate**
Constructs	Not required	Fettke & Loos (2003)
Model	Case Study Interviews Secondary Data Direct Observation Jacobson & Linstrom (1991)	Case Study Fettke & Loos (2003) Rosemann & Green (2002)

et al., 1987; Stake, 1995) and works well in case research (Yin, 1994).

Before observations were used in the research project, the three minimum conditions set out by Tull and Hawkins (1993) were met: the data were available for observation; the behaviour was repetitive, frequent, or otherwise predictable; and each event covered a reasonably short time span.

According to Jorgensen (1989), observation is appropriate for studies of almost every human existence. Through observation, it is possible to describe what goes on, who or what is involved, when and where things happen, how they occur, and why things happen as they do in particular situations (Jorgensen, 1989). A great deal of time is spent on paying attention, watching, and listening carefully (Neuman, 1994). The observer uses all the senses, noticing what is seen, heard, smelled, tasted, and touched (Neuman, 1994; Spradley, 1979).

In terms of research stance, Neuman (1994) identifies four possible roles for the participant observer:

- **Complete participant:** The researcher operates under conditions of secret observation and full participation;
- **Complete observer:** The researcher is behind a one-way mirror or in an invisible role that permits undetected and unnoticed observation and eavesdropping;
- **Participant as observer:** The researcher and members are aware of the research role, but the researcher is an intimate friend who is a pseudo-member;
- **Observer as participant:** The researcher is a known, overt observer from the beginning, who has more limited or formal contact with members.

In this study, the researcher visited the case study information system's site and observed its functionality as a *complete observer*. The justification for this role is to avoid intrusion in the normal operation of the information systems and learn the most by observing the users in the natural environment of the information systems.

The technique used to interview users, maintainers, and designers was open-ended interviews. The use of this technique is justified for this research by two main reasons. First, the goal is to elicit the respondent's views and experiences in his or her own terms, rather than to collect data that are simply a choice among pre-established response categories (Anderson, Aydin, & Jay, 1994). Second, the interview is not bound to a rigid interview format or set of questions that would be difficult to establish given the nature of the research and would limit the results (Anderson et al., 1994).

The final goal of the open interview is to interview system users, maintainers, and designers of the legacy systems in order to find out how the system was developed, what are the functions of the system, and the type of documentation used for the system development. The system owners consented to the participation of the developers in the interviews.

System documentation was collected in order to perform the reverse engineering analysis required to recover the conceptual models (Jacobson & Lindstrom, 1991). The legacy information system can be described by using different elements such as requirements specifications, user operating instructions, maintenance manuals, training manuals, design documentation, source code files, and database schema descriptions (Jacobson & Lindstrom, 1991). Information systems documentation is a valuable source of data. Documentation related to the system, including manuals, database schemas, and system architecture diagrams were collected.

Conceptual Model Recovery (Build)

In order to capture the conceptual model of the legacy system, the reverse engineering methodology, as specified in Jacobson and Lindstrom (1991), was applied. The following three steps were used:

- Develop a concrete graph that describes the components of the system and their interrelationship;
- Develop an abstract graph showing the behavior and the structure of the system;
- Develop a mapping between the two, that is, how something in the abstract graph relates to the concrete graph and vice versa.

The abstract graph should be free of implementation details. For example, mechanisms for persistent storage or partitioning into processes should not appear on this graph. The concrete graph must, on the other hand, show these details. The mapping between the two should explain how the abstract graph is implemented by way of the concrete graph (Jacobson & Lindstrom, 1991).

Use cases are an excellent tool for reverse engineering since they provide a sequence of user interactions with the system (Jacobson & Lindstrom, 1991). Their purpose is to define a typical way of using the system and to describe the business process, to document how the business works and what the business goals are of each interaction with the system. In the context of reverse engineering, it is possible to explore a legacy system with use cases (Jacobson & Lindstrom, 1991).

Use cases were developed to create the concrete graph for reverse engineering. These use cases show the interrelationship between manuals, documentation, interviews, source code, and researcher's observation of the system. The abstract graph described in the Jacobson and Lindstrom (1991) methodology is in fact an example of the legacy conceptual model. For this research project, the conceptual model was represented in terms of data flow diagrams (DFDs), a context diagram, and entity relationship (E-R) diagrams.

The description of the business process, business events, and responses is essential in generating a conceptual model (Whitten, Bentley, & Dittman, 2001). The use cases employed to construct the concrete graph document the business processes, events, and responses required to construct this legacy abstract graph. In order to generate the DFDs required to construct the legacy conceptual model, business events to which the system must respond and appropriate responses were identified with the help of the use cases. According to Whitten et al. (2001), there are essentially three types of events:

- **External events:** Are so named because they are initiated by external agents. When these events happen, an input data flow occurs for the system in the DFD;
- **Temporal events:** Trigger processes on the basis of time. When these events happen, an input called *control flow* occurs;
- **State events:** Trigger processes based on a system change from one state or condition to another.

Information systems usually respond to external or temporal events. State events are usually associated with real time systems (Whitten et al., 2001).

Once these events were identified, DFDs were drawn with the help of the list of mapping transformations suggested by Whitten et al. (2001). The concrete graph represented by the use case can be mapped to the abstract graph represented by the DFD. The actor in the use case that initiated the event will become the external agent; the event identified in the use case will be handled by a process in the DFD; the input or trigger in the use case will become the data or control flow in the DFD; all outputs and responses in the use case will become data flows in the DFD.

The data model of the legacy conceptual model is generated by identifying the data stores in the DFD, examining the use cases, and finally documented by using an E-R Diagram.

Component-Based Model Generation (Build)

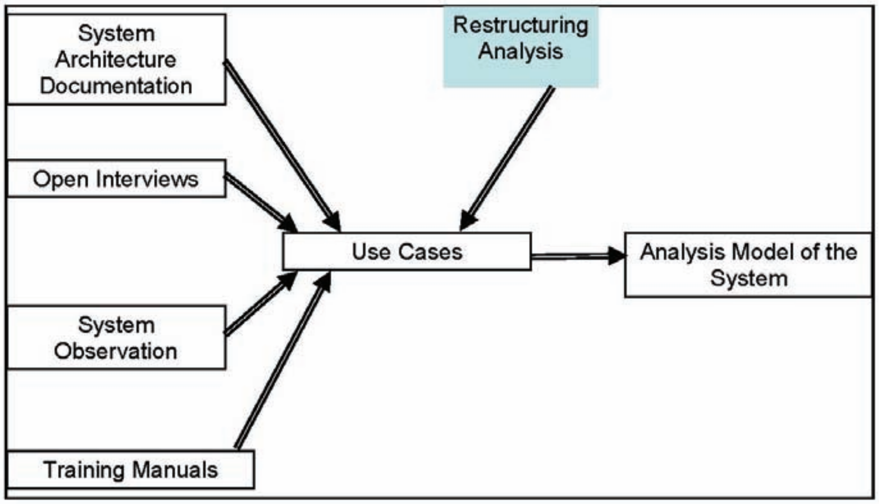
Once the model was reverse engineered from the legacy system, the legacy system was re-engineered for a complete change in implementation technique but no change in functionality by preparing an analysis model and then mapping each analysis object to the implementation of the old system (Jacobson & Lindstrom, 1991).

In the first step, an analysis model was prepared with the help of the use cases prepared in the reverse engineering process. These use cases already contain the information that was assimilated from the manuals, system architecture documentation, open interviews, and research observations described as description elements in the Jacobson and Lindstom (1991) methodology (Figure 1). Only the analysis model of the re-engineering process was required since the primary objective of the research project was the comparison of conceptual models and not the full implementation of the information systems.

An analysis model only contains the logical aspects and is free of physical implementation details. The logical representation of a component is concerned with its logical abstraction, its relationship with other logical elements, and its assigned responsibilities. The logical representation of a component-based system was modeled by using the UML diagrams: use case diagrams, class diagrams, sequence diagram, and state diagrams (Houston & Norris, 2001).

Actors were identified from the use cases and use case diagrams were constructed to identify the system scope and boundaries. The model should be free of physical implementation details. For the case of components, their logical representation was modeled using UML subsystems and identified inside the use case diagrams as proposed by Houston and Norris (2001). Class diagrams were prepared using the criteria for finding objects as described in Jacobson's (1987) object-oriented method. This step was accomplished by reviewing each use case to find nouns that correspond to business entities or events (Jacobson, 1987). Not all the nouns in the use cases represent valid business objects. A cleansing process removed nouns that represent synonyms, nouns outside

Figure 1. Preparation of the analysis model (adapted from Jacobson & Linstrom, 1991)



of the scope of the system, nouns that are roles without unique behavior or are external roles, unclear nouns that need focus, or nouns that are really actions or attributes (Whitten et al., 2001). Once objects were identified, their relationships were modeled as part of the class diagrams and interfaces were identified.

Ontological Evaluation (Evaluation)

Once the legacy conceptual model was recovered and the component business analysis model represented with the use of UML diagrams, the Fettke and Loos (2003) methodology was used to evaluate these models for equivalency of representation of business requirements.

As part of this evaluation, the ontological normalization of the legacy and re-engineered component models was generated. The ontological normalization of a reference model consisted of four steps (Fettke & Loos, 2003):

- **Step 1.** Develop a transformation mapping;
- **Step 2.** Identify ontological modeling deficiencies;
- **Step 3.** Transform the models; and
- **Step 4.** Assess the results.

In the first step of this method, a transformation mapping of the traditional and component-based (UML) diagrams used for representing the conceptual models was developed. This transformation mapping allowed converting the constructs of the traditional and component-based (UML) diagrams to the constructs of the BWW model. The first step was based on the method for the ontological evaluation of grammars proposed by Wand and Weber (1993).

The transformation mapping consisted of two mathematical mappings. First, a representation mapping described whether and how the constructs of the BWW model are mapped onto the traditional and component-based (UML) constructs. Second, the interpretation mapping described whether and how the traditional and component-based (UML) constructs are mapped onto the constructs of the BWW model (Fettke & Loos, 2003).

All ontological deficiencies of the conceptual models were identified as part of the second step of the generation of the normalized ontological models. To identify the ontological deficiencies of the recovered model and re-engineered component-based model, all constructs of the models were reviewed. Each construct of the models analyzed was examined with respect to whether the construct was used correctly regarding the interpretation mapping.

Three classifications of deficiencies were used:

- **Adequacy:** The grammatical construct is ontologically adequate. Nevertheless, an ontological deficiency can emerge by applying the grammatical construct to build the reference model. Therefore it must be examined whether the construct of the reference model is used correctly with respect to the interpretation mapping. The construct of the reference model is used adequately if it is used correctly with respect to the interpretation mapping.
- **Excess:** Construct excess is a modeling deficiency in general and needs special handling in the transformation step. Therefore, this construct should be marked as excessive in the reference model.
- **Overload:** Construct overload is a modeling deficiency in general and needs special handling in the transformation step. Therefore, this construct should be marked as overloaded in the reference model (Fettke & Loos, 2003).

Based on the representation mapping, it was decided whether the traditional and component-based grammar are incomplete or redundant.

An incomplete grammar suggests that specific facts of reality cannot be adequately represented in the model.

In the third step, the models were transformed to ontological models. The outcome of this step was two ontologically normalized models. The objective of both techniques was to represent the domain of interest in a normalized way by applying specific transformation patterns (Fettke & Loos, 2003).

The two models were compared based on their ontologically normalized models. The result of this comparison was an analysis that revealed whether the compared models are equivalent, complementary, or in conflict. In order to generate these normalized reference models in BWW terms, the Rosemann and Green (2002) BWW meta-models were used.

CONCLUSION

This chapter has discussed how design science can be used for the research of information systems re-engineering. The research activities identified by March and Smith (1995) were fundamental for this study. This framework requires two main activities: build and evaluate, which require the use of several methodologies as the first was used for construction of conceptual and BWW normalized models and the second for the evaluation of these models for equivalency of business requirements using the Fettke and Loos (2003) ontological methodology. The case study methodology was used as the main methodology to build and evaluate conceptual models. The Jacobson and Lindstrom (1991) approach for re-engineering of legacy systems was employed to build the original conceptual model of the legacy system under research and for the building of the component-based re-engineered models. Conceptual models were built with the help of data collected by using interviews, observation techniques, and review of information systems documents.

The methodology by Fettke and Loos (2003) was selected to evaluate the models generated by the reverse engineering (legacy conceptual model) and those generated by the re-engineering process (component model). Traditional and component-based constructs were also evaluated under the same methodology. The Rosemann and Green (2002) metamodels were used as the primary tool to represent the normalized models in BWW construct terms.

FUTURE RESEARCH DIRECTIONS

Future research can be concentrated in the development of automated tools for the re-engineering of information systems based on design science. A software tool could be constructed to build legacy and re-engineered conceptual models and evaluate them based on the methodology proposed. This software tool could translate the legacy and component models into ontological normalized reference models that could be used for comparison.

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Chapter 2.6

Improving IT-Enabled Sense and Respond Capabilities:

An Application of Business Activity Monitoring at Southern International Airlines

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EXECUTIVE SUMMARY

Commercial airlines face an extremely challenging operating and competitive environment. To remain in business they must comply with ever-changing regulatory requirements while, at the same time, minimizing their operational costs without sacrificing customer expectations of service levels. Increasingly, airlines are realizing that a "plan-execute" mode of operation must give way to a "sense-respond" mode of operation; in other words they must become a real-time (agile) organization, capable of sensing the occurrence of unforeseen events such as the placement of a last-minute shipping order, flight delays, and cancellations, and respond effectively in real-time to such events. To enable enterprises in general, and the airline industry in particular, to improve their sense-and-respond capabilities and ensure better resource utilization, a number of software vendors are offering event stream processing and Business Activity Monitoring (BAM) solutions. This case examines a longitudinal set of real-world implementation projects using such a solution at a major US airline (referred to as Southern International Airlines) and the results and lessons gained from this deployment.

ORGANIZATIONAL BACKGROUND

This case involves the interactions between two organizations—a solutions provider (Quantive, LLC) and a client for Quantive's products and services: Southern International Airlines (not their real name).

Quantive, LLC (www.quantive.com) is a small product and services company, founded in 2000 by Dwight Jones, and based in Alpharetta, Georgia. It employs several people as well as having contractual relationships with additional personnel when needed to staff projects for clients. As its Web site indicates, it uses a combination of software tools and services to: capture critical business events in real-time without touching existing application systems, and translates these events into actionable business information (called "BAM-alerts"). It does this without the need to engage IT staff at the client organization, save to make a one-time network connection to a router on the client organization's network. To do this, it uses a stack of software to capture transactional packets of data moving over the network (Packeterm), translating these captured packets into logical transactional events (Inquisitor), and then examining these resulting events to identify exception or alert situations, and sending messages to a manager or an application to take action regarding the BAM-alert (Medusa). Finally, Quantive Factory provides additional ways to evaluate and present event alert information from Medusa. For a more complete picture of their offering, see Appendix A.

Southern International Airlines (SIA) provides both domestic and international air travel and shipping from its primary base in the Southwest as well as other hubs located throughout the world. It was founded through an incorporation of several airline companies in 1930. It operates approximately 1,000 aircraft that fly ca. 420 million seat-miles per day with 3,900 flights per day to 250+ locations. Although SIA is better known for its passenger service, its cargo division flies roughly 5 million pounds of cargo each day, with services to 250 cities in 40 countries, providing one of most extensive cargo networks in the airline industry.

SETTING THE STAGE

Initial Problem

Southern International Airlines' original motivation to adopt a (Quantive) BAM solution was to improve compliance with federal regulations issued by the US Federal Aviation Administration (FAA) and thereby reduce (or avoid) the high cost of non-compliance. In the context of this implementation project, the relevant regulation is FAA AC 43.13-1B: *Acceptable Methods, Techniques, and Practices—Aircraft Inspection and Repair*, which came into force on September 8, 1998 (FAA, 2002). More specifically, chapter 10 of this regulation sets requirements for both the calculation of take-off parameters for commercial aircrafts and the disclosure of corresponding compliance figures.

The primary reason for issuing this regulation is to improve flight safety. It is to ensure that if a significant weight variation takes place after the initial flight parameters are loaded that new parameters are re-loaded. If no action is taken to recalculate these parameters, the aircraft is likely to take-off with inadequate stabilizer settings and thus decrease flight safety. In this scenario, depending on the significance of the shift in the center of gravity resulting from the non-computed weight variations, these changes could cause the aircraft to exhibit dangerous flight characteristics (FAA, 1999). To prevent this scenario from happening, Southern International Airlines must have a proper weight and balance control system to enable the cockpit crew to know the actual values of the take-off parameters in order to set the stabilizer trim properly, prior to take-off. This involves monitoring factors influencing the weight and balance condition of an aircraft, such as total weight and position of load as well as the amount and distribution of fuel. Typically, significant weight variations can result from the loading of heavy freight, an exceptionally high fuel use during ground operations due to, say, airport congestion and/or flight cancellations causing many new last-minute passengers on the flight. Under such circumstances, the take-off configuration of the aircraft must be recalculated, taking into account the new weight and balance condition.

In addition, this particular FAA regulation emphasizes the need to improve accuracy on the disclosure of information when non-compliance occurs. Non-compliance conditions are those situations where this FAA regulation is violated and an aircraft takes off with inappropriate trim settings. To gather data about this type of non-compliance, the FAA relies on data submitted by SIA on a self-disclosure basis. On the face of it, the FAA is only able to enforce compliance by auditing the control systems of SIA in order to assess their capabilities of complying with the regulation and reporting requirements.

Beyond risks for flight safety, repeated violations of the noted FAA regulation can lead to large fines, loss of reputation, and SIA managers can be held legally liable for any resulting consequences of inappropriate weight and balance settings. Compliance with this and other FAA regulations became a primary concern and SIA must be able to demonstrate to the FAA, via audits, that their weight and balance control systems are capable of:

- Detecting significant shifts in the center of gravity of aircrafts as they occur and warning those responsible for the calculation of the take-off configurations
- Recording weight and balance non-compliance cases for FAA disclosure purposes

Assessing the Business Needs

Despite the fact that the AC 43.13-1B regulation of the FAA has been in place for some time, compliance with the mentioned requirements remained an issue for SIA. Although the information about the weight and balance condition of any given SIA aircraft could, in principle, be evaluated across several transactions generated by SIA for all its flights, detecting significant weight variations in time to take compensating action (i.e., real-time) was not feasible for several reasons. First, the application systems creating these transactions did not converse with one another. And second, the detection of an out-of-balance condition was not programmed into the current systems and the reporting of the underlying transactions could not be done in real-time.

Typically, the full content of the transactions relevant to detecting an out-of-balance condition are written directly to a “flight log”. Because SIA operates approximately 3,900 flights per day, the resulting flight log is very large. To gather data about a certain flight, the personnel of SIA must search through the time-ordered sequence of messages associated with a particular flight and print out several of its sections to analyze the situation for any particular flight. This was a labor-intensive and time-consuming process that could only be justified in the most serious cases. And, in its current, manual state, the analysis process could take from hours to days and thus could only be used for off-line, retrospective analyses where situations had to be reconstructed.

The end result was that, even though the basic information on different aspects of aircraft weight distribution and changes were available in the flight log, SIA did not have the capability for detecting significant weight variations in real-time, as required by the FAA, and SIA’s managers knew they were unable to respond to these variations and avoid penalties or worse.

Technical Constraints to Implementing a Solution

There were important technical constraints to be taken into account when implementing a solution for the preceding FAA compliance problem. These constraints stem from the dependence of Southern International Airlines on their transactional systems and the need to keep them running and available 24x7. The characteristics of the transactional systems of Southern International Airlines will be briefly explained below.

Most load and balance procedures are carried out by the flight operations system. This is a legacy system that has been used by SIA for nearly 40 years. Though this old system is stable and reliable, it is not easily modified, nor is it capable of providing real-time visibility into take-off parameters. The system was originally designed to carry out transactions rapidly and reliably, rather than to provide adequate control mechanisms to monitor specific transaction information. Despite the fact that the transactions processed by this system contain all the information involving the weight and balance condition of aircrafts, it was not possible to directly access this information during the execution interval of the relevant transactions; only well after the fact via the resulting flight log.

Modifying the flight operations system to directly satisfy regulatory requirements was viewed as infeasible because it would involve a long project with a high degree of implementation risk and, due to the dependency of SIA on this system, any potential risk of adversely affecting the existing flight operations system was deemed unacceptable. While there are plans to replace the old system with a new system that will be fully operational in a few years, SIA remains dependent on the current system for the immediate future.

To conclude, the time and accessibility gap between information available from the existing flight operations system and that needed to assure load balancing requirements in real-time, cannot be remedied by patching the existing flight operations system due to the SIA's high dependency on this system, it's age, and the risk to ongoing operations inherent in making any change to the system. Instead, SIA had to look for a different way to solve the problem that did not in any way impact the existing flight operations system. This led them to explore the use of an event capture and reporting system (Business Activity Monitoring or "BAM") and to Quantive as a prospective solution provider.

Understanding Business Activity Monitoring (BAM)

BAM is a relatively new way of conceptualizing and solving business-related problems, Chandy and McGoveran (2004) describe BAM solutions as real-time control systems that capture events in real-time from multiple, heterogeneous sources and selectively raise alerts within time-limited windows of opportunity. These quick (low latency) alerts are aimed at providing their recipients (often operational managers) with sufficient operational insights to enable effective response to critical events (DeFee & Harmon, 2004). As such, BAM solutions are particularly well suited to managers who need to respond to exceptional combinations of events, in real time. This approach can be distinguished from seemingly similar approaches such as real-time data warehousing in that the source of the information is the accumulated events themselves (event log) rather than an ETL (extract-transfer-load) from a transaction processing system's database into a specifically designed data warehouse (Golfarelli et al., 2004).

Another important aspect of a BAM approach is that it does not affect the performance of the underlying transactional systems. Rather, BAM solutions provide a transparent platform in which events are detected by separately examining individual, pre-existing transactions and defining patterns of events over an event stream that, should they occur, warrant managerial intervention. To support the development of event-driven applications, BAM solutions are likely to include event-modelling functions that define and validate event patterns (Gassman, 2004). This makes BAM solutions highly adaptable, as new event-driven applications can be rapidly developed to address new or changing business problems.

To represent BAM solutions, Gartner, Inc. proposed a BAM model in 2002 that distinguishes three basic layers: the "Event Absorption Layer," the "Event Processing and Filtering Layer," and the "Event Delivery and Display Layer." In this model, the border of a BAM solution is the "Event Delivery and Display Layer", which is the interface of the BAM solution with the recipients of BAM alerts (Govekar et al., 2002). A simple representation of the basic three-tiered BAM model can be found in Figure 1. A more sophisticated model can be found in Schiefer and McGregor (2004).

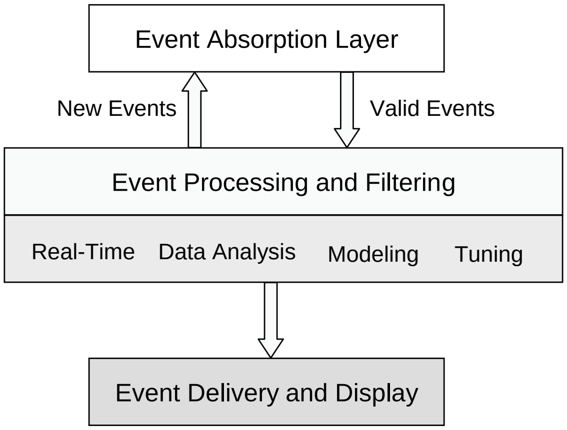
The Event Absorption Layer detects and acquires events that arrive from multiple and heterogeneous data sources (Gassman, 2004). The source of event messages will most often be business or process-related. However, technical events, such as the occurrence of technical failures during the execution of business processes might also be collected (Gassman, 2004). These sources can include both internal sources, such as (legacy) transaction processing systems, ERP systems, and RFID applications, as well as external sources such as those made available via the Internet (e.g., weather events), thus enabling a broader and richer view of business operations and its environment (McCoy et al., 2001).

These "raw" events, regardless of source, are first fed into the Event Absorption Layer. The Event Absorption Layer is most easily achieved by tapping into the stream of transaction events moving across a network via a middleware layer (i.e., data message transport layer) that carries transactional data messages across a network from transaction origination to the transaction application systems that process and store them. As these transactions move across the network, they can be defined, captured, and collected as events of potential interest and kept in an of event log, without disrupting their normal flow and usage.

At the next stage, Event Processing and Filtering software correlates this independent event stream data (McCoy, 2004). This layer sifts through and inter-relates the captured events, looking for combinations of events that occur, or should occur and does not, that in turn warrant managerial attention and intervention. More specifically, a set of event-based business rules are pre-defined and used by this layer to identify situations that are exceptions and create the conditions for an alert.

In the final layer (Event Delivery and Display) alerts created by the preceding layer are sent to those parties who are able to understand the nature of the exception and, as appropriate, take

Figure 1. Conceptual Model for BAM. Adapted from Govekar, et al. (2002)



the necessary action to circumvent or avoid an emerging problem that is identified by the event rules. The alerts can populate a display and/or trigger an action (Gassman, 2004). Alerts that are used to populate a display are often delivered via graphical displays in the form of BAM "dashboards" containing real-time values of critical business performance indicators. These corporate dashboards are normally customized for use in different parts of the enterprise and for different audiences (McCoy et al., 2001). Alternatively, or in addition to, the alerts can be sent as messages to specific recipients who are empowered to act, via existing channels such as e-mails, instant messages, pagers, and so forth (McCoy, 2003).

CASE DESCRIPTION

Initial Case: The Weight and Balance Solution

The Quantive BAM solution was first used by Southern International Airlines to design and deploy an event-driven application to improve compliance with FAA regulations. This section highlights this event-driven application by describing the event filtering conditions. In order to characterize the real-time decision support needs of the recipient for these "out-of-balance" BAM alerts, the performance-indicator monitored by the event-driven application and the tolerance for latency are taken into account. Table 1,summarizes the focus of this application.

For this case, SIA's BAM event-driven application raises alerts whenever significant weight changes occur after the initial flight parameters are set. These alerts, in turn, makes it possible for an operational manager in the weight and balance department to take corrective actions to ensure that the center of gravity is re-positioned within acceptable limits according to the aircraft flight manual before the aircraft takes off, as well as informing the cockpit crew about the actual take-off condition so that they can reset the stabilizer trim prior to take-off.

The primary event source is the Initial Weight and Balance Transaction (IWBT) used by the Flight Operations System, which contains the needed event properties that affect the weight and c.g. of an aircraft. This transaction is first captured at the absorption layer, then processed and filtered to create BAM alerts. The resulting application notifies appropriate BAM recipients (operational managers in the weight and balance department) of significant weight changes occurring that can affect the position of the aircraft's c.g.

Figure 2 provides a screenshot of all event properties captured using Quantive's event definition and absorption software, and contained in the IWBT transaction.

Table 2 shows the particular fields of the IWBT transaction that are captured in order to build the event to be logged and subsequently processed.

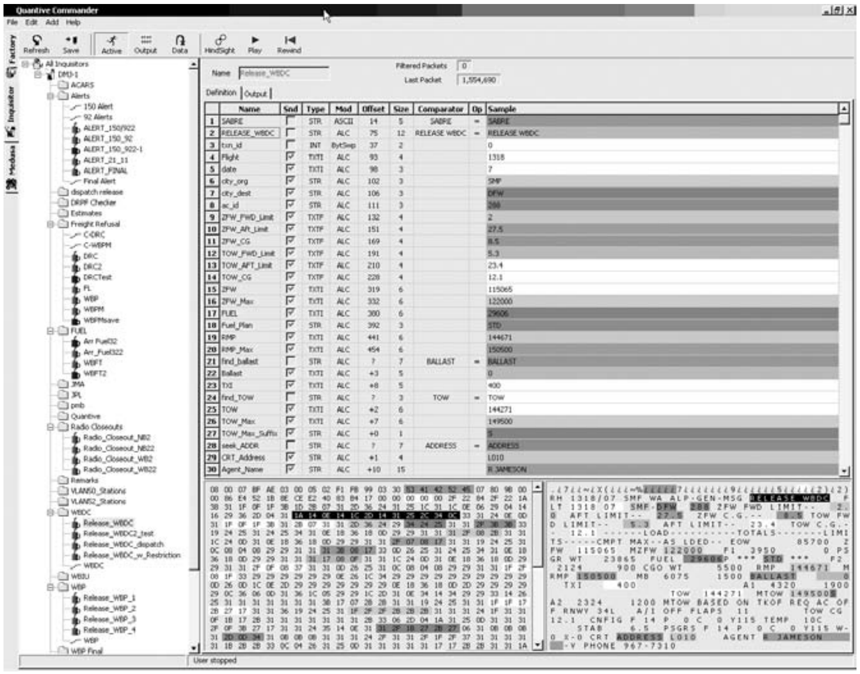
Event processing consists of using the resulting ZFW_CG, RMP, and TOW_WT values. Whenever one of those values comes within 2% of the forward and aft limit of the aircraft, an alert is raised and, at the third layer of BAM, a dashboard is updated to provide real-time visibility into this critical performance indicator.

Alerts raised by the weight and balance BAM application are also stored in a database. This

Table 1. Application characteristics of weight and balance

Application Characteristics	
Performance-Indicators	Position center-of-gravity, total weight
BAM recipient	Operational Managers in the Weight and Balance Department
Tolerance for Latency	Seconds-minutes

Figure 2. Release IWBT filter: screenshot provided by quantive



Name: Release_WBDC
Filtered Packets: 0
Last Packet: 1,554,690

	Name	Snd	Type	Mod	Offset	Size	Comparator	Op	Sample
1	SABRE	☐	STR	ASCII	14	5	SABRE	=	SABRE
2	RELEASE_WBDC	☐	STR	ALC	75	12	RELEASE WBDC	=	RELEASE WBDC
3	txn_id	☐	INT	BytSwp	37	2			0
4	Flight	☑	TXTI	ALC	93	4			1318
5	date	☑	TXTI	ALC	98	3			7
6	city_org	☑	STR	ALC	102	3			SMF
7	city_dest	☑	STR	ALC	106	3			DFW
8	ac_id	☑	STR	ALC	111	3			288
9	ZFW_FWD_Limit	☑	TXTF	ALC	132	4			2
10	ZFW_Aft_Limit	☑	TXTF	ALC	151	4			27.5
11	ZFW_CG	☑	TXTF	ALC	169	4			8.5
12	TOW_FWD_Limit	☑	TXTF	ALC	191	4			5.3
13	TOW_AFT_Limit	☑	TXTF	ALC	210	4			23.4
14	TOW_CG	☑	TXTF	ALC	228	4			12.1
15	ZFW	☑	TXTI	ALC	319	6			115065
16	ZFW_Max	☑	TXTI	ALC	332	6			122000
17	FUEL	☑	TXTI	ALC	380	6			29606
18	Fuel_Plan	☑	STR	ALC	392	3			STD
19	RMP	☑	TXTI	ALC	441	6			144671
20	RMP_Max	☑	TXTI	ALC	454	6			150500
21	find_ballast	☐	STR	ALC	?	7	BALLAST	=	BALLAST
22	Ballast	☑	TXTI	ALC	+3	5			0
23	TXI	☑	TXTI	ALC	+8	5			400
24	find_TOW	☐	STR	ALC	?	3	TOW	=	TOW
25	TOW	☑	TXTI	ALC	+2	6			144271
26	TOW_Max	☑	TXTI	ALC	+7	6			149500
27	TOW_Max_Suffix	☑	STR	ALC	+0	1			S
28	seek_ADDR	☐	STR	ALC	?	7	ADDRESS	=	ADDRESS
29	CRT_Address	☑	STR	ALC	+1	4			L010
30	Agent_Name	☑	STR	ALC	+10	15			R JAMESON

```
RH 1318/07 SMF WA ALP-GEN-MSG RELEASE WBDC  F
LT 1318 07  SMF-DFW  288 ZFW FWD LIMIT--  2.
0  AFT LIMIT--  27.5  ZFW C.G.--  8.5 TOW FW
D LIMIT--  5.3  AFT LIMIT--  23.4  TOW C.G.-
-  12.1 ------LOAD-----------TOTALS-------LIMI
TS-----CMPT MAX--AS LDED-- EOW        85700  Z
FW  115065  MZFW 122000    F1  3950     0 PS
GR WT   23865  FUEL  29606P *** STD ***    F2
 2124      900 CGO WT        5500  RMP 144671  M
RMP 150500    MB  6075      1500 BALLAST     0
  TXI      400                 A1  4320     1900
                  TOW  144271  MTOW 149500S
A2  2324      1200 MTOW BASED ON TKOF REQ AC OF
F RNWY 34L    A/1 OFF FLAPS  11         TOW CG
12.1  CNFIG F 14 P  0 C  0 Y115 TEMP  10C
      STAB     6.5  PSGRS F 14 P  0 C  0 Y115 W-
0 X-0 CRT ADDRESS L010     AGENT R JAMESON
  -Y PHONE 967-7310
```

Table 2. IWBT transaction contains these properties of interest for real-time weight-balance monitoring

Line	***Event Property***	***Description***
4	Flight	The flight number, as seen by the traveling public
5	Date	The numeric day of the month
6	City_org	The origination city
7	City_dest	The destination city
9	ZFW_FWD_Limit	The "forward limit" of the center of gravity
10	ZFW_AFT_Limit	The "aft limit" of the center of gravity
11	ZFW_CG	The center of gravity value at the time of transaction
19	RMP	Aircraft weight before it leaves the gate (Ramp weight)
20	RMP_Max	Max allowed Ramp weight
22	Ballast	Ballast weight the aircraft is carrying
25	TOW	Expected Take-Off weight
26	TOW_Max	Max. allowable Take-Off weight

makes it possible for SIA to disclose these alerts when reporting to the FAA about the occurrence of significant weight variations along with the corrective actions taken by SIA. In addition, the database is used to improve SIA's knowledge on patterns of balance event occurrences and, as a result, to provide this additional information to the FAA as well.

Follow-on BAM Applications

Although Southern International Airlines' decision to adopt Quantive's BAM solution was initially driven by the need to improve regulatory compliance without disturbing existing transactional systems, once managers began to see the power of re-thinking operational problems and potential solutions in terms of business events and event exceptions, other event-driven applications were identified and subsequently pursued. An additional attraction of the adopted BAM approach was that these applications could be implemented by the operations personnel directly. There was no need to have the IT unit involved in developing these solutions; operation's own people could easily master the identification of transactions moving across the organization's WAN (wide-are network) and create event definitions, filters, alerts, analysis, and display capabilities. This pattern of assimilation and adoption tended to follow the widely studied "diffusion of innovation" patterns documented in the marketing and information systems literature (Rogers, 1995).

At the time of this case (2005), ten event-driven applications, employing event 60 filters, had been implemented by Southern International Airlines. According to Quantive, these 10 applications raise an average of 30 to 40 alerts per day, each indicating a potential exception condition requiring intervention. At that level, the alert recipients are able to respond to all BAM alerts. However, it should be noted that as the number of event-driven applications increases, the risk increases of overloading the alert recipients with too many alerts (McCoy & Govekar, 2002). In such cases, BAM recipients are likely to start ignoring some of the alerts due to a lack of time to interpret and react upon the information contained in the alert (Klein & Besson, 2003). This situation is often referred to as cognitive overload (of the BAM recipient).

Three of these follow-on applications are given. Each highlights a problem identified by specific business unit managers following the installation and presentation on the original (weight-balance) application. Of these, the first two were successful. A third, while technically feasible and economically attractive, was nevertheless abandoned due to inadequate attention to social constraints.

Freight Refusal Application

Freight refusal presents an interesting problem to SIA, with significant negative financial implications. It involves scenarios in which sufficient cargo space is available on an aircraft but some of the freight booked for that flight is not loaded. This condition is referred to as freight refusal. For the sake of maximizing SIA's resources and revenues, it is obviously important to ensure that the maximum amount of freight booked for a flight is loaded onto the aircraft prior to take-off, especially for perishable goods that quickly deteriorate if they are not loaded and shipped as originally planned (e.g., flowers). In this case, SIA would have to reimburse customers for their resulting loss in addition to the loss of SIA shipping revenue. Since urgency and perishability are two of the primary reasons for using air cargo over other logistical choices, nearly all freight refusal conditions have significant economic and quality of service impacts. Table 3 summarizes the characteristics of this application.

In examining the freight refusal scenario, SIA managers determined that there are both legitimate and non-legitimate reasons for freight refusals. The list of legitimate reasons include lack of space in the aircraft, insufficient time to load all booked freight before the scheduled departure time due to

Table 3. Application characteristics of Freight Refusal

Application Characteristics	
Performance-Indicators	Shipping status
BAM recipient	Supervisors of Ramp Crew
Tolerance for Latency	Hours-Days

late arrival of the aircraft, the freight itself was not delivered to the airport in time, loading equipment damage, and so forth. In general, non-legitimate reasons result directly from failure of the ramp crew to load awaiting freight.

Southern International Airlines needed to identify the occurrence of non-legitimate freight refusal so that corrective measures could be taken with the associated ramp crew. However, the effort required investigating the reason for the occurrence of freight refusal and also required a time-consuming search of the flight log. Again, given the large volumes of data stored there, such an analysis was rarely undertaken and disciplinary measures seldom initiated, while non-legitimate freight refusal continued to occur.

The basic pattern for freight loading was then examined for the existence of signal events that could aid in identifying cases of freight refusal. For every flight of Southern International Airlines, there is a ramp controller who is in charge of registering the status of booked freight in a manifest document (transaction) provided by the flight operations system. In the case of freight refusal, the ramp controller is supposed to register the reason for not loading the booked freight.

The event-driven application designed to tackle the non-legitimate occurrences of freight refusals work was based on monitoring the execution of transactions containing cargo information. Basically, after the first IWBT is executed, a system transaction (the Cargo Transaction) containing event properties pertaining to cargo, is also executed. These two transactions, in turn, provide the basis to develop a set of event rules and BAM application that would provide real-time notification of the occurrence of non-legitimate freight refusals.

While the actual set of transaction events and associated properties used is complex, to provide a sense of this application, a few simplifications are made. First, the Cargo Transaction contains an event property that identifies each product to be shipped, which is called PIC (Product Identification Code). Second, there is an event property to indicate the status of all products that are booked for shipment on a specific flight, called SPBS (Status of Products Booked for Shipment). SPBS can assume the values:

- *Confirmed*, meaning that product is ready for shipment
- *Cancelled*, meaning that a legitimate reason exists for not shipping the product according to shipment book
- *Shipped*, meaning that product was loaded into the aircraft

The event logic then becomes that of comparing the change of SPBS values during the loading process. Specifically, alerts are generated indicating non-legitimate freight refusals by searching for *confirmed products* that do not change their status to *shipped* in the course of the loading process. By this logic, it is possible to identify a possible failure of the assigned ramp controller for this flight to load that particular product shipment.

Monitoring Flight Planners

The allocation of passenger-sensitive resources to a particular flight is the responsibility of SIA's flight planners. Such resources can range from the number of meals carried to the fuel to be loaded on the plane. SIA management sought a way to develop an event-driven application to monitor the individual performance of flight planners with respect to optimal resource allocation. It is important to mention that flight planners' work in a non-unionized department, otherwise such monitoring would likely be opposed by their representation union officials. Table 4 highlights the properties of this application.

The event-analysis approach taken here relied upon two transactional events occurring within the flight operations system: the IWBT transaction and a Passenger Destination Transaction (PDT). After the IWBT is executed, the flight operations

Table 4. Application characteristics of monitoring flight planners

Application Characteristics	
Performance-Indicators	Variation in number of passengers near flight departure
BAM recipient	Supervisor of Flight Planners
Tolerance for Latency	Minutes-Hours

system executes a PDT transaction that contains properties indicating passenger destinations. The analysis showed that the Passenger Destination Transaction is executed automatically for the first time between 150 and 92 minutes prior to departure.

By aggregating the PDT's at a particular time point, one can compare the number of passengers at a particular point in time with the passengers indicated from a preceding point in time. This, in turn, can be compared to the flight planner's resource allocation for the flight (from a different transaction). In principle, the passenger configuration of a flight should not vary significantly, especially as the time of departure approaches. Variations beyond a pre-determined, SIA-specified level, can signify that the flight planner is not keeping up with the changing status of the flight in a proper way.

Using this application it becomes possible for SIA management to analyze the performance of individual flight planners with respect to their allocating resources to their assigned flights and identify those flight planners who may need additional training and/or mentoring.

And, while this application was a post-mortem analysis, the same logic could be used to provide event alerts to the flight planner and/or his/her supervisor in real-time.

Monitoring Dispatchers

Not all event-based applications that were considered by SIA were successfully deployed. At the beginning it was acknowledged by the Quantive-provided trainers and developers that organizational resistance could be an obstacle to the deployment of some event-based applications. This proposed application is one such example.

The way of event-thinking that resulted in the preceding flight planner monitoring application led SIA management to consider extending the concept into an application to monitor the dispatchers that provide information support to the cockpit crew. The idea was to monitor whether dispatchers were paying sufficient attention to all flights by examining a combination of transactional events drawn from the flight operations system to assess the frequency and duration of message interactions between the cockpit crew and the dispatcher, as suggested in Table 5. However, this prospective application did not proceed beyond the conceptualization phase.

In contrast to flight planners, the dispatchers work in a unionized department. For this reason, the proposed development of an event-driven application to monitor individual performance of dispatchers triggered fierce resistance from their union. To avoid possible conflicts with the union, the decision was taken to cancel any further development and deployment of this application. The experience gained with this attempted application demonstrates that an application that is technically and economically feasible can be socially infeasible. As such, the organizational setting becomes a very important aspect to be taken into account when considering event-driven monitoring applications.

Table 5. Application characteristics of monitoring dispatchers

Application Characteristics	
Performance-Indicators	Time length of communication between cockpit crew and dispatcher
BAM recipient	Supervisors of Dispatchers
Tolerance for Latency	Minutes-Hours

CURRENT CHALLENGES FACING THE ORGANIZATION

A first challenge arises from the fact that many of Southern International Airlines business processes are highly regulated. As new regulations are added, these in turn require SIA to implement new, real-time control systems to monitor for compliance. However, in order for SIA to comply, they must continue to rely on their legacy transactional systems, which were not designed to comply with such regulations. The challenge, then, is to overlay the existing systems with a new layer of processing that is transparent to the functioning of the existing systems while providing the needed regulatory compliance. While SIA was able to do this for the weight balancing regulation, there are many other regulations requiring compliance that must also be met in a cost-effective fashion. For example, the arrival of Sarbanes-Oxley (SarbOx) requires, among other things, the monitoring and control of various financial transactions and the early reporting of material events affecting financial disclosures "Section 409 is also important because material changes affecting financial disclosures must be reported on a rapid and current basis. This means systems must be able to provide timely information within days, not weeks, of an event." (Kaarst-Brown & Kelly, 2005, p. 2). Can an approach similar to the FAA compliance problem be taken to this set of regulations? If so, how does one expand the other areas of the organization, base of knowledge gained by the SIA flight operations managers in ways of event-thinking?

Another challenge (or more correctly, opportunity) faced by Southern International Airlines, once they had their initial BAM capability in place, was to re-think non-compliance-related problem-solution scenarios in event-based terms. As this case points out, there is a type of "ah-ha" moment that seems to occur when (some) managers begin to re-interpret other problems they are having in a manner that fits an event-stream, BAM-like solution. While SIA could continue to rely on random awakenings to form the strategy for their next applications, is there a better way to identify opportunities and determine which of these are most applicable for solving using a BAM approach? Conversely, how should one avoid over-use of such a capability—the all-too-familiar problem of a solution looking for problems?

A third challenge that is associated a broader application of BAM-style application, particularly into areas with higher exception frequencies, is the already mentioned "alert overload" problem. Even though the number of alerts per day has been relatively small for the applications implemented to date, an increase in the number of event-driven applications could easily overload BAM recipients with too many alerts in much the same way that e-mails have done. While the volume of alerts can obviously be throttled back by more aggressive event filtering, this gives rise to the well know statistical problem of Type I and Type II errors, for example, rejecting events that should be seen versus accepting events as alerts that are not important. Can risk analyses similar to deciding Type I vs. Type II error levels be applied here? Or, are there other, better ways to accomplish this, drawn from (say) the area of Decision Support Systems?

A fourth and final challenge is how organizations in general, and SIA in particular, should anticipate and overcome organizational issues and constraints that often accompany real-time monitoring situations. As with any system change, technical and economic feasibility are not the only pre-conditions for a successful system implementation and change. It is widely known that "social failures" (i.e., the rejection of the system by the users themselves) are a major, if not primary cause of IT implementation failures. The last case discussed illustrates that unionized departments strongly tend to oppose the implementation of applications designed to monitor individual performance of employees. But more employees in general (unionized or not) are averse to having their work monitored in real-time, particularly when the monitoring results in disciplinary action. And, while they may not be able to prevent its implementation, as the unionized employees were in this case, there are many other ways they can cause the resulting system to fail.

It should be noted, however, that BAM-style monitoring solutions are not inherently punitive; they can be used proactively as well as reactively. For example, in the case of dispatcher monitoring, the alerts could instead be sent to the dispatchers themselves as a stimulus to them to increase their engagement with the specific flight crew. Rather, from the applications presented (both implemented and withdrawn) it appears that SIA management is of the "Theory X" style and some of the BAM solutions implemented allow them to become even more so. How, then could the developers of these solutions approach their design so that the result to monitoring is more proactive/supportive rather than reactive/punitive? Should they? More generally, could/should BAM development adopt a socio-technical approach (Bostrom & Heinen, 1977; Mumford & Weir, 1979) to development so as to enhance implementation success, rather than the more mechanistic development approaches taken from real-time mechanical control system design, where the objects being monitored are machines rather than humans?

CONCLUSION

The implementation of a BAM solution at Southern International Airlines resulted in significant improvement of the event-response capabilities of the airline without having to modify or add to existing transactional systems and in time frames measured in days and weeks rather than months or years. The benefits produced by the projects described include: better regulatory compliance, reduction of operational costs, improved flight safety, greater management visibility into ongoing operations, and improved customer service. As with any new set of concepts and tools, the standard pattern of innovation diffusion can be observed as potential users of the system slowly begin to re-cast problems they may have in terms of events, real-time event monitoring and alerts. This diffusion is made particularly difficult in that the development of event-driven applications requires a combination of knowledge about business processes, regulations, transactional systems, and the BAM solution itself. A final consideration of the cases presented suggests the need for a broader framework and methodology base that addresses and integrates all the many aspects involved in an event-driven BAM implementation project and its subsequent implementation success.

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APPENDIX A. TECHNICAL NOTE ON BAM SOLUTIONS

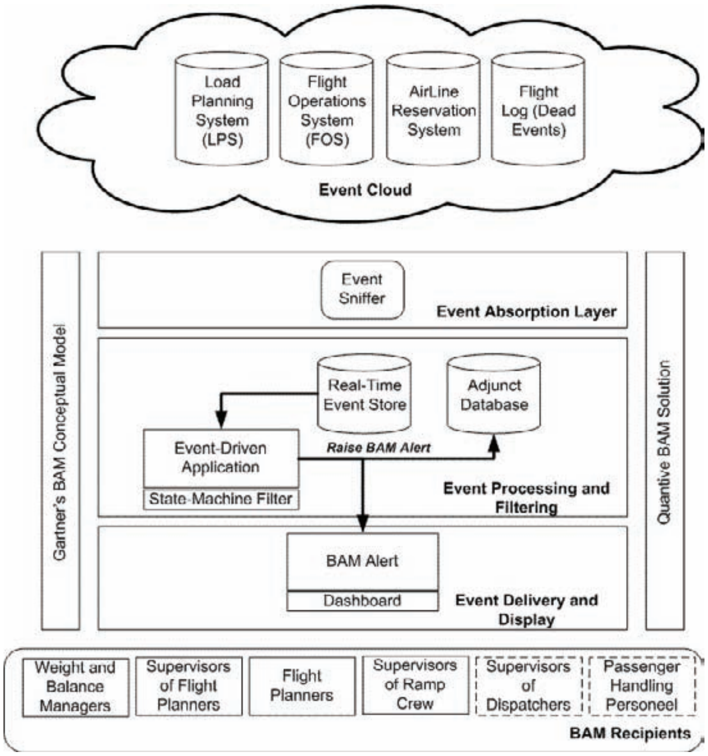
Business Activity Monitoring is a comparatively new concept, first introduced ca. 2002 in the professional literature (McCoy, 2002) and appearing in the academic literature ca. 2004; primarily in conference proceedings (cf. Golfarelli, et al, 2004). In order provide additional insight into SIA's implementation project, additional details regarding the Quantive BAM solution are provided below.

Figure A-1 places the Quantive BAM solution within the SIA flight operations "event cloud" of generated transactions and adopts the nomenclature of the previously presented Gartner conceptual model for BAM. At each level, the Quantive BAM solution provides products or built components that represent their approach to the functional need associated with the generic BAM model level.

Event Execution

For the initial SIA weight-and-balance application, the primary event of interest is considered a "complex event," for example, one that is defined as the occurrence of several basic transactional events that occur in a predefined sequence. For this application, the initial weight and balance transaction (IWBT) is the initiating transaction (triggering event) indicating the existence of a flight. The IWBT contains the basic flight information and the first execution of this transaction confirms that a flight is scheduled for departure within about 4 hours. There is a timing relationship between the IWBT and the other transactions carrying information about a certain flight. After IWBT's detection, a transaction sequence containing transactions about basic flight information regarding passengers, freight, fuel, and

Figure A-1. Functional components of the quantive BAM solution

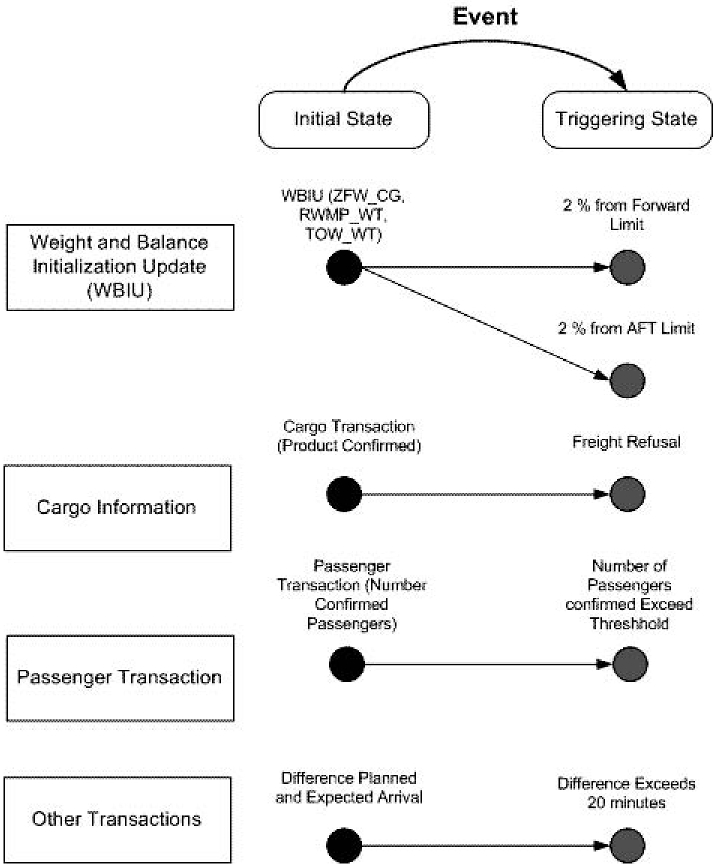


other elements of the flight occurs. Figure A-2 illustrates the associated events of interest that are then monitored by event-driven applications that were deployed by Southern International Airlines. When a pre-specified set of transactions and their associated events occur with specific values, a complex event of interest to the weight-and-balance application is then said to occur.

Event Sourcing

The primary source of events for this implementation project is the flight operations system. This is a widely distributed, message-based transactional system that is responsible for managing resources of all flights of Southern International Airlines throughout the world. The flight operations system supports transaction-based applications used by SIA's personnel to carry out business processes related to flights. Alongside the flight operations system, Quantive's BAM solution also monitors event streams output by other systems that interact with the flight operations system, such as the Loading Planning System (LPS) and Southern International Airlines' reservation system. The LPS is a subsystem of the flight operations system, which was designed to automate the load planning processes. The LPS sits on the top of the flight operations system, but executes underlying transactions that require data from both the flight operations system and the reservation system.

Figure A-2. Set of events of interest monitored by Southern International Airlines



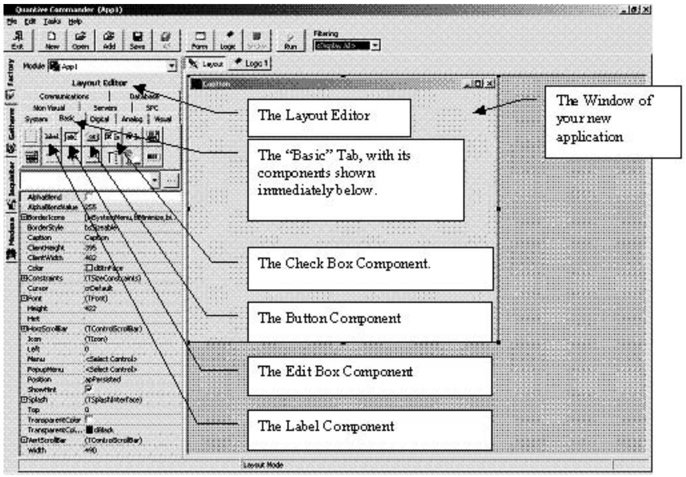
To acquire all the raw transactional events, Quantive's solution literally taps into SIA's switched LAN and, using transaction definition filters created by SIA's operations personnel, it reconstructs the packets of data moving into complete images of the various transactions moving across SIA's corporate network. More generally, any transaction moving over the LAN can be defined, captured and logged in this manner.

Developing an Event-Driven Application with Quantive Tool Set

Quantive's BAM solution includes an application development environment called the Quantive Factory. This environment provides business event modeling tools to specify event selectors used by applications to detect both single and complex events of interest. The application development environment, which is illustrated by Figure A-3, includes modeling functions that can be used to specify the performance indicators to monitor, logic formulas to characterize a complex event pattern corresponding to an exceptional situation of interest, and the characteristics of the alert to be issued when the defined, complex event is detected. Alerts are normally delivered by graphic displays "dashboards" that are customized for different BAM recipients, although as in the SIA case, they were also sent as (real-time) messages to appropriate devices (pagers, PDA's).

The interface of the Quantive Factory was designed for use by business managers, rather than IT developers. As such, complete applications can be and were developed without the need for IT-specialist knowledge. For this reason, the development cycle of event-driven applications was much shorter then would be the case for conventional IT applications. Each of the applications discussed in this case took days or several weeks to develop and implement and in some cases, less than a day. It also provides a much higher degree of "ownership" by the business unit itself, as well as providing a tool for subsequent adaptation and experimentation.

Figure A-3. Graphical user interface of quantive's event-driven application development environment. source: quantive



The Layout Editor

The "Basic" Tab, with its components shown immediately below.

The Window of your new application

The Check Box Component.

The Button Component

The Edit Box Component

The Label Component

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Chapter 2.7

A Model for IT Service Strategy

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ABSTRACT

This chapter describes a suggested model for developing a service strategy within IT services. It considers the context, the organization of IT services which might be appropriate for a service strategy. It discusses the content of an IT service strategy which it suggests should be presented as a portfolio of services. It reviews the process of developing the service strategy, suggesting a set of steps which may lead to the development of appropriate content within the right management structure. The example of hospital information systems is used to illustrate the strategic process. In order to set the scene for the strategic process, the state of information systems strategy research is discussed and set in the context of the developing service management research literature. The term service-centric is used and the difference between service-centric IT management and service-oriented architecture is clarified. A case is made for a migration from an IT strategy based primarily on the development of a portfolio of IT systems to a service-strategy based on the development of a portfolio of business services.

INTRODUCTION

In the last decade there has been a significant shift in many IT departments. IT departments increasingly recognize that IT within an organization is a service which, like other services within organizations, aims to deliver value to the organization through the way that it supports the activities of the business. This has led to an increasing emphasis on the delivery of IT operations as a service which not only involves the building and delivery of the software and hardware, but also the execution of a wide range of activities around the technology.

The influences that have led to the realignment of IT as a service are complex. Economies, particularly in the West, are changing from a goods base to a service base (Rai & Sambamurthy, 2006). In terms of business models, many companies are repositioning themselves as service organizations. The technological products, which were previously the focus, become part of a larger service. The Volvo lorry is part of a logistics service and is seen in that context (Edvardsson, Gustafsson, Johnson & Sanden, 2000). A technological product is seen as a service waiting to happen. In addition to the manufactured goods being set in a service context, they are also surrounded by support services involving maintenance, replacement, and training.

In IT departments, the rise of outsourcing, the move from making software internally to buying it and the recasting of IT as a commodity has further aroused a service mindset. The service focus of these changes has particularly been around quality. In delivering services and IT products to clients, outsourcers had to work on the definition of what the service was that was being contracted by the client, how it could be measured and how it could be judged as being up to a mutually acceptable standard. Hence, outsourcing led not only to a focus on contracts, but to the development of service level agreements and to attention to the expectations and perceptions of the customer. It was not just the technology that mattered—its reliability, availability and security—but the customer-focused services around it. IT outsourcers were no longer judged by the number of bugs in their software and its usability, but by the empathy, adaptability, and competence of their staff. In IT, quality became a much more complex subject.

A third influence on IT departments has been ITIL which emerged in the 1980's as a UK government response to the need to increase the efficiency and effectiveness of IT in the public sector. ITIL was taken up by many companies during the 1990's and became the standard approach to running IT service operations. However, until the release of ITIL3 in 2007, the focus of ITIL was in service operations, and particularly in the support of information system applications. Strategy was not effectively addressed. This recent recognition in ITIL of the importance of IT as a service function and of the need for a service strategy has been recognized for some time in industry in IS management, and expressed in a central concern for alignment: alignment of strategy, alignment of operations, and alignment of culture. In ITIL3, the Service Strategy text (Iqbal & Nieves, 2007) recognizes that the purpose of IT, like any service organization, is to provide value to the customer. The service must ensure that the customer can use her assets effectively to achieve business outcomes which are produced by business processes. This suggests a massive shift away from IT as technical support to IT as a service organization delivering business value to its customers.

However, even ITIL3 is weak on the processes by which a service strategy is developed. This chapter proposes a set of steps that may be undertaken in developing a service strategy and develops an IT governance approach that complements the organizational structures suggested in ITIL3. It also draws from the management literature to suggest service strategy techniques.

BACKGROUND

The development of the field of services marketing from the late 1980s onwards provided a new set of concepts which could be used in the academic development of IT as a service discipline. An initial focus of service marketing was around the intangible nature of services (Brown, Fisk & Bitner, 1994; Bitner & Brown, 2006). A definition of the characteristics of a service remains of great significance to IT practice because of the contrast that can be drawn with a manufactured product. Although it should be recognized that the definition of a "product" in marketing is wide ranging, since a product can involve a service as part of its makeup—financial products are a good example, for the IT practitioner, the idea that IT can be portrayed as service can come as somewhat of a shock. For the IT professional, whose interest and training has focused on the technology and its construction, the idea that the IT system is subservient to the information delivery service it provides to customers, may be difficult to take on board.

While the goods vs. service paradigm has more recently been questioned (Lovelock & Gummesson, 2004), a consideration of the concepts provides a strong marker for the types of changes in management and attitude needed in IT services. Services are indeed intangible (Lovelock, Vandermerwe & Lewis, 1996). They cannot be stored. Once a service is consumed – usually at a time and place where the producer and consumer are both present – it cannot be reused, sold on or demonstrated. Unlike technical artifacts, the customer is an integral part of the service, must be present for the delivery of the services (excepting some electronic services) and takes part in service delivery.

Taking a service-centric view of IT means that the intangible and temporary characteristics of the service have wide-ranging consequences for the delivery of that service. The classification of services as service factories, service shops, mass services, and professional services according to the extent of customer involvement and the diversity of demand (Verma, 2000) has significant effects on IT delivery (Peppard, 2003; Rands, 1992). The extent of customer involvement can be managed and used as a basis for designing the service product.

The diffusion of service thought into the IT department has had significant effects on the management of quality. Service quality is itself ephemeral and difficult to measure. While the quality of the technical product, the IT hardware and software remains of importance, dimensions such as empathy, assurance and reliability come into play. Quality is much more a matter of customer expectation and perception, driven by the quality of service encounters and the perceptions of moments of truth rather than the internal quality of IT technology as defined in quality manuals. The development and use of SERVQUAL (Berry & Parasuraman, 1991; Parasuraman, Zeithaml & Berry, 1988), has had some influence on IT services and has been well explored in the information systems academic literature (Kang & Bradley, 2002; Pitt, Berthon & Lane, 1998; Pitt, Watson & Kavan, 1995; Yoon & Suh, 2004). Furthermore, DeLone and McLean (2003) in their ten-year review of their information systems success model, describe the need for service quality, as measured by SERVQUAL, as an extension to the model.

SERVICE-CENTRIC IT MANAGEMENT AND SERVICE-ORIENTED ARCHITECTURE

The recognition of the service nature of IT has not only been a concern of IT managers and information systems academics, but has also come to the attention of computer scientists. Spohrer and Riecker (2006), in their introduction to a special service sciences issue of Communications of the ACM, discuss the rise of the service sector and its influence on IT services. In that same issue, Rust and Miu (2006) suggest that it is the rise of the service sector which is driving a computer revolution. In other words they are suggesting a link between IT and Industry cemented by the spread of service concepts.

However, for many IT professionals and computer scientists, “service-oriented” refers to an approach to software architecture in which software agents are loosely coupled to fulfill an application need. Here, customers, or rather customers’ computers, request services from providers through a small set of well-defined, universally available interfaces. The service is then the unit of work offered by the service provider; and the customer can find out who can provide that service through a registry of services. The service-oriented architecture is used in the implementation of Web services (Barry, 2003). However, service-oriented architecture is about the design and management of dynamic technical architecture, not the management of people-oriented services.

Some confusion can be caused in IT circles by referring to the process of IT service management, which centres on the provision of service desks and the management of service operations, as service-oriented IT management. "Service-centric" may be a better term because it focuses on the service nature of the IT function. It is important to understand the need for a shift to a service mindset, which sets the technology – even service-oriented architecture – in the context of the people it serves.

The join between service-oriented architecture and service-centric IT management may be found in the glue of the service-level agreement which will define the nature of the service and the quality parameters of the service. Service-oriented architecture then provides a framework for delivering the technical components required as part of the service. IT service managers must then worry about the delivery of the service as a whole.

IT STRATEGY AND IT SERVICE STRATEGY

One field where the changes from techno-centric to service-centric should have a significant effect is in the field of strategic information systems planning. If we look at the academic literature, the underlying perception of strategic information systems planning has been that it is an exercise in defining a portfolio of information systems to be developed or procured which will contribute to the organization's competitive strategy (Earl, 1989; Elliot & Melhuish, 1995; Fidler & Rogerson, 1996; Hackney & Little 1999; Ward & Peppard, 2005). The focus of such academic strategic exercises has moved away from competitive advantage towards a model using the resource-based view of the firm (Gordon, Lee & Lucas, 2005; Mata, Fuerst & Barney, 1995; Ward and Peppard, 2004). However, those models that are found in the literature take a techno-centric view of IT. Their concern is to identify a set of system requirements that can then become systems development or procurement projects. Their goal is to align the outputs, the strategy, and the development of IT with the whole business.

In organizations where information system planning occurs, the concern is with identifying projects that can be implemented (Earl, 1993). However, the view taken of projects may be more service-centric in industry. The role of the Chief Information Officer, ultimately responsible for information systems planning, may be more as a deliverer of cost-effective services. But there is a paradox here. This industrial shift from a focus on a technology portfolio to a focus on a service portfolio, with the accompanying development of a service-centric mindset, may be achieved at the cost of any role for IT management in driving business strategy (Teubner, 2007).

Indeed, there is a wide gap between academic discussion of strategic information systems planning and industrial practice. Industrial practice puts IT in a much more realistic context as a service provider, supporting the information and business processes of the organization.

Its role is then more behind the business than in front. IT strategic concerns differ significantly in academic studies as compared to business practice (Teubner, 2007).

Additionally to the academic-practitioner gap, there is a gap between the service-centric focus newly found in IT departments and the competitive, business strategy focus of the organization. An IT service department, following ITIL guidelines, may end up being less strategically focused than a techno-centric IT department.

But even in the context of a service-centric IT department, the services that are supplied are support services, in support of technical artifacts. The role of IT is again too limited. It is, in a sense, hiding behind the technology. Information Technology's service role is then in servicing business processes through the delivery and maintenance of technology. This is still the prevalent philosophy of ITIL v3 where the service disciplines of ITIL version 2 are maintained. The service involves support areas such as managing the availability of technology, managing incidents when technology fails, and providing contingency plans for dealing with any disasters occurring to technical capital.

Hence, even in a service-centric IT department, which is aware of the importance of services and pursuing ITIL best practice, the services offered are still techno-centric. It is still a case of services in the support of technology, rather than technology supporting services.

THE CASE FOR A SERVICE STRATEGY

Where organizations take a service-centric view of IT, adopt ITIL, and pursue ISO20000, they run the risk of focusing on the operations and neglecting strategy. The core of ITIL is about the efficient running of service processes, not the evolving of service portfolios to meet changing business needs. The focus remains on the smooth running of the technology.

Services designed within IT services are often support services for organizational customers, e.g. a service to support desktops, or a service to procure and support ERP. They are not business services. A business process or business unit may require a service from IT services. That service will involve infrastructure (system hardware, systems software, DBMS, networks) and applications. The business functionality and requirements will be decided, teams appointed, suppliers appointed and the service delivered. The model in ITIL3 Service Design (Lloyd & Rudd, 2007), still suggests focus on the IT systems to support the system. Requirements engineering is about the functional requirements; the design outputs are essentially the classic systems development outputs—forms, user interface, object model, use cases, and process models.

IT governance may be designed around the technology or around business groups (Sambamurthy & Zmud, 1999). Departments may be grouped around technical expertise—desktops, networking, Unix, for example, or by business grouping—sales, product development, marketing, manufacture, for example. However, IT governance is implemented, and however frequently it oscillates between different organizational structures, it can remain focused on the IT artifact.

What is required is an approach to IT service strategy and IT governance which puts the IT artifact back in place as only part of a business service or process. Such an approach should consider the whole service of which the IT artifact is only a part. It should involve the design of the whole service and the whole business process. The service-centric view should permeate the whole strategic process.

The following outlines a service-centric model for IT service strategy. The context is the IT governance model which structures the IT department around business services. The content is the output of the strategic exercise which is seen as a set of services to be designed, implemented and operated. The processes are a putative set of steps and modeling tools by which that output is obtained.

THE SERVICE STRATEGY MODEL

Context: Organizing IT around the Businesses Customer Facing Services

A service-centric model seeks to divide the IT infrastructure into service teams that support the services provided by the organization. Each team provides the information and system needs of a particular service element, business process or business function. A service-focused IT infrastructure then directs the attention of IT staff outwards to the organizations' services and customers and away from a notion of the primacy of the IT.

The service team may operate within a service unit. That service unit would be driven by defined service contracts and measurables. How the service is delivered would be up to the team. For example, the team would make decisions as to whether to meet the service need by tweaking an existing computer system, buying or building. Also the team would decide when to retire an existing computer system. The delivery of the service to the organizational service area or business unit should continue without the service customers needing to get involved with implementation of a new system and without them having to organize their activities according to an IT agenda. Thus the service team retains some autonomy concerning the delivery of the service. The IT service strategy then defines the nature of the service to be delivered, its scope and quality.

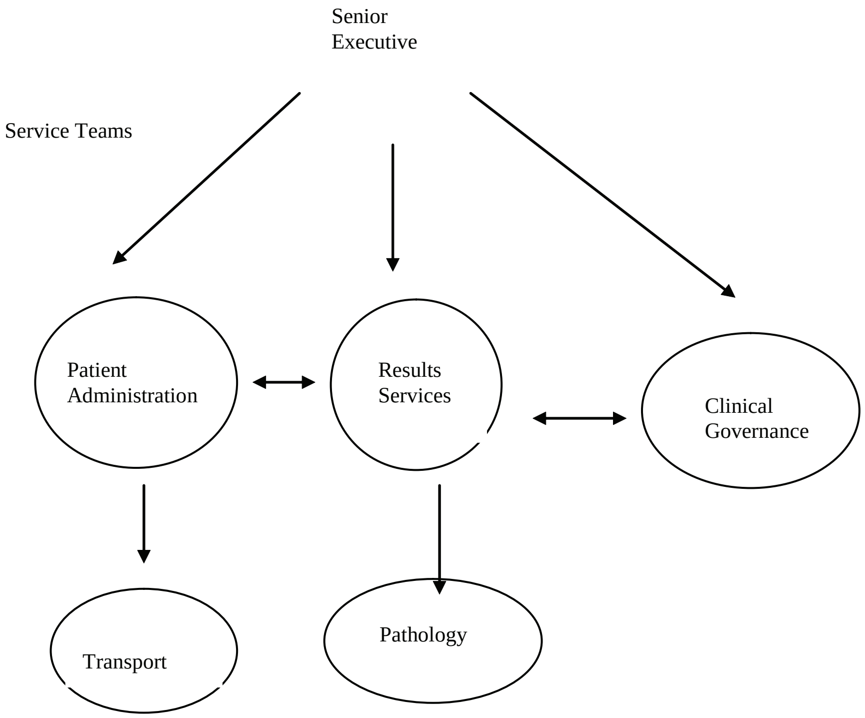
There are several key points to note in this model. Firstly, the focus of the service unit is on a business process. Whether that is loan processing, pharmaceutical sales, or patient administration, the process being supported is not an IT process. Secondly, the service unit team will need to be an integration of IT experts and business experts, all focused on the business needs. IT is subservient to, and only part of the business focus. Thirdly, it should be noted that the service is not just an infrastructure service. Services such as application maintenance, information security, and document management and disaster recovery may be part of the service unit, but they are all subservient to the business process.

Take a hospital as an example. In a hospital, a separate IT department delivers the IT requirements of the whole hospital. The department may concentrate on the large IT developments as the expense of smaller services, departmental and specialty needs. In a service oriented IT organization, there is no visible IT department. Technical expertise is grouped around business structures. An outline service-based structure for a hospital may be envisaged as illustrated in Figure 1.

Here, service teams support bounded areas of hospital services and processes. IT is an important part of each service team, and may be the primary focus of effort, but each service team has service outcome goals to meet, not technology delivery goals. At the top level, these might be:

- **Patient administration:** Provision of integrated information flows to support the entire patient experience from outpatients, through inpatients stay and operations to discharge, including connections with primary care and other organizations.
- **Results:** The results services provides information support and information systems support for the requests for diagnostic procedures including pathology, x-ray and other procedures, and the delivery of the results of those procedures inside the hospital and to requestors outside the hospital.
- **Clinical governance:** Provision of information to enable effective clinical practice, including provision of systems and services to enable evidence-based medicine, the development of integrated care pathways and the development of information databases to enable effective clinical audit. Clinical governance at a primary care group level will also be supported where it interfaces with the hospital.

Figure 1. Service-centric IT management structure for a hospital trust



These service teams may interact with more departmentally based service teams in for example, transport and pathology. Smaller service teams supporting specialist service requirements within particular specialties (for example, intensive care and Magnetic Resonance Imaging) might be formed as subteams within the patient administration or clinical governance service teams. However, note that each service unit is defined in terms of the service it delivers to meet the needs of its customer base, not in terms of the technology it supports or provides. If we replace the development of information technology strategy, with its emphasis on boxes and their technical implementation, with the development of service strategy with its emphasis on the delivery of services which make business processes work, which achieve business outcomes, we are freed up in two ways. We can consider business processes and their delivery without being constrained or slowed down by considerations of IT implementation, and we can be freer with our consideration of IT requirements for a business process because the technology requirements have not been fixed in an IT strategy, but can be changed and adapted as required.

The effect of such an IT service structure may be to:

- Generate a service culture;
- Move the IT interface right next to the appropriate hospital services;
- Enable faster support for changes in services or processes;
- Generate greater understanding of the IT within the service area and
- Generate greater responsiveness from the technologists.

It should be noted that the skills set within the service teams would need to extend beyond the IT to the organizational services. A Patient Administration Service team would need to understand the processes in outpatient clinics, medical records, ward-based services and theatre. Practitioners from these areas would be part of the team; defining services and working on the delivery of these services in concert with IT-Skilled staff who would quickly gain business and service understanding within the area. These teams may be managed by organizational service-centric staff. For example, clinical governance may be managed by a clinician.

While ideally the business and technical skills should be encapsulated within the service team, which is able to develop the service set and apply IT understanding to deliver it, we recognize that, in large organizations, economies of scale may demand that some of the IT elements are delivered by technical teams. For example, IT networking may be delivered by a networking team whose customers are the various service teams. Such technical elements may be outsourced.

However, an overall service philosophy can be used. In a service-centric IT infrastructure, business services are supported by IT services which draw on applications, training, and information resources to deliver a holistic service which meets the service needs for information and does not just focus on technology. This contrasts with a traditional model in which a computer application is built for the business and IT services support the computer application (Figure 2)

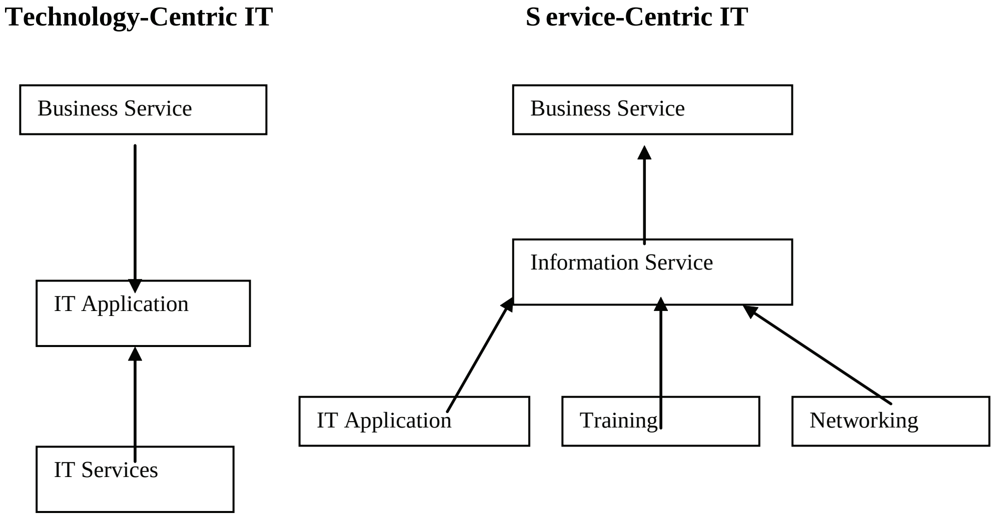
Content: IT Service Strategy as a Portfolio of Services

The content of an IT Service strategy focuses on the nature of the services to be delivered by the service teams within the IT management infrastructure and not on the computer systems and technology.

The content of the strategy will consist of a series of service definitions together with explanations of the philosophy behind each service and the strategy for service-delivery. At a greater level of detail, the IT service strategy would define the service level agreements and the level and type of service the internal customer might expect.

It may be appropriate for the strategy to define the resources required to deliver that service in terms of computer systems and applications, networking, staff training, IT staff and so on. The risk here is that the definition of the technology within what is a service strategy, moves the focus right back to the technology. However, it may be more effective to leave that level of implementation strategy to the service teams and restrict the IT

Figure 2. Changing from IT application focus to information service focus



service strategy to a definition of services, service content and SLA which the service teams will have to adhere to. Such a focus on services reduces the risk of the strategist's attention being deflected by the technology needs and hence the technology actually driving the service definitions.

The contents of an IT Service Strategy may include:

- Definition and description of business/customer services provided by the organization;
- Definition of the service teams and mapping of service teams to business services or business units;
- Description of mission and scope of each service team, including definition of strategy and philosophy behind the service;
- Definition of services provided by each team presented as a service catalogue;
- Description of service including a diagram of the service processes, delineating service team, activities, customer activities and the interaction between the two;
- Definition of one or more SLAs associated with that service;
- Constraints on service;
- Information provision associated with that service;
- Summary of resource requirements focused on enabling costing and pricing of the service;
- Definition of quality measures associated with each service and description of process by which quality will be monitored, particularly including a definition of the outcomes expected from the service and the measures associated with those outcomes;
- Management policies associated with the service;
- Definition of any generic services which may be provided on behalf of the service teams, either centrally or outsourced. Examples may include installation and maintenance of physical IT infrastructure and servicing of PCs.

The IT service strategy provides a blueprint for the development of IT services within each service group. The level of detail for the definition of each service may vary. In some cases it may be appropriate for the service team to negotiate the SLAs with the business services it supports. Also, depending on the maturity of the service area, significant service innovation and design may be required.

Process: Developing an IT Service Strategy

The process of developing the service strategy may be tackled in a number of ways. A top-down/bottom-up approach may be considered, as has been used in Method/1 (Earl, 1989; Lederer & Gardiner, 1992). Alternatively, a more evolutionary approach may be considered. Regardless of the process model, a number of tasks must be tackled. Suggested tasks in the development of an IT Service Strategy follow:

Definition of business services. An understanding of what the organization does and the structure of its services must be gained since this will be required for mapping IT services and service teams to business services. If we take a purist service view, then where a company provides products we need to consider the customer service that the product is part of. This may generate ideas for new business services which will require IT services. The definition of services that are provided by the business should be split down enough to generate service support requests (i.e., definitions of what IT services are needed to make that service work or to underpin the service.).

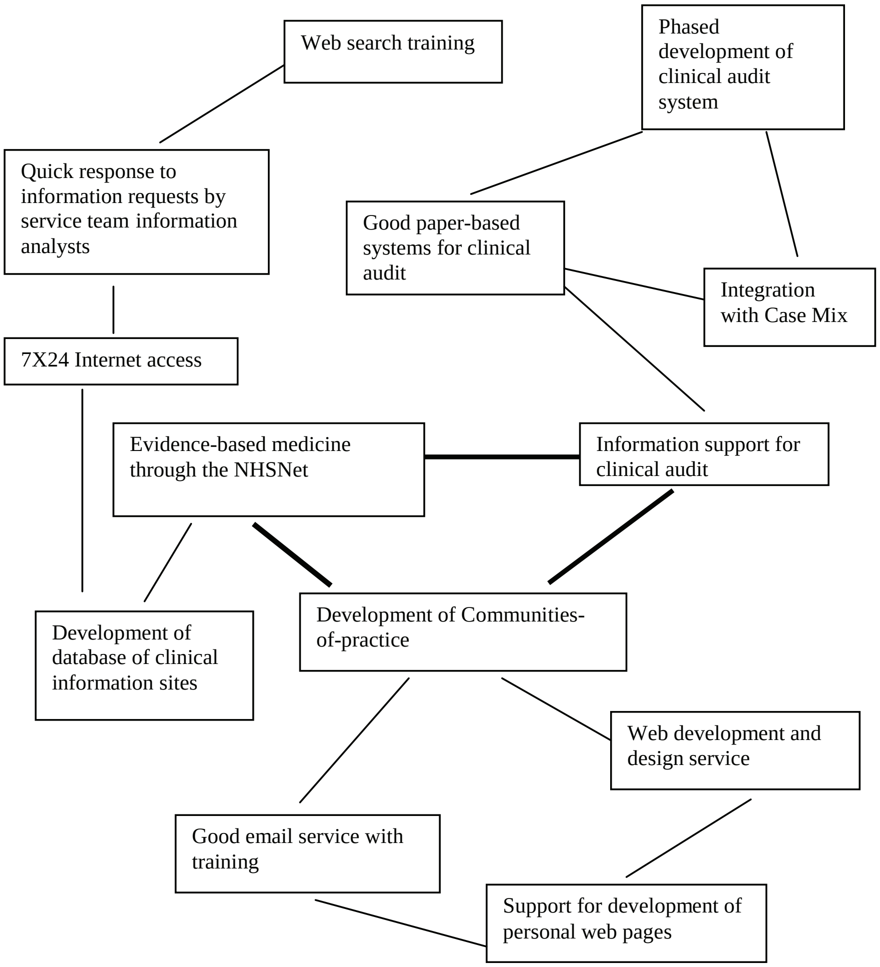
The definition of business services will require a detailed understanding of the customer and her business processes. Iqbal and Nieves (2007) see this step as driven by a marketing exercise.

Customer outcomes are analysed and a service catalogue defined to match them. Such an approach may be weighted toward type 3 services which are outsourced. Here the outsourcing company is trying to develop services – usually IT services—which will attract customers in a competitive market. In type 1, insourced IT services, an emphasis on the business processes of the host company may be more appropriate.

Definition of Service Teams. The analysis of the business's services will lead to the construction of a IT management structure consisting of a series of service teams which map to the business services.

Definition of service strategy. For each service team a service strategy should be developed. Competitive analysis and an analysis of organizational effectiveness may be carried out at this stage. While traditional management tools such as five forces and value chain can be used in determining the strategy (Botton & McManus, 1999), we would recommend the use of activity-system maps (Porter, 1996) An activity-system map enables the principle philosophy of the service and the activities which will be used to implement that philosophy to be defined (Edvardsson et al., 2000). Figure 3 illustrates an outline activity-system map for the clinical governance service team. Note that the strategy exercise is driven by

Figure 3. Outline activity-system map for clinical governance service team



the service needs of the business, taking a service view of both the organization and the information systems within it.

Definition of services. Exact service provision should be defined for each service team. Draft SLAs should be developed based on the business needs. Information needs should be explored and an initial set of services defined. Definition of services may also involve service innovation. It is in this step that technology innovation should be considered as a basis of new services. Services should be defined at a high level. Detailed service design may not take place until an understanding of current IT services is carried out and a gap analysis done.

Analysis of current IT services. Current IT in the organization may be product-oriented. The IT needs to be considered as a portfolio of services, so an understanding of how IT can currently be represented as services will be needed.

Gap analysis. Gaps between current IT services and the services required within the service teams will need to be analysed. The IT services will be mapped to the service teams. It is at this point that consideration of which IT service elements should be delegated to the service teams and which might be provided as a generic service may be considered. For example, while network administration may be offered as a centralized, generic service, all application development, application support, systems procurement, user training, and system evolution should be allocated to service teams. It should be a policy to minimize generic services since these can only be provided at a distance from the business services. We would suggest that the proliferation of generic IT services may only serve to widen the IT/ business service gap and reduce business effective and service focus.

IT business integration. Once the service gaps are understood plans can be developed for the integration of IT services and the business. How each service team is going to obtain its IT resources and take over appropriate applications should be considered.

Definition of SLAs. At this point there should be sufficient information and understanding of the services to generate detailed SLAs. These will involve negotiation between members or potential members of service teams and the business service areas.

Implementation. Detailed SLAs provide the core of the strategy. At this point a detailed IT service strategy can be written up and the focus moves to service team discussion of how the SLAs are to be fulfilled. Guidelines for implementation may form part of the written IT services strategy, but detailed implementation should, we suggest, be left to the service teams to encourage ownership and a close fit with the business services.

The IT service strategy development process needs to be conducted in a flexible manner. Since the strategy definition is a service in itself, the project team must contain a significant number of active representatives from the business service areas. Service innovation cannot be done without close involvement of internal customers. In planning the strategy development process, internal customer involvement must be defined.

CONCLUSION

It is widely recognized that there is a need for the integration of IT service elements with the business services. This process of alignment has become a major concern for IT departments. Alignment of IT services with the business it serves involves an engagement with the purpose and strategy of the business. The chief information officer cannot retreat into service support, while changing from a focus on the artifact and the technology to a focus on the service and the people. The strategic view must not become myopic. There must be continued effort to contribute strategically to the business.

Furthermore, the academic/practitioner gap must be bridged. Practitioners see strategy in terms of pursuing themes and investigating new technologies. Academics see strategy as using resources strategically to deliver competitive advantage. Both views are important and should be integrated.

While many writers have addressed the issue of IT services—for example, Applegate, Austin, and McFarlan (2003) see the managing of IT operations, the provision of reliable and secure IT services, and the management of diverse IT infrastructure as integral to corporate information strategy—the attention to service concepts is limited. There is a tendency to become techno-centric in both service strategy and service design.

At the core of this chapter is the idea that everything is a service. Even the most technical product is only of value when it is used in a service. The car is an element of a transport service. The computer is a part of an information service.

This chapter involves a call for a service first, technology second philosophy. Technology supports service. It is designed in the context of the service. Therefore at both a strategy and design level, the main concern of the IT service department should be in the developing of the service into which supporting technology is fitted.

Hence, the strategic exercise should be about the definition of services to be provided by the IT department. And those services should be business process services, centred on the services that the organization provides to its customers. Then the focus of IT is on its service catalogue, the list of what services it provides to its customers. This is of importance to its customers. For example, the service the customer gets in managing patient administration or the service the customer gets in managing materials planning is at the centre of the strategic exercise.

The information system tools used to deliver those services are of little interest to the customer, provided they support the service adequately. The technology used as platforms for those services—the relational database, the network system, the servers—and how the technology is implemented is not only of no interest to the customer but is more a positive hindrance to the customer's goals.

IT within organizations is becoming pervasive. The use of computers is a natural part of most business roles. The computer control of business environments, processes and activities is a given. But computers are not only becoming pervasive in organizations, they are disappearing. Eventually IT will become so embedded in the environment that the use of the technology will become as natural as breathing. In such an environment, technical issues are not a concern of the user who is only aware of a service, of the business processes that are being supported.

In such an environment, IT is seen by the customer as being responsible for the processes. The service is seen as business processes delivered to enable the internal customer to earn revenue for the business in some way. The technology behind those processes is invisible to the customer. It is a black box, a taken-for-granted. Issues concerning breakdowns of technology are invisible to the user: dealt with by IT without disturbing the customer. It is assumed that IT takes the best technical decisions concerning the technical support of processes and the provision of the invisible infrastructure, the invisible computers. There is no need for the customer to talk about the technology or even consider it. The customer comes to IT to talk about services, the request new services, to consider changes in existing services.

In terms of strategy, the IT department delivers those services; so the strategic exercise is about services. This chapter has provided one possible framework for developing that service strategy.

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Chapter 2.8

Perspectives of IT-Service Quality Management:

A Concept for Life Cycle Based Quality Management of IT-Services

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ABSTRACT

This chapter introduces an IT-Service management framework for the use of quality management concepts in the context of the life cycle phases of IT-Services. It argues that IT-Service management, combined with quality management and a life cycle approach for IT-Services provides a new perspective for organizations to provide high quality IT-Services. Based on the IT-industrialisation and an increased customer orientation in the IT-Service management the aspect of quality becomes increasingly important. Therefore, the authors give an overview about existing concepts of IT-Service management, life cycle management and quality management for IT-Services. The aim is to support organizations in the effective use of quality management concepts depending on IT-Service life cycles.

INTRODUCTION

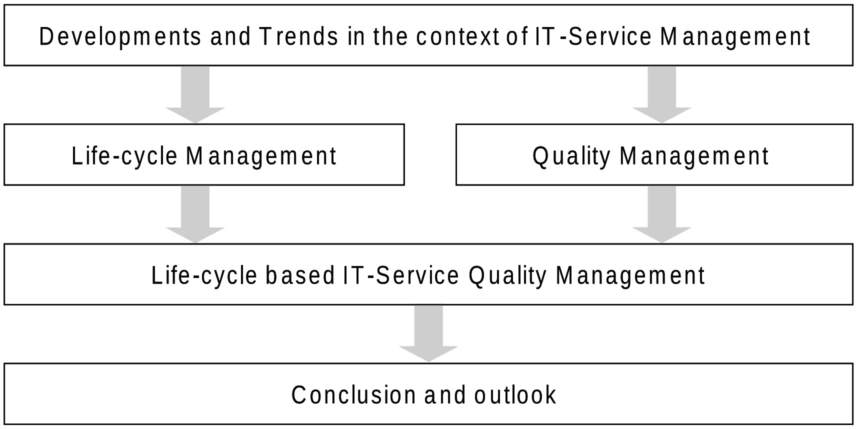
In context of IT-Governance there are numerous concepts and models that can enable organizations to be more effective and more efficient in using IT-Solutions. IT-Governance is supposed to help organizations to enhance their competitiveness by using Information Technology (IT). On the one hand a big issue in this discussion is the realization and evaluation of the business value due to the use of IT (Weill & Ross, 2004). On the other hand the constant change of business needs also demands a reliable and effective IT support for the business processes. Therefore IT-Governance and IT-Business alignment are key success factors for creating business value due to the use of IT-Services in an organization. In the wake of constantly changing business requirements the existing IT-Infrastructure and the IT-Services which support the business processes have to adapt as well. The developments in Information Technology and IT-Service management enable organizations to use IT-Solutions in a way which differs completely from earlier concepts. Therefore the management concepts for IT-Service management have to adjust to these new developments. In this situation the quality of the provided IT-Services becomes an important issue for IT-Service providers and service recipients. Hence quality management is one important aspect in the context of IT-Governance.

Experiences from the industrial sectors show that organizations are able to achieve strategic and operational targets concerning quality and customer satisfaction by using quality management approaches. In the context of IT-Quality management, IT-Governance defines the rules for the decision making process and competencies within an organization. It describes the framework for the IT-Strategy and defines the guidelines for the IT-Service management within an organization. Based on the importance of service quality, as outlined above, this chapter focuses on the quality management of IT-Services in dependence on the life cycle phase of IT-Services.

In the current discussion about IT-Services and quality management has so far not provided a concept which integrates these two dimensions in a life cycle based concept for IT-service quality management. This chapter aims to close this gap and provide a model which enables organizations to map selected quality management methods with previously defined phases of an IT-Service life cycle. The goal is to present managers a practical approach for matching quality management methods with life cycle phases of IT-Services.

From a research point of view, relevant questions concern the possibilities of transferring quality management concepts from the industrial sector to IT-Service management. In the context of the developments for IT-Service management it is important how a holistic life cycle for IT-Services can be illustrated. The final research question in this chapter focuses on mapping the different life cycle phases of IT-services and quality management concepts. To answer these questions the chapter will follow the structure outlined below (see Figure 1). It illustrates the several aspects in the context of life cycle management and IT-Service quality management which shall be merged into an integrated model of life cycle based IT-Service Quality Management.

Figure 1. Structure of the chapter life cycle based IT-service management



Following Glass Ramesh, and Vessey (2004) the described solution promoted in this chapter is a conceptual analysis and an instrumental development based on a design science approach (Glass et al., 2004; Hevner, March, Park & Ram, 2004). In IT research science the design science creates and evaluates IT artifacts intended to solve organizational problems. In this context the organizational problem is the use of adequate quality management methods for IT-Service management within an organization. IT artifacts are generally defined as constructs (vocabulary and symbols), models (abstractions and representations), methods (algorithms and practices), and instantiations (implemented and prototype systems) (Hevner et al., 2004).

This chapter focuses on illustrating a model for the transfer and use of quality management methods depending on the life cycle phase of an IT-Service. One research hypothesis is that the transfer of engineering focused quality management methods to IT-Service management can support IT-Service providers and organizations to improve the quality of their IT-Services.

The first part of this chapter provides an overview of selected developments in IT-Service management and describes and the relation between the trends and their impact for IT-Service Quality Management. The following part introduces the life cycle concept for physical products and transfers this approach to a life cycle concept for IT-Services. The third part presents the basics of quality management, the total quality management concepts as well as several concepts in context of service quality. The fourth part integrates the life cycle concepts with quality management and presents a concept for a life cycle based IT-Service quality management approach. It also offers a brief overview of the theoretical basis of the concept. This combination of life cycle concepts and IT-Service quality aspects enables organizations to match selected quality management methods with the different phases of the IT-Service life cycle and achieve increased service quality and customer satisfaction. The final part describes opportunities for further research and highlights challenges for the organizations in case of quality management for IT-Services.

DEVELOPMENTS IN IT-SERVICE MANAGEMENT

During the past years IT-Departments and IT-Service providers have been faced with new challenges. The main challenges are internal restructuring of the IT-Department, the importance of service orientation caused by increased market and customer orientation as well as the industrialisation in IT-Service management. As a result of the increasing focus on efficiency and performance, organizations recognize that the operation of IT is not their key competence. Hence the organizational structure of IT-Departments is changed from internal cost centres to market oriented service providers. Organizations have started to evaluate the added value and performance of their internal IT-Departments and benchmark them against market offers from external IT-Service providers. On the one hand, this follows in a changed position of the IT-Departments and IT-Service providers as well in a modified situation for managing IT-Services. On the other hand, this results in an increasing procurement of IT-Service via external markets for IT-Services (Kotabe & Murray, 2004).

To illustrate selected trends and developments in IT-Management this chapter shows the need for a new concept of IT-Service quality management. The goal is to emphasize important developments in IT-Service management and show their impact on the IT-Service quality management.

According to the situation mentioned before, there is an increased market and customer orientation in the IT-Management sector. The different departments in an organization become customers of the IT-Department or an external service provider. As a result, the relationship between the several departments and the IT-Provider is similar to a partnership with external customers. Both parties work together on basis of defined service levels under real market conditions.

Therefore, market and customer orientation makes new demands on IT-Departments and IT-Service providers. They are forced to define products and services which are provided for the customers. The definition of IT-Services, the "product" of the IT-Department, becomes a key challenge for the IT-Management (Zarnekow & Brenner, 2004). The development and customization of suitable service packages will be a future challenge for service providers in general (Spath, van Husen, Meyer & Elze, 2007). "IT-Products" are a combination of different IT-Services which support business processes (Uebernickel, Bravo-Sànchez, Zarnekow & Brenner, 2006). From a service providers' point of view, this product orientation implies that a portfolio of offered services has to be defined and regularly updated to the customers` demands. From a service recipient point of view, the IT-Service portfolio has to be actively managed and continuously adapted to the changing business requirements and the business processes.

The increased focus on business value and performance results puts an increasing pressure for IT-Service providers to improve their efficiency. In this context, the term "industrialisation" describes the transformation of productivity methods from the industry sector to IT-Service management.

There are four basic aspects concerning the IT-Industrialisation (Hochstein, Ebert, Uebernickel & Brenner, 2007): Firstly, automation and standardization, that is, IT-cost reduction due to standardisation of business processes and IT-Services. According to the standardisation of processes, there is also efficiency potential due to automation. The second aspect focuses on the modularisation of IT-Services. Comparable to the production industry the modularisation here enables the customizing of services to individual customer demands due to the use and combination of different standardized IT-Modules (Böhmann & Krcmar, 2003). Schnabel, Dold, Fröschle, Layer, Roll, and Skempes (2006) highlight the capability of customization of services to the stakeholder requirement as a key success factor especially for service companies. The third aspect of industrialisation focuses on the quality management and the implementation of continuous improvement processes within the providers' organization. Thanks to the use of quality management concepts, processes have to be improved, become more efficient and enable performance measurement (Hochstein et al., 2007). The fourth aspect is focussing on core competencies and fostering the outsourcing of processes and business fields which are not relevant for creating a unique selling proposition. According to this principle the depth of the value added chain in the organization will be reduced. Furthermore, this enables an organization to react faster on market developments and to provide high quality services for the market.

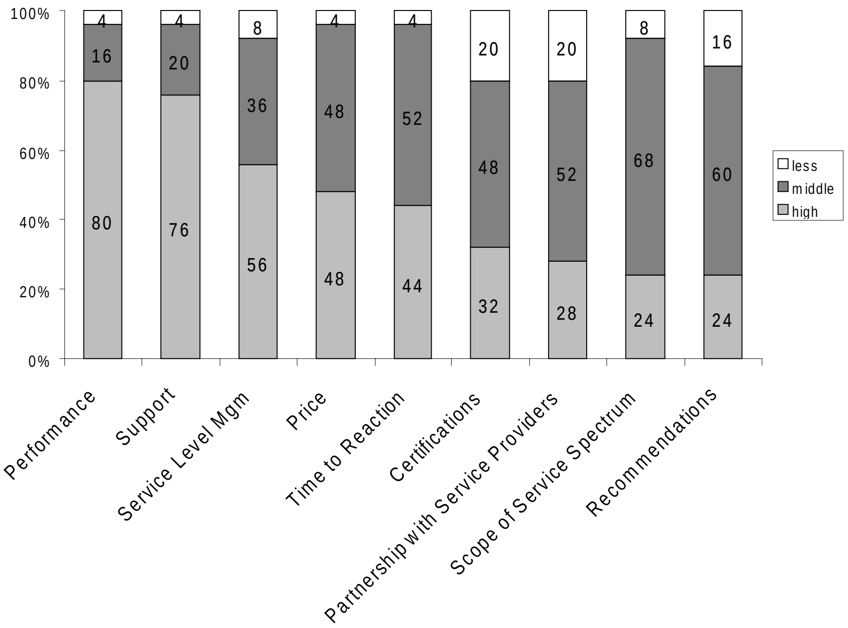
From a customers' point of view the focus on IT-Services highlights the increased meaning of the quality of IT-Services. Service quality is the output of different organizational processes and procedures which ensure a constant level of performance by systematically engineering IT-Services (Spath & Demuß, 2003). The quality parameters of IT-Services, like availability, reliability and functionality, instead of technical aspects of IT-Application and infrastructure should therefore be high priority (Zarnekow, Hochstein & Brenner, 2005). As a consequence of this increased service orientation and the supply of IT-Services through external providers, there is also a need for a systematic quality management by providers as well as service customers to ensure the availability and the quality of the IT-Services. Due to the increased meaning of IT-Services, the technical aspects became less important and. the "engineering" of IT-Services is pales in comparison to the perceived quality of the service provision. For IT-Departments and IT-Service providers this means an increased significance of quality management of offered IT-Services and customer services.

A survey form the IT-Service Management Forum (itSMF) in Germany, comprising 122 participating service providers and service recipients, highlights the importance of the offered service portfolio and the quality of the customer service (Praeg & Schnabel, 2006). This market survey proves that today, the most important criteria for customers in choosing an IT-Service Provider, is the performance of the IT-Service provider followed by the support and the performance of the service level management of an IT-Service provider (see Figure 2).

The results show that the price of the services is not the critical factor for organizations contracting a service provider. Customers focus on performance and quality of an IT-Service provider. The service quality depends strongly on the customer specific perception.

Therefore, the primary target of the IT-Service management is to align the offered service portfolio to the customer requirements and adjust the IT-Service portfolio to the customer demands regularly. To foster this management concept, the IT-Service providers must recognize that IT-Services have their own life cycle when used by the customers. The meaning of the IT-Services will change according to the change of the business processes which follow changed market situations. This concept of life cycle based management of IT-Services is not yet very common in existing IT-Management concepts. Most of the actual and instruments of IT-Management in practice are focused on separated phases (planning, development, operation) of IT-Management. But there is an important gap in the relation between the stages of the IT-Management phases. Therefore the following chapter gives an overview of different lifecycle concepts which can be adapted and used for the IT-Service management.

Figure 2. IT-Service provider selection criteria's from customers' perspective



LIFE CYCLE BASED APPROACHES FOR IT-SERVICE MANAGEMENT

The developments outlined in the previous chapter illustrate the increased product orientation of IT-Services. Within an organization, IT-Services are managed like a portfolio (Zarnekow et al., 2004). This product orientation means that the IT-Services have to be managed comparable to physical assets in an organization. Compared to the life cycles of physical goods IT-Services have shown an equal development when they are being used in organizations.

Originally, life cycle concepts have been used in the context of engineering and managing physical products. The aim here is the distribution of existing resources in dependence of the life cycle phases and also the management of costs and benefits within the life cycle. Based on these experiences the concept of life cycle management was adapted for software and application development (Mercurio *et al.*, 1990). Regarding IT-Service management there are also different concepts which directly or indirectly consider life cycle phases. The subsequent paragraphs present selected concepts of life cycle based IT-Service management.

Life Cycle Model of Physical Products

In general, a life cycle characterizes the different stages of a product during its market appearance (Bullinger, 1994). The product life cycle management is the process of managing the entire life cycle of a product. For that reason the traditional life cycle concepts are described from a market perspective. For physical products the life cycle covers several phases, from conception, design, testing to manufacturing, market introduction and the disposal of products. In the first phase of the life cycle the products' requirements are defined based on customer and markets demands. In the following phase the detailed design, development and also the testing of prototypes are center stage. This covers many engineering tasks and disciplines. These phases generate the highest costs for an organization. The subsequent life cycle phase focuses on the growth and the maturity period, before the product runs out of the market (Macharzina, 2003). The final phase of the product life cycle is the replacement of the product by other, new products. The challenge for organizations as well as IT-Service providers is the transformation of this product life cycle to the requirements of the IT-Service management. Thanks to life cycle management, organizations are able to get products faster on the market, provide improved support for their use, and manage end-of-life better. In today's highly competitive global markets, companies must meet the increasing demands of customers by rapidly and continually improving their products and services (Stark, 2004).

Concerning IT-Service management, the existing methods can be separated in public domain approaches and nonpublic domain approaches.

IT-Infrastructure Library (ITIL)

ITIL was developed at the end of the 1980's by the British Office of Government commerce (formerly Central Computer and Telecommunication Agency (CCTA)). ITIL is the de facto standard for IT-Service management and it is the most widely adopted approach for IT-Service management (Sallé, 2004). The ITIL framework is a collection of best practice processes for IT-Service management.

In the updated third version a life cycle based structure for IT-Service management was implemented. The different phases are Service Strategies, Service Design, Service Transition, Service Operation and continual Service Improvement (OGC, 2006). The Service Strategy defines the targets and the guidelines for the IT-Service management. The phases Service Design, Service Transition and Service Operation represent the implementation, operation and change of

IT-Service management within an organization. The continual service improvement supports the internal implementation of improvement programs and projects. One important issue of the ITIL version 3 is a glossary of standard terms and definitions, it emphasizes the integration between business and IT-aspects and should support the implementation of value added networks between IT-Service Providers and service recipients.

Control Objectives for Information and Related Technology (CobiT)

CobiT was developed from the Information Systems Audit and Control Association (ISACA) and is promoted by the IT-Government Institute. It is designed to be an IT-Government aid for the management in identifying and managing the risks and benefits associated with IT. CobiT creates the link between the business objectives of an entity and the specific IT and IT-Management tasks via statements about the control objectives (Sallé, 2004).

The CobiT-Framework covers a life cycle concept that is oriented on the use of IT within an organization and it is closely connected to the IT-Governance. The CobiT Framework identifies four domains which are covering 34 IT-processes. Furthermore, it defines 318 detailed control objectives and audit guidelines to assess the 34 IT-processes (Sallé, 2004).

The domains are Planning & Organization, Acquisition & Implementation, Delivery & Support and Monitoring. The domain Planning & Organization covers strategy as well as tactics and identifies ways on how IT can support the achievement of the business objectives most effectively. Acquisition & Implementation focuses on the identification, development or acquirement of suitable IT-solutions. The Delivery & Support domain is concerned with the actual delivery of required services. The Monitoring domain focuses on the assessment of quality and compliance with control requirements over time (Sallé, 2004).

Nonpublic Domain IT Service Management Methods

The HP IT Service Management Reference Model is a high level IT-process map, which provides a coherent representation of IT processes and a common language for defining IT process requirements and solutions. The model is structured around five groups: Business-IT alignment, Service design and management, Service delivery assurance, Service development and deployment and Service operations (Sallé, 2004).

The Microsoft Operations Framework provides technical guidance that supports organizations to achieve critical system reliability, availability, supportability, and manageability of IT solutions based on Microsoft products and technology. The process model is a functional model that operations teams perform to manage and maintain IT-Services. It is organized around four quadrants and twenty management functions the quadrants are changing, operating, supporting, and optimizing (Sallé, 2004).

The IBM System Management Solutions Lifecycle Framework provides a high level consulting road map. The four-phase process is similar to the former ITIL processes. The IBM approach considers the phases of process assessment, process improvement definition, analysis and design, and pilot deployment. Furthermore, there are extensions to provide an integrated and comprehensive solution (Sallé, 2004).

The Integrated Information Management Model

A life cycle concept focussing on information management is described by Zarnekow and Brenner (2003). The typical phases of the product life cycle, development, market introduction, growth, maturity and retention, can be adapted to a life cycle of IT-Systems which are defined as plan, built and run (Zarnekow & Brenner, 2004).

In their model of an integrated information management, they focus on IT-Products and describe the key processes and tasks of the life cycle from a service provider and a service recipient point of view (see Figure 3).

Traditionally, the IT-Management has a strong technology and project orientation. Conventional IT-Management focused on planning and developing IT-applications and maintaining IT-Infrastructures. Most of these tasks were organized in projects. Therefore, the management of the classical IT-life cycle is divided into three phases: Plan, Built and Run. Contrary to the traditional "plan, built and run" concept, Zarnekow and Brenner in their approach focus on the "source, make and delivery" processes (Zarnekow & Brenner, 2004). Accordingly, they regard the increased market orientation and the changed sourcing strategies of many organizations.

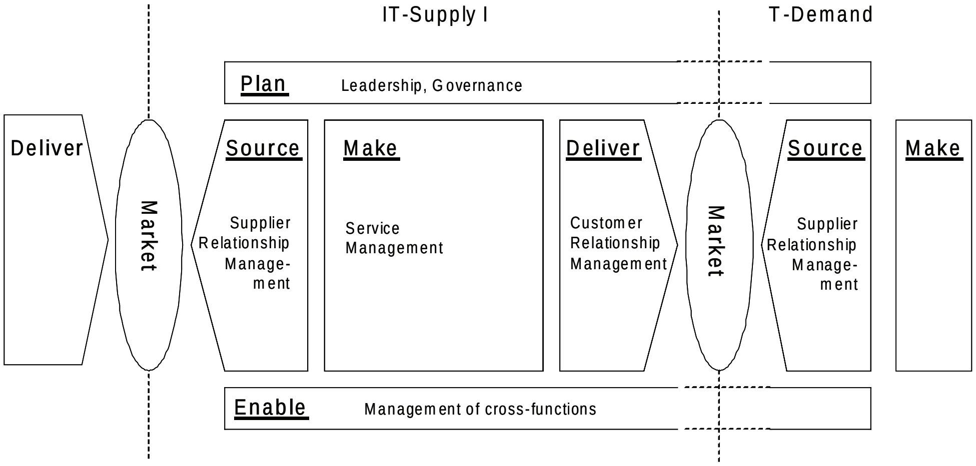
The sourcing process is the interface to the service provider and contains every task which is necessary for the procurement of IT-Products. The procured IT-Products are the basis for the "make"-process. This process describes all tasks which are necessary for the operation and maintenance of IT-solutions (Zarnekow & Brenner, 2004). The process is also responsible for managing the service portfolio, the development and the operation in the organization. The delivery process focuses on the customer relationship management. In this case, customers are all internal and/or external recipients of the IT-Services from the IT-Department. The delivery process comprises on the delivery of the IT-Services to support customers' business processes or other processes.

These concepts give a first impression that the benefits which accompany IT-Service in an organization will change during the different life cycle phases. For this reason it is necessary to have suitable and integrated management tools over the whole life cycle. Actually most of the life cycle concepts for IT issues are concentrate on the life cycle of software development projects (Zarnekow & Brenner, 2004). But the concept of Zarnekow and Brenner does not regard the entire life cycle. In this approach the life cycle ends with the operation phase and does not consider the replacement phase. The enhancement of the whole IT-Service life cycle is a real challenge for the IT-Management in organizations.

IT-Service Life Cycle Model

For the IT-Services there are different approaches which describe the life cycle of IT-Services in an

Figure 3. Integrated IT-Management model (Source: Zarnekow & Brenner, 2004)



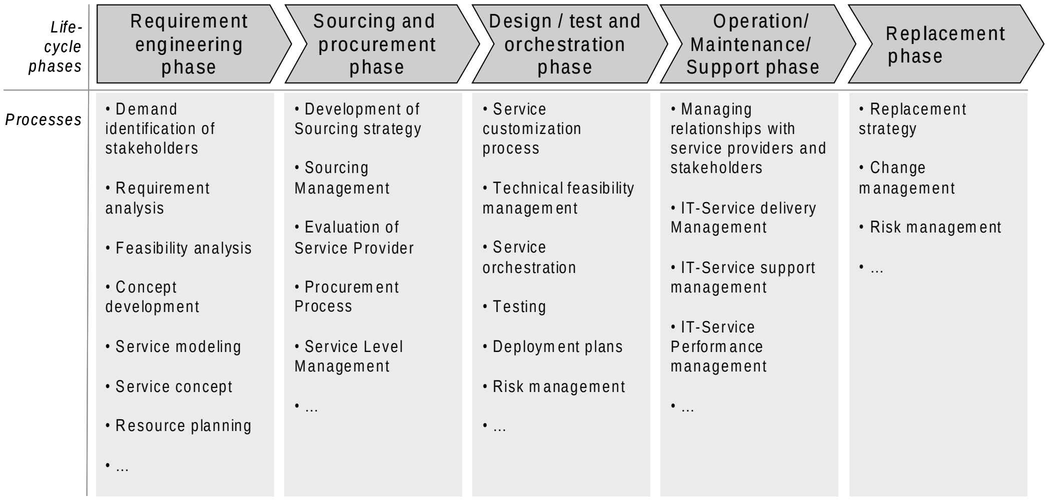
organization. Praeg and Schnabel introduce an IT-Service life cycle model which describes five phases for the IT-Service management (Praeg & Schnabel, 2006). This model describes a complete service life cycle which considers the phases from the procurement until the replacement of the IT-Services. Other concepts do not consider this holistic view of an IT-Service life cycle. Contrary to the market perspective of a product life cycle this approach describes the IT-Service life cycle from an intraorganizational perspective.

As illustrated in Figure 4 this IT-Service life cycle model can be separated into five phases. The first phase, requirement engineering, considers all aspects which are necessary for the definition of requirements for IT-Services. In this phase it is necessary to know about the customer demands and consider the internal organizational structure, i.e. business processes as well as the existing IT-Infrastructure within the organization. As a result, during this phase the organization is able to document a description of the concrete service demands as well as a specification. With regard to the quality requirements in this phase it is necessary to ensure that the customer demands and expectations concerning the services are analyzed as detailed as possible. This is the foundation for the sourcing of IT-services from internal or external service providers.

The next step in the IT-Service life cycle covers the sourcing and procurement phase. After defining the service and customer requirements, potential service providers are identified and requested to submit an offer. Practical experience shows that the offers from different service providers differ in structure, wording, and complexity. Therefore, it is difficult to evaluate and compare the different offers with each other. Another common problem is the lack of suitable methods especially when it comes to finding and evaluating a suitable service provider. In this situation, the quality management must provide a suitable concept to evaluate the different offers as well as the service providers by providing a proofed set of quality indicators (Praeg & Schnabel, 2006).

During the design, test and orchestration phase a detailed description of the IT-service parameters is set up, the performance indicators have to be created and the measurement procedures have to be documented. The test must consider the quality in business process support, usability aspects as well as the interfaces to other IT-Services. Furthermore, the orchestration of the available IT-Services has to be tested and validated with re-

Figure 4. IT-service life cycle



Life-cycle phases	Requirement engineering phase	Sourcing and procurement phase	Design / test and orchestration phase	Operation/ Maintenance/ Support phase	Replacement phase
Processes	• Demand identification of stakeholders • Requirement analysis • Feasibility analysis • Concept development • Service modeling • Service concept • Resource planning • ...	• Development of Sourcing strategy • Sourcing Management • Evaluation of Service Provider • Procurement Process • Service Level Management • ...	• Service customization process • Technical feasibility management • Service orchestration • Testing • Deployment plans • Risk management • ...	• Managing relationships with service providers and stakeholders • IT-Service delivery Management • IT-Service support management • IT-Service Performance management • ...	• Replacement strategy • Change management • Risk management • ...

gard to quality and performance. In this phase, the quality management has to provide test routines and configuration tests must ensure the availability and reliability of the IT-Support of the business processes. Additionally, it should start with the implementation of adequate structures, processes and methods for quality management.

The phase operation, maintenance and support cover all concepts which are relevant for a high quality service delivery. Most of the existing IT-Service management concepts focusing on this phase (Praeg & Schnabel, 2006). In this context existing IT-Service management and IT-risk management approaches can be used to support users in managing IT-services. With regard to the quality requirement for this phase, the quality management must ensure that the IT-support of the business processes is top-performing. Additionally, a continuous improvement process has to be implemented which ensures that the requirements for IT-Service quality management are met.

The final phase of the life cycle focuses on the replacement of IT-Services. Due to changed business requirements or technical developments the replacement of IT-Services could become necessary. In this phase, the demand made on quality management is to hold up the business processes and manage the possible risks caused by the replacement.

Conclusion for the Life Cycle Concepts

The benefits of a life cycle oriented management for the IT-Service management in organizations are obvious: It enables organizations to analyze new IT-Projects as well as the evaluation of the existing IT-Landscape. During the planning phase, it supports the management decision concerning the expected benefits from new IT-Services and it fosters the development of an organization-wide IT-Service portfolio management. For existing IT-Applications and services, the life cycle concept supports the economic evaluation of the possible detachment of IT-Solutions. Today, most of this decisions are made ad-hoc with neither an economical foundation nor an institutional management process (Zarnekow & Brenner, 2004).

Recapitulatory, we can see that the different phases of the IT-Service life cycle define the requirements for the quality management. The previous chapter showed that the business value of IT-Services as well as the requirements according to quality management will change during the life cycle. Hence, adequate methods for the service management as well as the quality management are necessary for an organization.

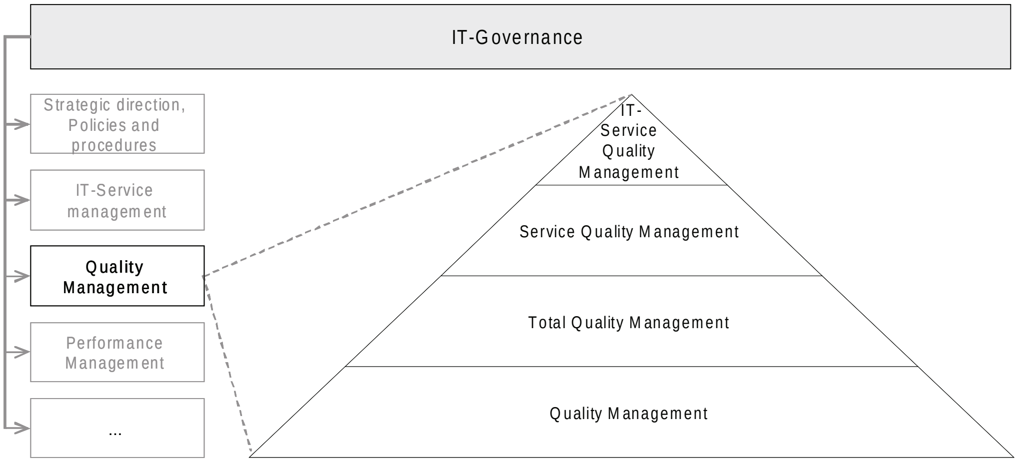
OVERVIEW OF SELECTED QUALITY MANAGEMENT CONCEPTS FOR IT-SERVICES

The quality of services is a key success factor for service providers in the market competition. Therefore it is important for the service providers to find a suitable quality management concept for managing the quality of services. Regarding the IT-Service life cycle there is no possibility for a "one-size-fits-all" quality management. An IT-Service provider has to adapt different quality management methods and match them with the different phases of the IT-Service life cycle. This chapter gives an overview about selected quality management concepts which are relevant in the context of IT-Service management. As illustrated in Figure 5, the structure of this chapter starts with a definition of quality and quality management. Based on this, quality management is introduced and selected approaches for service quality are described. The final part describes concepts and requirements for IT-Service quality management.

Quality and Quality Management

In general, the International Standard ISO 8402 defines "quality" as the total characteristic of a

Figure 5. From quality management to IT-service quality management



product or service concerning their suitability to fulfil predefined requirements (ISO 8402). Based on this definition there are two perspectives for the interpretation of the term "quality":

Firstly, quality can be described as the "degree to which a set of inherent characteristics fulfils requirements" (ISO 9000). This approach focuses on hard facts and objective criteria of products or services (product based view). Secondly, quality can be interpreted from a customers' point of view. In this case, quality is perceived by the customer conception (user-based). Contrary to the product based view, this approach focuses on the subjective perception of a service product by the customer. The customer individually evaluates the quality of a product or service with regard to his personal values. Hence, the challenge for companies is the fulfilment of a great number of heterogeneous customer demands (Bruhn, 2004).

The term "quality management" was intensively discussed in theory and in practice. Based on these discussions quality management can be described by the integration of all parts of the management which enable the internal and external analysis, planning, organization, operation and controlling of all quality relevant aspects in service offering by a service company (Bruhn, 2004). Quality management is the coordinated management task for governing an organization in terms of quality. Therefore quality management defines quality policies, quality targets, quality controlling and continuous quality improvement within an organization. To achieve these goals, quality management focuses on human resources within an organization and also considers business processes and the technological infrastructure. Based on this concept, quality of services and products is the result of a commitment from the employees to quality standards (Kamiske & Umbreit, 2001). Therefore, quality cannot only be defined and managed within an organization – first and foremost it has to be exemplified though the performance of all involved parties and employees. Besides this human aspect, quality management has to ensure that the existing processes and infrastructure enable the engineering of products and services with predefined quality levels. The management of quality also takes into account the use of different concepts and methods for achieving the quality goals in an organization. In the following paragraph selected concepts for quality management are introduced.

Total Quality Management (TQM)

The Total Quality Management approach is the foundation for an integrated quality management concept in an organization. But TQM is more than a quality management concept. Due to the high importance of quality, especially in service-oriented companies, TQM must be part of the corporate culture and strategy. It influences all management activities and leadership concepts which are used in the organization. For this reason, the conceptual basis of the TQM approach is that the management as well as the employees are responsible for the insurance and improvement of quality of products and services. Quality can not be "created" and supervised by audits. Quality must be implemented in the business processes and needs the commitment of each employee in the company (Deming, 1982). Hence, TQM focuses on all structures, processes, regulations, instructions, and measures which are relevant for ensuring and continuously improving the produced quality of products and services in all departments of an organization under participation of all employees to achieve the highest possible level of satisfaction of customer demands. The basis of this management concept is the conviction that quality is the most important key success factor for companies.

Translated into the context of service providers the TQM concept can be focused on three parts (Bruhn, 2004; Wonigeit, 1994):

- **Total:** The integration of all persons, which are involved in the service development and operation
- **Quality:** The consequent concentration on the quality demands of internal and external customers concerning all activities and processes in the service company
- **Management:** The responsibility of the management for a systematic identification with the quality culture and goals as well as continuos quality improvement.

According to the requirements of IT-Service quality management this means that customer demands, organizational structure, organizational and business processes, employee commitment as well as a quality focused corporate culture must be considered.

For the realisation of these requirements quality standards support organizations by the implementing adequate processes and structures.

The ISO 9000 Standard for Quality Management

The International Standards ISO 9000ff. define which requirements an organization have to fulfil in order to live up to a defined level of quality management. The most important standards out this collection are the ISO 9000 (describes fundamentals of quality management systems and specifies the terminology of quality management), 9001 (specifies requirements for quality management) and 9004 (provides guidelines that consider both the effectiveness and efficiency of quality management systems) (ISO 9000). The ISO 9000 standards interpret quality management as a leadership task for the continuous improvement of the organizational processes to meet customer requirements and expectation and generate customer satisfaction.

The standards promote the adoption of a process approach when developing, implementing, and improving the effectiveness of a quality management system (ISO 9001). According to the ISO 9001 "… this process orientation emphasizes the importance of:

- Understanding and meeting requirements
- The need to consider processes in terms of added value
- Obtaining results of process performance and effectiveness
- Continual improvement of process based on objective measurements."

The standard ISO 9004 suggests the implementation of quality management principles in order to lead organizations towards improved performance. According to ISO 9004 these principles are: customer focus, leadership, involvement of people, process approach, system approach to management, continual improvement, factual approach to decision making, mutually beneficial supplier relationship (ISO 9004).

Usually the ISO 9000 standards are oriented on conventional production organizations. They are focussing on distributed production processes and procedures which are typical for the production sector. Nevertheless, service organizations also recognized the advantages of a quality management system based on the ISO 9000 standards.

All the concepts and quality perspectives described above are originally developed from a traditional industrial oriented understanding of quality and quality management. Because of the focus on services in general and IT-Services in particular, it cannot focus on the customer demands but must also consider further requirements such as the competition and the general situation of the company.

Service Quality Concepts

During the last couple of years, service quality has become of great interest to researches as well as practitioners and managers. One reason is the strong impact of service quality to business performance, cost reduction, customer satisfaction, customer loyalty and profitability (Seth, Deshmukh & Vrat, 2005). Conceptual models of service quality enable organizations to identify quality problems and thus help managing a quality improvement program and support the improvement of efficiency and performance.

According to Bruhn (2004) service quality is defined “as the capability of a service provider, to provide primary intangible and customer oriented service on a predefined performance level corresponding with the customer expectations.” Based on this definition service quality represents a defined performance level of service.

For a systematic development and implementation of service quality management, certain requirements must be fulfilled. There are several criteria which help to evaluate the quality of services (Figure 7).

Figure 6. ISO 9000 process based quality management model (Source: ISO 9000)

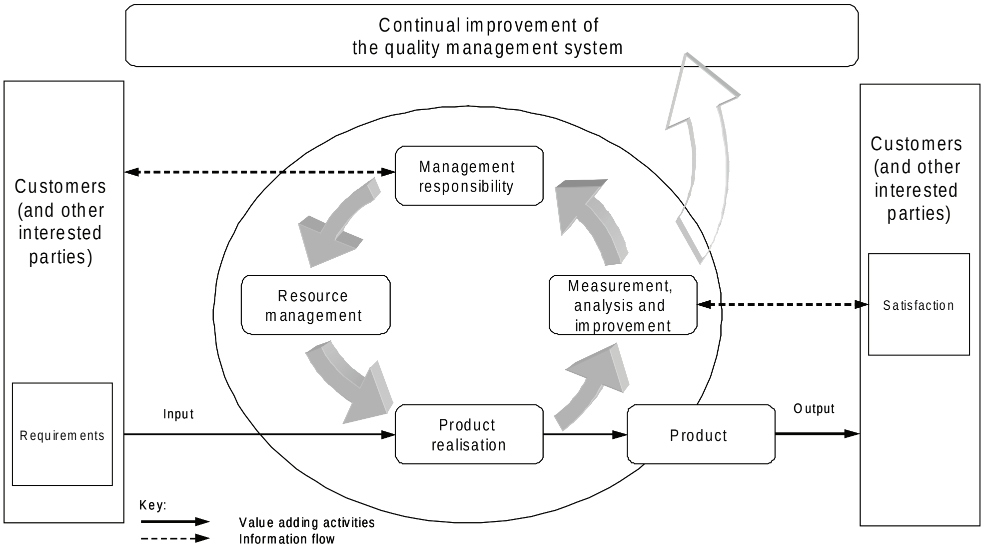
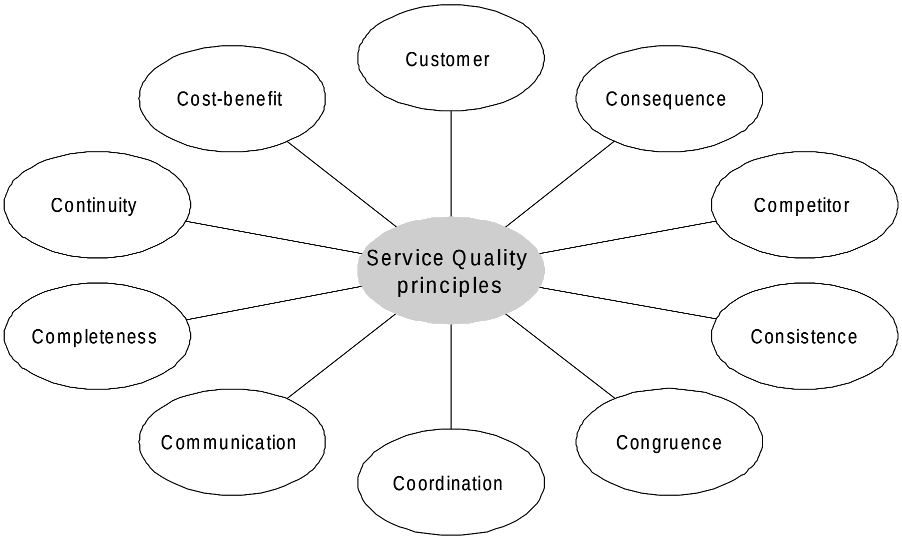


Figure 7. Service quality principles (Source: Bruhn, 2004)



As illustrated in Figure 7, there are ten principles describing service quality management (Bruhn, 2004):

- **Customer orientation:** For successful service management the perceived quality of service by the customers is a key success factor.
- **Consequence:** Everyone within the organization has to align with the customer orientation and there is a need for awareness for quality.
- **Competitor separation:** To be successful in competition, the service provider has to separate from competitors.
- **Consistence:** It must be ensured that from a customer's point of view there are no conflicts concerning form and content during service provision.
- **Congruence:** The internal behaviour of employees has to be conform to customer communication. The congruency between internal and external service and customer orientation is an important competition factor.
- **Coordination:** Every task in the organization has to be aligned to the quality goals.
- **Communication:** The internal and external communication of the organization must be aligned with the quality requirements.
- **Completeness:** The quality management system has to take up a holistic view on quality in the organization.
- **Continuity:** The implementation of an integrated quality management needs medium and long-term experience in the use of different quality management concepts, methods and instruments.
- **Cost-benefit orientation:** The development and implementation of a quality management system must take into account the costs and benefits due to quality management. Quality management must support the performance as well as the efficiency of an organization.

These perspectives of service quality are the foundation for the development of numerous service quality concepts. There are three characteristics of services which have to be considered when managing service quality: the intangibility of services, the uno-actu principle (concurrent providing and consuming of services) and the integration of external factors (Haller, 2002).

During the last years, numerous models have been developed for managing service quality. One common goal of all these models is to operationalize service quality in order to be able to measure and manage service quality (Bruhn, 2004). An overview of selected concepts of service quality management is documented in Seth et al. (2005). Due to space restrictions, only the models of Grönroos and Parasuraman are highlighted in the following paragraphs.

The model from Grönroos defines the perceived quality as the difference between the customer expectations and their experiences according to the service (Grönroos, 1984). For an organization this means that it has to match the expected service and the perceived service to each other so that customer satisfaction will be accomplished. A high service quality is achieved if the perceived quality is higher than the expected quality level. Grönroos identified three components of service quality: technical quality, functional quality and image. The technical quality is the quality of what customers actually receives as a result of the interaction with the service provider, the importance and the evaluation of the service quality (Seth et al., 2005). Functional quality focuses on how the customer gets the technical outcome and emphasizes the subjective perception. In addition to these two dimensions the image of an organization also influences the customer perception of the service quality. The image of an organization can enforce or weaken the perception of the technical and functional quality (Bruhn, 2004).

The GAP Model of Parasuraman et al. (1985) argues that service quality is a result of the differences between expectations and performance of the service (Parasuraman, Zeithamel & Berry, 1985). In their model Parasuraman et al. describe how consumer evaluate service quality. The basis of their model is the interaction between consumers and service providers and possible gaps in this relationship. The authors identified five possible gaps (Seth et al., 2005):

- **GAP 1:** Difference between consumers' expectations and the management perceptions of those consumer expectations.
- **GAP 2:** Differences between management's perceptions of consumer's expectations and service quality specifications.
- **GAP 3:** Difference between service quality specifications and service actually delivered.
- **GAP 4:** Difference between service delivery and the communication to consumers about service delivery.
- **GAP 5:** Difference between consumer's expectation and perceived service. This gap depends on direction and size of the four gaps mentioned before, associated with the delivery of service quality on the providers' side.

The performance expectations and the performance level are defined from a customer's point of view. Service quality has a strong focus on the customer demands and the customer perception of quality. For service providers this means that they have to match requirement according to expected services and perceived services to achieve customer satisfaction (Seth et al., 2005). For the measurement of the service quality a combination between the product-based view and the user-based view is helpful.

As a result of their exploratory research Parasuraman et al. identified ten quality dimensions which are relevant for the evaluation of the perceived service quality from customers' point of view. Based on this results they refined the SERVQUAL model for measuring customers' perception of service quality (Parasuraman, Zeithamel, & Berry, 1988; Seth et al., 2005). The SERVQUAL approach covers five dimensions which are used to measure service quality: reliability, responsiveness, tangibles, assurance and empathy.

Based on the developments in the IT-Service area which are described in the previous chapters, the IT-Service management has to adapt to the demands of IT-Services. In the past there are no international agreed standards which are focusing on the quality management of IT-Services. With the implementation of the International Standard 20000 this situation has changed.

The ISO 20000 Standard for IT-Service Quality Management

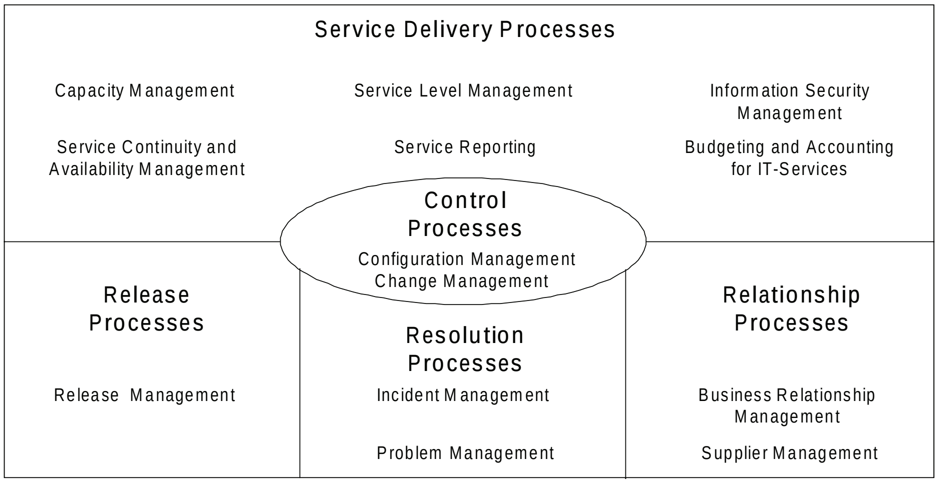
The ISO 20000 Standard suite provides a basis for a measurable quality standard for IT-Service management. It is the further development of the former British Standard (BS) 15000. Therefore the original orientation of the ISO 20000 standard was derived from the BS 15000. On the basis of the ISO 20000 standard organizations can be audited and certified to proof the compliance with this international standard. Furthermore the ISO 20000 fosters the implementation of an integrated process approach for the IT-Service management within an organization. The standard covers all aspects which are relevant to implement an optimal service management. Hereby the standard especially focuses on the service providers perspectives. ISO 20000 consists of two parts. The first part promotes the adoption of an integrated process approach to effectively deliver managed services to meet the business and customer requirements (ISO 20000). The second part is a code of practice and describes the best practices for service management within the scope of the first part.

The goal of the standard focuses on the provision of a common reference standard for all organizations which provides services to internal and/or external customers. Due to the great importance of the communication between service provider and service recipients one of the main targets of the standard is the definition of a common glossary for the service providers and their customers.

To ensure the provision of a defined quality of the IT-Services the ISO 20000 Standard specifies and describes the necessary processes which an organization has to implement to provide quality proofed IT-Services. For that reason the ISO 20000 Standard describes a set of management processes ("Objectives and Controls") which are oriented on the ITIL-processes and expand this process model (see Figure 8).

The ISO 20000 enables organizations to implement standardized processes for IT-Service management and supports the improvement of the IT-Service quality management.

Figure 8. Structure of the ISO 20000 model for IT-service management (Source: ISO 20000)



Conclusions for Quality Management Concepts

This chapter showed the basic concepts of quality management and service quality management. It was shown that the implementation of a quality management system in an organization is complex and is a strategically issue. Furthermore the overview showed that there are numerous quality management methods which can be used for organizational quality management. As a finding of the description of the different quality management methods it can be shown that from a management perspective quality management has to support the organizational goals in case of value, quality and reliability. At a high level primary management goals can be a high level of customer satisfaction, the organizational and business process performance, aligned IT-Services and –products, contracting the right IT-providers and achieve employee satisfaction. Based on these management goals, factors for quality management can be derived to manage the achievement of these goals. In this case quality management has to consider the following factors: customer demands, organizational structures and processes, IT-Services, service provider performance and employees. A challenge for organizations is to find the most relevant and suitable methods according to the life cycle phase. This mapping between quality management methods and the IT-Service life cycle phases is described in the following chapter.

MODEL FOR A LIFE CYCLE BASED IT-SERVICE QUALITY MANAGEMENT

The previous chapters illustrate basic concepts for IT-Service quality management and give an overview about life cycle concepts for IT-Service management. For the model which will be described in the following paragraphs the life cycle model from Praeg & Schnabel (2006) is the basis, because it is the only approach which describes a complete life cycle for IT-Services. With regard to the industrial sector it is common to use different quality management concepts on different parts of the organizational added value chain (Malorny & Kassebohm, 1994).

Due to the great number of quality methods and instruments and the limited space of this book we can only show the principle and make a suggestion about possible criteria for the matching between the life cycle phases and the quality management methods. The organizational implementation of this approach must regard the individual situation and competencies of the organization.

The mapping process between the IT-Service life cycle phases and the quality management methods is described in two steps. The first step covers the mapping between quality factors, derived from the methods in the previous chapter and the different life cycle phases. The reason is that each phase set different focuses for quality management. On this basis the second step in the mapping process is focussing on the association between quality management methods and the different life cycle phases. Each quality management method concentrates on the support and the fulfilment of one or more quality factors. Therefore for each life cycle phase different quality management methods can be used to support the quality factors. As illustrated in the following paragraphs there is no strict one-to-one mapping between a life cycle phase and a quality management method. Due to the different situations and competencies in organizations a regit one-to-one mapping makes no sense. The intention here is to sensitize organizations and IT-Managers to think about using suitable quality methods in dependence of the situation according to the expected goals of the IT-Service management instead of focusing on one quality management method for IT-Service management. In the following paragraphs the process of mapping is illustrated.

Mapping of Quality Factors

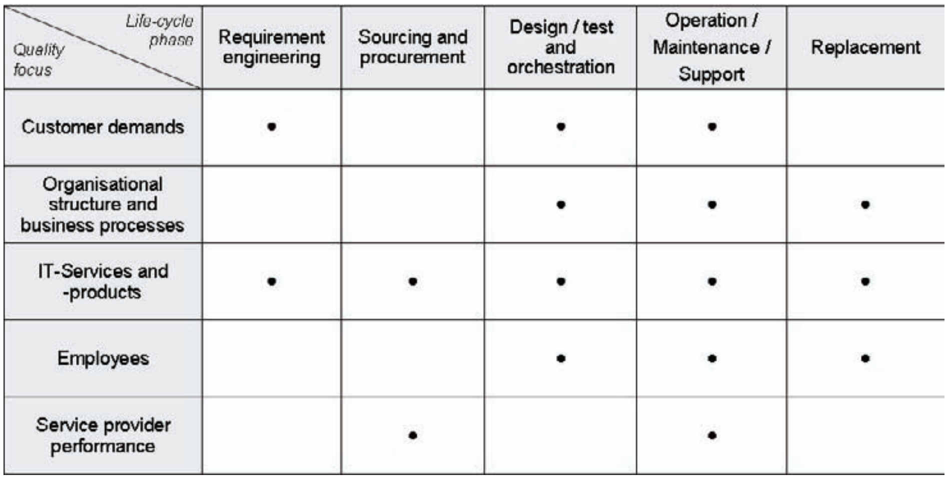
To match different quality management methods with IT-Service life cycle phases the life cycle approach described here suggests a two-step procedure. In the first step organizations have to think about the quality factors which are aligned with the strategic goals. The quality factors are the targets for organizational management. These are the outcomes from the use of quality management methods. The quality management methods are focusing on input variables which have an influence on the later outcome. Therefore it is necessary to implement an PDCA cycle (plan-do-check-act) (Deming, 1982) to measure how the different input variables influences the outcome in case of quality and in case of the achievement of the quality factors. Based on the results of Chapter 4 the following factors for managing quality within organizations and according to IT-Service are relevant for the life cycle based quality management approach:

- Customer demands,
- Organizational structure and business processes,
- Product and services,
- Employees
- Performance of service provider

As previously described the relevance of these quality factors depends on the life cycle phase and will change from one phase to another. For example in the development phase of the services, the consideration of the customer demands is more important than the focus on service providers because the goal of this phase is the documentation on the requirements for the service based on customer requirements and demands. Therefore a quality management method which focuses on considering customer requirements is better matched with the goals of this phase than a method which focuses on organizational structures or business processes. Based on this fact Table 1 show the relation and relevance of the quality factors for each life cycle phase of the IT-Services.

The markers highlight the quality factors with the highest priority in each life cycle phase. By example in the sourcing phase quality aspects regarding to the IT-Services and IT-Service providers (internal and/or) external have a higher priority in this phase than aspects according to customer demands. Due to this evaluation Table

Table 1. Life cycle phases and quality factors



Life-cycle phase Quality focus	Requirement engineering	Sourcing and procurement	Design / test and orchestration	Operation / Maintenance / Support	Replacement
Customer demands	●		●	●	
Organisational structure and business processes			●	●	●
IT-Services and -products	●	●	●	●	●
Employees			●	●	●
Service provider performance		●		●	

1 highlights the focal points according to quality issues in each life cycle phase.

Mapping of Quality Management Methods

In the second step of the life cycle based quality management procedure, selected quality management methods are mapped with the life cycle phases based on the focus of the quality criteria. Due to the scope of the quality management methods it does not make sense to restrict one quality method exactly to one life cycle phase. Based on the connections between different phases the use of the quality methods may vary.

As shown in Figure 9 the quality concepts described in the previous chapter do not depend on a life cycle phase. They are defining the framework for the quality management. The quality management methods are mapped with the life cycle phases of IT-Services.

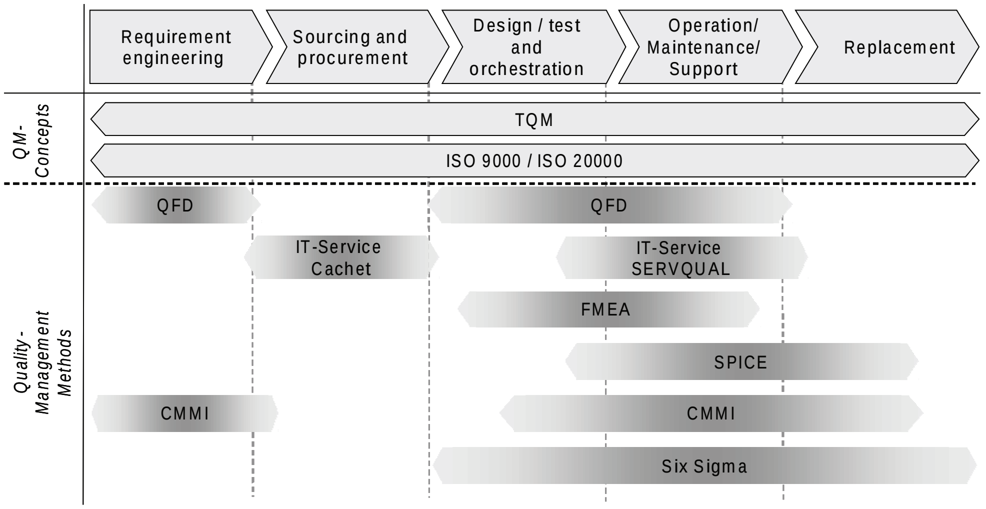
As illustrated in Figure 9 it is necessary to map one or more adequate quality management methods to the different life cycle phases. The quality factors help to select the suitable methods due to prioritize the importance of the items.

Quality Management Methods for the Life Cycle Phase 1

From a quality management point of view it is necessary to focus on the customer demands in the first phase of the IT-Service life cycle. As seen in Chapter 0 quality of service is defined by the customer requirements. Therefore it is required to find an adequate quality management method which focuses on the customer demands and requirements. But on the other hand the other quality items must also be considered in this phase but with a minor priority. As a result in this phase a quality management method is needed, which focuses on customer requirements and also consider business processes, products and services with a minor priority.

In this case the Quality Function Deployment (QFD) is a suitable method. Quality Function Deployment is a method which focuses on the planning phase of quality management. QFD supports the transformation of customer needs into engineering characteristics (and appropriate test methods) of a product or service, prioritizing each product/service characteristic while simultaneously setting development targets for product

Figure 9. Life cycle phases and quality management methods



or service development. QFD can strongly help an organization focus on the critical characteristics of a new or existing product or service from the separate viewpoints of the customer market segments, company, or technology-development needs.

The QFD method covers a six-step process. The first step focuses on the identification of relevant customer groups. In a second step the customer demands and requirements are documented and evaluated. The third step focuses on the derivation of necessary performance and quality indicators, followed by the definition of target values for each goal in the fourth step. In step five possible negative or positive correlations between the different performance and quality indicators must be analyzed. The final step focuses on internal or external customers evaluates the provided services and compares them with the services from competitors. The results of this process are documented in a so called “House of Quality” (Bruhn, 2004). The results of the technique yield transparent and visible graphs and matrices that can be reused for future product/service developments.

Quality Management Methods for the Life Cycle Phase 2

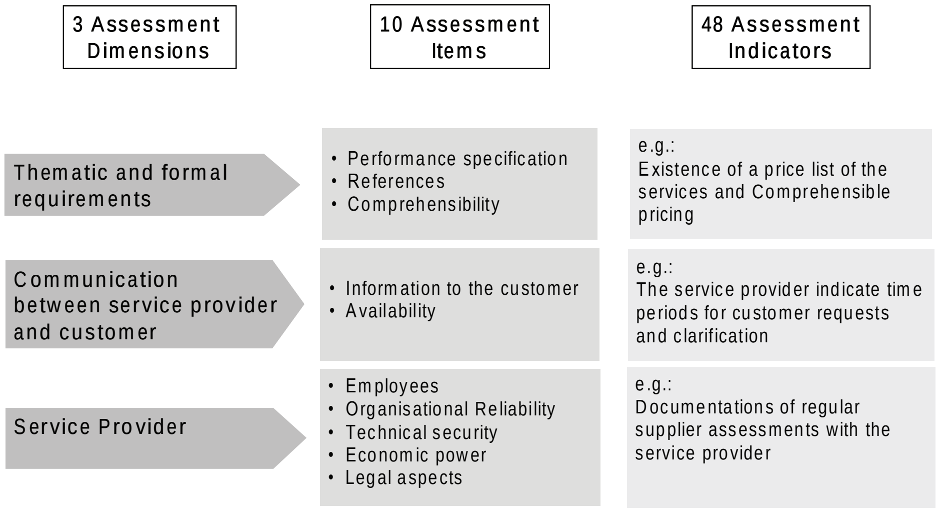
In the following phase the priority will change. After defining the requirements for the services there is a need to find a suitable IT-Service provider. Due to the developments described in Chapter 0, an internal or external IT-Service provider must be found for delivering the IT-Services. From the quality management point of view, it is required to evaluate the IT-Service provider prior signing the provider contract. In this phase a suitable quality management method must focus on the evaluation of the quality of an IT-Service provider and should also consider aspects of business processes and the delivered services. In this case organizations could use the IT-Service Cachet (Praeg & Schnabel, 2006).

The IT-Service cachet is developed by a consortium of IT Service Management Forum (itSMF, Chapter Germany) together with well-known IT-Service providers and the participation of the Fraunhofer Institute for Industrial Engineering and other research institutions. The Cachet supports organizations in evaluating IT-Service provider from a customer point of view. The cachet is developed to audit service providers concerning the quality of their offers and IT-Services from a customers’ point of view in the IT-Service procurement process (Praeg & Schnabel, 2006). To define a quality management approach for service some characteristics of service have to be considered. It must be taken into account that services are intangible and their quality is only measured with difficulties. The second aspect refers to the uncertainty in the procurement process, which exists from the customer point of view to minimize the possible consequences of an erroneous decision as far as possible. Even after completion of a contract it must be possible to evaluate the current efficiency of the service provider in a fast and simply way according to the quality management with suitable features. The decision process from the user site would be simplified and the decision maker will be supported according to the quality of his decision through a proved and guaranteed minimum level of service quality. Therefore, the customer of the IT services can easily check the price-performance payoff and is able to evaluate whether it is a good offer or it is just “cheap.”

The primary target groups of the cachet are service providers, which should be audited by means of the IT-Service cachet. However, the cachet is also helpful for the service recipients evaluating the service offers from the providers.

The evaluation catalog for the IT-Service cachet contains 48 assessment criteria to evaluate the quality of the IT-Service offers. The cachet measures the different quality dimensions with the level of fulfilment of quality indicators. These

Figure 10. Structure of the IT-Service Cachet



indicators for the service offers can be separated into ten dimensions.

The first part describes the "thematic and formal requirements of the offers," the second part focuses on the "Communication between service provider and Customer" and the third part concentrates on the characteristics of the "Service Provider." For each part several assessment items are developed which are measured due to assessment indicators. For each assessment indicator, there is a detailed description on how to measure, document and evaluate the criteria and there are defined levels of fulfilment (Praeg & Schnabel, 2006).

Quality Management Methods for the Life Cycle Phase 3

The third phase of the defined IT-Service life cycle describes the development, orchestration and testing of the IT-Services. Hence the quality items organizational structure and business processes as well as the services have a high priority in this phase. Therefore adequate quality management methods must regard these aspects. In the area of the software development there are some quality management methods which can be used for this phase. But it has to be mentioned that these methods have to customize to the requirements of IT-Service management.

In this phase suitable quality management methods are the Failure Mode and Effects Analysis (FMEA), Capability Maturity Model, software process improvement capability determination (SPICE) and the ISO 15504.

From a service provider's point of view the avoidance of failures is a central aspect for the quality management. Especially due to the concurrent providing and consumption of services an improvement of the delivered service is not possible. For this reason the Failure Mode and Effects Analysis (FMEA) is a method, which enables organization previously analyzes and evaluates potential problems and risks before they are realized. Therefore the FMEA method provides a risk assessment technique for systematically identifying potential failures in a system or a process. Failure modes mean the way, or modes, in which something might fail. Failures are any errors or defects, especially ones that affect the customer, and can be potential or actual. Effects analysis refers to studying the consequences of those failures. Comparable to the production area, there are three types of FMEA for services (Bruhn, 2004):

- System FMEA, which focuses on the organization as whole or different departments,
- Subsystem-FMEA, which focuses on service components and their interaction and
- Process FMEA, which focuses on the business and service processes.

The process of the FMEA covers the steps of failure description, risk assessment, generating suitable measures and the evaluation of the achieved results. The FMEA method supports organizations in controlling and managing the quality of IT-Services during various phases of the product life cycle.

The Capability Maturity Model Integration (CMMI) is a process improvement approach that provides organizations with the essential elements of effective processes. For the quality management CMMI can be used to improve the management maturity as well as the quality of services. According to a five level scale the processes of service providing can be systematically analyzed and the management quality improved. Originally CMMI was developed by the Software Engineering Institute from Carnegie Mellon University in 1987. This method is focused on the structured and systematically improvement of software engineering processes. During the past years CMMI was adapted to several other business areas. The CMMI model describes five levels of process maturity. On the first level (initial) there are processes defined. On the second level (repeatable) several tasks for a process management are implemented and processes can be managed with repeatable levels of performance. In the third level (defined) processes are defined and documented within the organization. The level four (managed) focuses on the quality and performance measurement of the existing processes. Level five (optimized) demands for the implementation of continuous improvement programs in the organization for optimizing quality and performance of processes.

The software process improvement capability determination (SPICE) method was originally developed for managing the software development processes. The SPICE approach is also a maturity management method which supports the quality and performance of implemented services in an organization. The SPICE method is a two dimensional approach for managing development processes. The first dimension consists of the processes that are actually assessed (the process dimension which is grouped into five categories). The second dimension consists of the capability scale that is used to evaluate the process capability (the capability dimension). The same capability scale is used across all processes (El Emam & Birk, 2000). The ISO/IEC 15504 is an international standard on software process assessment. It defines a number of software engineering processes, and a scale for measuring their capability. In ISO/IEC 15504, there are 5 levels of capability that can be rated, from Level 1 to Level 5. The rating scheme consists of a 4-point achievement scale for each attribute. The four points are designated as F, L, P, N for Fully Achieved, Largely Achieved, Partially Achieved, and Not Achieved (El Emam & Birk, 2000).

Quality Management Methods for the Life Cycle Phase 4

In the fourth phase of the life cycle the operation, maintenance and the support of the used IT-Services must be managed in the organization. Most of the established IT-Service management concepts are focussing on this phase of the life cycle (Praeg & Schnabel, 2006). From the quality management point of view it is necessary to focus on the business processes and the organizational structure which is responsible for the Service providing. Additional to this the quality of the service provider is also from high interest as well as the service itself. Therefore suitable quality management methods must consider these aspects in a proper way.

In this phase possible quality management methods are Six Sigma and IT-Service SERVQUAL.

Six Sigma is a quality management concept which focuses on the improvement of business processes in organization. It is a statistically based quality improvement program which should organization help to improve business processes by reducing costs resulting from poor quality (Hensley & Dobie, 2005). It should also support improving the levels of efficiency and effectiveness in processes (Hensley & Dobie, 2005). These processes improvement should result in an improved customer satisfaction with the firm's products and services and an increased firm's profitability (Antony & Banuelas, 2001).

The most common used tool in the six-sigma concept is the DMAIC cycle (define, measure, analyze, improve, control).

- During the definition part the processes for improvement are identified and the identified problems as well as the targeted goals are documented.
- In the measurement part the focus is on the measurement of the current process and collect relevant data for benchmarking and also determination how good the process meets the customer expectations is made.
- The analyze-part concentrates on the verification of relationships and causality of the quality factors. It determines what the relationship is and attempts to ensure that all factors have been considered.
- The improvement part optimizes and improves the process based upon the analysis using techniques like Design of Experiments.
- The part control ensures that any variances are corrected before they result in defects. Set up pilot runs to establish process capability, transition to production and thereafter continuously measure the process and institute control mechanisms.

Six Sigma was originally used in manufacturing environments but there are also transformations to the service sector. Especially financial service companies started to use Six Sigma to improve the customer satisfaction (Hensley & Dobie, 2005).

The traditional SERVQUAL is an instrument for analysing functional performance of service units. It is an instrument for assessing customer perceptions of service quality (Hochstein, 2004; Parasuraman et al., 1985). Characteristic for the SERVQUAL approach is that the different quality dimensions are measured with indicators. Quality is defined as the gap between the real value and a target-value. SERVQUAL is a multi-attributive measurement procedure, which uses five dimensions to define service performance quality. Parasuraman et al. (1985) developed this multiple-item approach consisting of five quality dimensions:

"Tangibles" describe the convenience of the material environment in which the service is rendered. Facilities, premises, technical equipment, phenotype of the staff etc., are part of it. "Reliability" is the trustworthiness of the supplier that indicates the ability to deliver the promised performance reliably and exactly. "Responsiveness" concerns the availability of the support, that the customer at the demands of the service (open-mindedness). "Assurance" refers to the safety of the performance claims on credibility of the supplier according to of competence, politeness and trustworthiness. "Empathy" concerns the ability of the service provider to cater to individual customer needs and the readiness to satisfy them (Hochstein, 2004; Parasuraman et al., 1985).

Therefore, the service performance quality arises from the difference between customer expectations and the customer perception. According to Donabedian, the five dimensions used in the SERVQUAL approach can be assigned to the dimensions of the process-, potential- and outcome- quality (Donabedian, 1980). While "Reliability" can be corresponded with the result quality and assigned to "Tangibles" and "Assurance" of the potential quality, analogies exist between "Responsiveness" and "Empathy" to the process quality (Praeg & Schnabel, 2006).

According to the special requirements Hochstein customized the SERVQUAL approach with regard to IT-Service management (Hochstein, 2004). In this approach IT-SERVQUAL is proposed due to adjusting elements for the traditional concepts and institutionalized to a service specific approach.

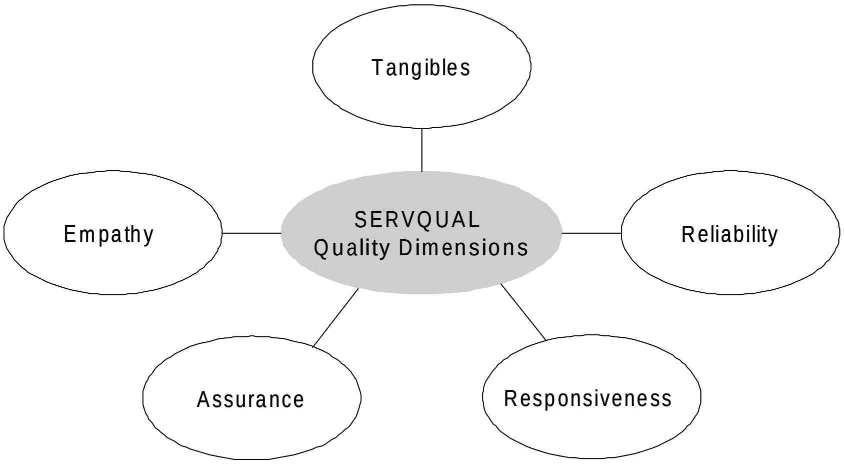
Quality Management Methods for the Life Cycle Phase 5

The final phase of the life cycle describes the detachment of the IT-Services which are no longer used in the organization. Most of the life cycle management concepts do not mention this phase but it is important to manage the detachment of IT-Services. Due to the connections and interfaces between different Services or due to a new release of an implemented serviced there is a need for the detachment of "old IT-Services" and it is also a great challenge for the organization to ensure the operation of the business processes. Therefore the suitable quality management methods have to consider aspects of change and risk management as well as the operational business process in the organization. In this phase the quality management methods previously described can also be used in this phase.

Conclusion for Life Cycle Based IT-Service Quality Management

This chapter shows the changing relevance of different quality aspects during the IT-Service life cycle phases. As a result organizations should use different quality management methods regarding to their individual situation. The described framework gives an example how organizations can map quality management methods with the changing requirements of the different life cycle phases to establish an effective and efficient IT-Service Quality Management. A great challenge from customer and providers point of view is the evaluation in which life cycle phase the different IT-Services are used. A further challenge will also be the organizational implementation of an adequate set of suitable quality management methods and instruments in the organization. Therefore the skills and capabilities for the selected quality management methods must be developed and systematically managed. It is obvious that the implementation of this model is a strategic decision

Figure 11. SERVQUAL dimensions



in the organization and it needs time to realize and establish this concept in the organizational management processes.

CONCLUSION AND OUTLOOK

This chapter showed that IT-Service quality management is an important issue for implementing and managing IT-Governance. Due to the dynamic developments in IT-Service management and the increasing focus on IT-Services, market orientation and use of external service providers as well as the quality management of services becomes more important for organizations. But not only on the customer side, there is a growing importance for this issue. The management of IT-Service quality becomes also a key success factor for internal and external service providers. In future, the satisfaction of changing customer demands will be a great challenge for them.

As a result of the industrialisation of IT in organizations, the services of IT-Providers will be more and more separated into individual IT-products which have several life cycle phases. Hence, the IT-Service quality management must consider the requirements of the different life cycle phases. The use of quality management methods have to be adapted to the demands of the life cycle phase and the business requirements.

This chapter illustrated a general life cycle concept of IT-Services and highlighted requirements according to the quality management and quality methods. Based upon this approach, a model for a life cycle based IT-Service quality management was developed. According to the traditional use case, the industry sector, the use of existing quality management methods must align with the requirements of the different life cycle phases. In the context of IT-Service quality management this perspective has not been adopted yet. In the past, there were a lot of discussions concerning the translation of approaches for service quality into the special demands of IT-Services, but the dynamics of IT-Service management were not considered.

For future developments there is a strong demand for the transformation of experiences from industrial quality management to IT-Service management. With regard to the production industry, the implementation of quality gates helps to ensure the quality from external providers. For IT-Services this concept must customized to the special demands of the organization and the services.

Due to the increased meaning of IT-Services and the importance of service quality as a key success factor, this topic has great potential and offers ample possibilities for future research. As seen in this chapter, quality management is a Top-Management issue for organizations. Consequently, there is a need for implementing suitable quality management concepts and research has to provide adequate evaluation concepts for improving quality management in dependence of the individual life cycle. Furthermore, there is a need for the organization implementation of the life cycle based IT-Service quality management. Especially the training of employees and the development of a quality focused culture within the organization represent great challenges for the management. A further challenge is the implementation and adaptation of existing infrastructures in an organization to manage the requirements which are tied to increased service orientation. An additional challenge is to establish trust between the service provider and the service recipient. Such confidence between the parties supports service perception and as a result service quality management.

Quality management is a continuous process, which will never stops and creates potential for future competitive advantages of service providers. Thus, the perspectives of IT-Managers and the focus of IT-Governance should expand to life cycle aspects of IT-Service quality management, because the quality of IT-Services is the key success factor for creating competitive advantages in the IT-Service market.

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Chapter 2.9

Design and Development of a Quality Management Information System

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INTRODUCTION

Due to the evolution of globalization (Benavent, Ros, & Moreno-Luzon, 2005), modern companies have been striving to compete with their competitors who are operating from different parts of the world. One of the methods adopted by them for attaining this objective is the installation of quality systems by implementing ISO 9001:2000 standard (Williams, 2004). Since the introduction of this standard among the international community (Chin, Kim, & Kim, 2004), the companies implementing it enjoy reputation in the global market. It is a common practice on the part of the major companies to insist on the supplier companies to install ISO 9001:2000 compatible quality systems. Because of this trend, more than 4,00,000 numbers of modern companies of different sizes and nature have installed ISO 9000 based quality systems (Gingele, Childe, & Miles, 2002). While this is an appreciable trend, it is to be noted that mere implementation of the ISO

9001:2000 standard does not enable the companies to acquire core competence. Hence, despite their effectiveness, suitable leveraging mechanisms are yet to be incorporated with ISO 9001:2000 compatible quality systems (Gotzamani & Tsiotras, 2001; Williams, 2004). One of the additional leverages to be included is the information system component (Tan, Lin, & Hung, 2003). Hence, it is high time that information system elements were incorporated with ISO 9001:2000 based quality systems. Presumably on realizing the information requirements, ISO 9001:2000 is incorporated with more information elements (Lari, 2002) than its previous version ISO 9001:1994 (Devadasan, Kathiravan, Sakthivel, Kulandaivelu, & Sundararaj, 2003). However, careful studies revealed that those information elements are not sufficient to install and manage quality information system (QIS) compatible to ISO 9001:2000. Considering this requirement, the research project reported in this paper has been carried out. The scope of this module of work was limited to the design and development of information system pertaining to Clause 4 of ISO 9001:2000 quality system. This information system is titled as quality management information system (QMIS). Subsequently, a validation study was carried out in a high technology-oriented job shop company to assess the penetration of QMIS. After noting the existing gap, the QMIS was developed in this company. The details of this work are presented in this paper.

MANAGEMENT INFORMATION SYSTEMS AND QUALITY INFORMATION SYSTEMS

Management professionals have been using information systems for more than five decades. Particularly, managers started to use computer-based information systems which today are known as management information systems (MIS). Since then, the scope of MIS (O'Brien, 2003; Oz, 2002) has been increasing and widening (Laudon & Laudon, 2002). In coincidence to MIS development, the world has been attempting to achieve continuous quality improvement in organizations. Yet, there has been no concrete effort by management professionals toward integrating continuous quality improvement projects with information systems (Forza, 1995). In fact, no major discussions have taken place in managerial conferences and seminars about extending support to enhance the effectiveness of continuous quality improvement projects through the application of MIS concepts (Peppard, 1995). At this juncture, it should be noted that a large number of companies have been benefitted by implementing total quality management (TQM) (Pearson, McCahon, & Hightower, 1995) and enterprise resource planning (ERP) systems (Themistocleous, Irani, & O'Keefe, 2001). ERP projects are incorporated with MIS elements (Subramanian & Hoffer, 2005). Presumably, due to lack of proper guidance, not many companies have invested on developing information systems for enhancing the efficiency of TQM projects. Some experts and researchers in the TQM field have advocated the need of developing information systems to support continuous quality improvement projects. The most noticeable is the contribution of Juran and Gryna (1995) who coined the term "quality information system (QIS)" (p.548). After they advocated the use of QIS, some researchers worked in the direction of developing QIS during the 1980s (Forza, 1995). After which time, the importance of QIS was not much felt by both theoreticians and practitioners (Pearson et al., 1995). This is probably due to the reason that from the late 1980s, companies began to view ISO 9000 series as an essential ingredient for implementing TQM (Ho, 1999; Martinez-Lorente & Martinez-Costa, 2004). Hence, it is projected that the efforts directed toward bridging MIS and TQM principles would be yielding solutions for enhancing the performance quality of companies (Pearson et al., 1995).

The fundamental tenets of MIS envisage the processing of data to evolve useful information to the target users (Adeoti-Adekeye, 1997), whereas the research in QIS has addressed its development features in a different way. The difference in approaches will make it difficult or impossible to integrate MIS principles with TQM projects. Hence, QIS should be developed in accordance with the stipulations of MIS principles. Meanwhile, it is prudent to note that the TQM field has grown to a very large extent to encompass a number of new models, techniques, tools, and approaches (Tari, 2005). If the scope of QIS includes all of the earlier mentioned components of TQM, then managing it will become a cumbersome task. Hence, QIS should be coupled with only the vital elements of TQM. However, such elements of QIS should not discord the other elements. Particularly, such elements should facilitate in integrating the resources of the organizations for the purpose of attaining continuous quality improvement. In this regard, the discussion in literature (Vouzas & Gotzamani, 2005) on the contribution of ISO 9000 series quality systems standards based models in organizations is to be recognized. Moreover, during the recent times, the credibility of ISO 9001:2000 quality system standard is being appraised. Hence, it will be an effective work if QIS is developed by integrating with ISO 9001:2000 quality system based model. Hence, if a QIS compatible with an ISO 9001:2000 standard is implemented in a company, it will leverage the performance of the ISO 9001:2000 standard and offer very powerful solutions towards achieving continuous quality improvement.

DESCRIPTION OF CLAUSE 4 OF ISO 9001:2000

ISO 9001:2000 encompasses eight major clauses (BIS, 2000). Out of these, the first three are primitive and required only for referral and clarifying purposes. While installing ISO 9001:2000 based quality system, Clauses 4 to 8 are required to be adopted. Out of these, Clause 4, which is titled as "Quality management system" (BIS, 2000, p.2), is the foundation of all of the other clauses of ISO 9001:2000. This clause is considered foundational because it stipulates all of the instruments, which are required to build the quality management system (QMS). These instruments are: quality manual, procedures, quality policy, and quality objectives. Furthermore, this clause specifies the most important activity of managing ISO 9001:2000 based quality system, namely documentation.

Clause 4 of ISO 9001:2000 consists of two sub-clauses. The first sub-clause is given a code number 4.1 and titled as "General requirements" (BIS, 2000, p.2). As the title implies, this sub-clause stipulates the requirements that the organization shall adhere to manage the quality system and continually improve it. This sub-clause also specifies the processes, which shall have to be managed according to the stipulations of ISO 9001:2000 standard. This particular sub-clause is very specific in stipulating the general requirement of achieving continual improvement of QMS. The second sub-clause is given a code name 4.2 and titled as "Documentation requirements" (BIS, 2000, p.2). This sub-clause further consists of four sub-clauses. As the title implies, this sub-clause deals with documents that are required to be developed for building the QMS. Further, this sub-clause specifies the requirements for controlling the records. The filled-in documents are called records and Clause 4.2 specifies the requirements for controlling them. A distinct difference of Sub-Clause 4.2 from 4.1 is the absence of specific stipulation on continual improvement of QMS. But the stipulations of Sub-Clause 4.2 are vital for effecting continual improvement of QMS.

Organizations installing ISO 9001:2000 based quality systems without fulfilling either partially or fully the requirements of QMS specified by Clause 4 of ISO 9001:2000 are prone to fail in achieving continual quality improvement in spite of their adherence to the remaining clauses of ISO 9001:2000. This aspect is depicted in the figure given in ISO 9001:2000, which is titled as "Model of a process based quality management system" (BIS, 2000, pp. iii). The slightly modified version of this model is shown in Figure 1. This figure stipulates that the Clauses 5-8 in sequence act to achieve continual improvement of the QMS. This implies that any leveraging action that is intended to be applied through ISO 9001:2000 must have to begin from Clause 4. Accordingly, in the module of the research project being reported in this paper, the leveraging action through information system management has been applied through Clause 4 of ISO 9001:2000. In order to carry out this leveraging action, Clause 4 was searched to locate any stipulation about the information system management. Though there is no mentioning about MIS in Clause 4, the listing d) given under Sub-Clause 4.1 specifies the need of the availability of information necessary to support the operation and monitoring of the processes included in QMS. This kind of monitoring information is inadequate to develop leveraging action and hence an exclusive design of QIS by referring to Clause 4 is vitiated.

QUALITY MANAGEMENT INFORMATION SYSTEM

In order to design QMIS, the traditional MIS principles were referred. This is due to the reason that traditional MIS principles have been found to offer powerful information system management solutions in organizations of all types. The fundamental tenet of MIS is that the collected data shall be processed using appropriate models to provide information to the target users (Laudon & Laudon, 2002; O'Brien, 2003; Stair & Reynolds, 2001). This methodology is depicted in Figure 2.

The principles depicted in this figure have been used to design QMIS. For this purpose, each sub-clause of Clause 4 of ISO 9001:2000 was studied, and corresponding to four information system elements, namely Data, Database, Processing Methodology and Models and Information, have been designed. As a sample, the design of information system elements designed pertaining to Sub-Clause 4.1 of ISO 9001:2000 is described in this section.

Sub-Clause 4.1 General Requirements

The contents of Sub-Clause 4.1 of ISO 9001:2000 (BIS, 2000, p.2) are reproduced below: "The organization shall establish, document, implement

Figure 1. Continual quality improvement journey through ISO 9001:2000

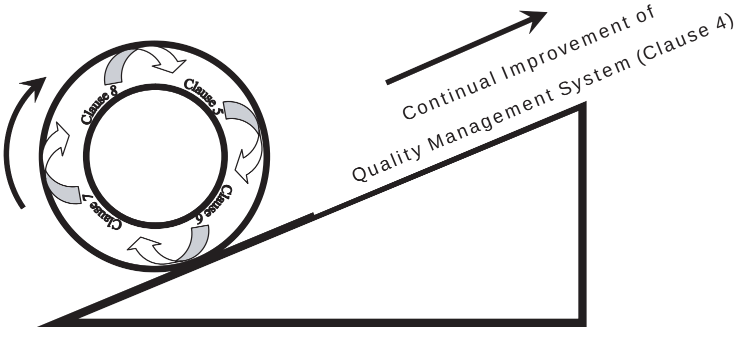
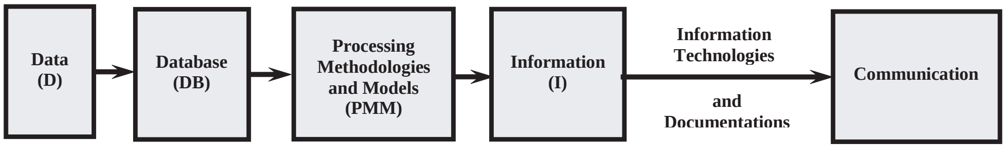


Figure 2. Traditional MIS methodology



and maintain a quality management system and continually improve its effectiveness in accordance with the requirements of this International standard.

The organization shall:

1. identify the processes needed for the quality management system and their application throughout the organization
2. determine the sequence and interaction of these processes
3. determine criteria and methods needed to ensure that both the operation and control of these processes are effective
4. ensure the availability of resources and information necessary to support the operation and monitoring of these processes
5. monitor, measure and analyze these processes, and
6. implement actions necessary to achieve planned results and continual improvement of these processes."

The data pertaining to the stipulations of Sub-Clause 4.1 have been identified and listed in Table 1.

The database requirements pertaining to the "data" of Sub-Clause 4.1 have been identified and are enumerated in Table 2.

The methods and models recommended for processing the data are presented in Table 3.

The information elements designed pertaining to Clause 4.1 of ISO 9001:2000 standard are presented in Table 4.

The texts are italicized in Table 1-4 to indicate that the stipulations are pertaining to QMIS. All of the elements indicated in these tables are designed using the MIS process indicated in Figure

Table 1. Data pertaining to the stipulations of Sub-Clause 4.1

Element Number	***Data***
D-1	*ISO 9001:2000 standard.*
D-2	*List of processes needed for the QMS.*
D-3	*List of sequence and interaction required for the listed processes.*
D-4	*List of criteria and methods required for ensuring the effective operation and control of the listed processes.*
D-5	*List of locations indicating the availability of resources and information necessary to support the operation and monitoring of these processes.*
D-6	*List of methods to measure, monitor and analyze these processes and required actions for implementation.*
D-7	*List of planned results required for the QMS.*
D-8	*Data on continual improvement measures.*

Table 2. Database pertaining to the stipulations of Sub-Clause 4.1

Element Number	*Database*
DB-1	*Posting of ISO 9001:2000 standard in an electronic environment with the provision for retrieving the data based upon the clause number, product, processes, and procedures, etc. The hard copy of this standard may also be given to all employees or shall be deposited with section heads.*
DB-2	*Preparation of a handbook containing the processes needed for the QMS with proper chronological ordering and indexing procedures.*
DB-3	*Preparation of a handbook containing the sequence and interaction needed for the execution of the listed processes with proper chronological ordering and indexing procedures.*
DB-4	*Preparation of a handbook containing the criteria and methods needed for the execution of the listed processes with proper chronological ordering and indexing procedures.*
DB-5	*Preparation of a handbook containing the availability of resources and information with proper chronological ordering and indexing procedures*
DB-6	*Preparation of a handbook containing the methods to measure, monitor, and analyze these processes with proper chronological ordering and indexing procedures.*
DB-7	*Preparing a pamphlet on planned results and pasting it on strategic locations of the company. Electronic devices shall be chosen to accommodate the earlier-mentioned database elements, which should enable easy retrieval of the required data within a fraction of second.*
DB-8	*Preparing a pamphlet on data on continual improvement measures and pasting it at strategic locations of the company.*

1. As a sample, the design of the first element indicated in these tables is illustrated. As shown in Table 1, the data element denoted as D-1 (D stands for Data) pertaining to the first element is ISO 9001:2000 standard itself. As shown in Table 2, the database of this element deals with its electronic posting and deposition of its hard copy with the section head. This is denoted as DB-1 (DB stands for Database). As shown in Table 3, the indexing methodology and FAQs are stipulated as the processing methodologies and models of the Sub-Clause 4.1. This is denoted as PMM-1 (PMM stands for Processing Methodologies and Models). Finally, as indicated in Table 4, dissemination of the information is envisaged through physical disseminations and display in electronic environments. Thus, a scientific approach incorporated with the principles of MIS (as indicated in Figure 2) was adopted to design QMIS.

PENETRATION OF QMIS IN PRACTICE

Due to the economical availability of software and information technologies, modern companies have been incorporated with various elements of information systems. Hence, it is expected that even without explicit enunciation, modern companies are likely to have been incorporated with a few or many elements of QMIS. Considering this probability, it was decided to estimate the penetration of ISO 9001:2000 based QMIS in a real-time environment. For this purpose, a company involved in machining metal alloy components using high technology-based machining system namely, CNC Machining Center, was approached. This company is situated in Coimbatore City of India. Large-size companies place job orders with this company. The machined components are received by large-size companies, which in turn are exported by them to the companies lo-

Table 3. Processing methodology and models pertaining to the stipulations of Sub-Clause 4.1

Element Number	*Processing Methodology and Models*
PMM-1	*An index of the keywords may be prepared with page numbers of ISO 9001:2000 standard which should enable the user to obtain the right information. Besides, a list of frequently asked questions (FAQs) may be prepared to guide the users to get appropriate information from the standard. Display boards may be designed to paint the appropriate contents of ISO 9001: 2000 standard as required by the user.*
PMM-2	*An index of the keywords may be prepared with page numbers of the handbook containing processes needed which should enable the user to obtain the right information. Besides, a list of FAQs may be prepared to guide the users to get appropriate information from the handbook.*
PMM-3	*An index of the keywords may be prepared with page numbers of the handbook containing sequences and interaction of the listed processes, which should enable the user to obtain the right information. Besides, a list of FAQs may be prepared to guide the users to get appropriate information from the handbook.*
PMM-4	*An index of the keywords may be prepared with page numbers of the handbook containing criteria and methods needed for the execution of the listed processes, which should enable the user to obtain the right information. Besides, a list of FAQs may be prepared to guide the users to get appropriate information from the handbook.*
PMM-5	*An index of the keywords may be prepared with page numbers of the handbook containing the availability of resources and information, which should enable the user to obtain the right information. Besides, a list of FAQs may be prepared to guide the users to get appropriate information from the handbook.*
PMM-6	*An index of the keywords may be prepared with page numbers of the handbook containing the methods to measure, monitor, and analyze, which should enable the user to obtain the right information. Besides, a list of FAQs may be prepared to guide the users to get appropriate information from the handbook.*
PMM-7	*Impressive font sizes and colors of the letters should be chosen for displaying planned results, which should enable the user to obtain information.*
PMM-8	*An impressive font size and color of the letters should be chosen for displaying data on continual improvement measures, which should enable the user to obtain the right information.*

cated in various parts of the world. Two reasons prompted the company to install ISO 9001:2000 based quality system and obtain certification from TUV. The first reason is that the customers from different parts of the world insisted on the company to install ISO 9001:2000 based quality system. This is coinciding with the observation of Arauz and Suzuki (2004) who claim that the ISO 9000 certification provides opportunities for today's companies to obtain international recognition and establishment of the trade. The second reason was due to the desire of the managing partners for continuously improving the quality of performance. Due to the personal acquaintance of first and second authors with one of the managerial partners, it was possible to obtain permission to estimate the penetration of QMIS in the company. In order to carry out this estimation process, a workbook containing the design specifications of ISO 9001:2000 based QMIS was prepared. The manager who is taking care of ISO 9001:2000 quality system maintenance was approached with the workbook. This manager was interviewed by referring to the elements given in the workbook. In total, there were 24 elements included in the workbook.

The data were collected by interviewing the manager as well as by referring to the records and

Table 4. Information pertaining to the stipulations of Sub-Clause 4.1

Element Number	***Information***
I-1	*Circulation of the stipulation ISO 9001:2000 standard to the target users using circulars and display of the same through electronic media.*
I-2	*Circulation of the stipulation of processes needed for QMS to the target users using circulars and display of the same through electronic media.*
I-3	*Circulation of the stipulation of sequence and interaction of the listed processes to the target users using circulars and display of the same through electronic media.*
I-4	*Circulation of the stipulation of criteria and methods required for the execution of the listed processes to the target users using circulars and display of the same through electronic media.*
I-5	*Circulation of the stipulation of availability of resources and information to the target users using circulars and display of the same through electronic media.*
I-6	*Circulation of stipulation concerning methods to measure, monitor, and analyze the listed processes to the target users using circulars and display of the same through electronic media.*
I-7	*Pasting of the planned results in the locations where the target users are working and displaying the same through electronic media.*
I-8	*Pasting of the continual improvement measures in the locations where the target users are working and displaying the same through electronic media.*

through personal observation. After completion of data collection, the data were analyzed. The results indicated that the data pertaining to QMIS exist to the extent of 87% against the actual requirement. In the case of database, it is 50% against the requirements. However, it was understood that no activities pertaining to processing data and information have been carried out. These findings are depicted in Figures 3 and 4. These quantified results indicate that already the data and database have been created by the company while installing and managing ISO 9001:2000 based quality system implementation. This observation very much tallies with the stipulation of Clause 4.1 of ISO 9001:2000. That is, in this clause, the word information is specified only once. Accordingly, the company has developed the data and database to a good extent whereas the information is fully missed. It is understood that despite the economical availability of the Internet, intranet and extranet technologies, they have yet to be appropriately used by the company to leverage Clause 4 of ISO 9001:2000 standard to create QMIS.

DEVELOPMENT OF QMIS

As the study on penetration of QMIS revealed the existence of only the data and database, the remaining stipulations under the titles "processing methodologies and models" and "information" had to be developed in the company. As a sample, the development of first and second elements listed under the QMIS is briefly presented here. The development of QMIS was started by referring to D-1 (see Table 1). According to its stipulation, the availability of ISO 9001:2000 standard was examined. Since this was not available, a copy of it was made available in the company. While referring to DB-1 (see Table 2), it was noted that ISO 9001:2000 was not available in both electronic and hard copy forms among the company personnel. Hence, a HTML-based electronic file containing ISO 9001:2000 standard was developed. The front window of this file is shown in Figure 5. Also, hard copies of ISO 9001:2000 were made available in different sections, which are now accessible to the employees.

Figure 3. Analysis of responses under Data

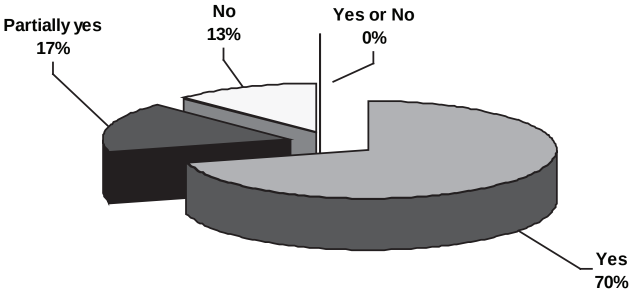


Figure 4. Analysis of responses under Database

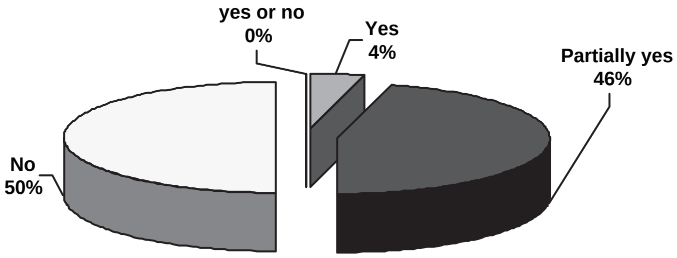
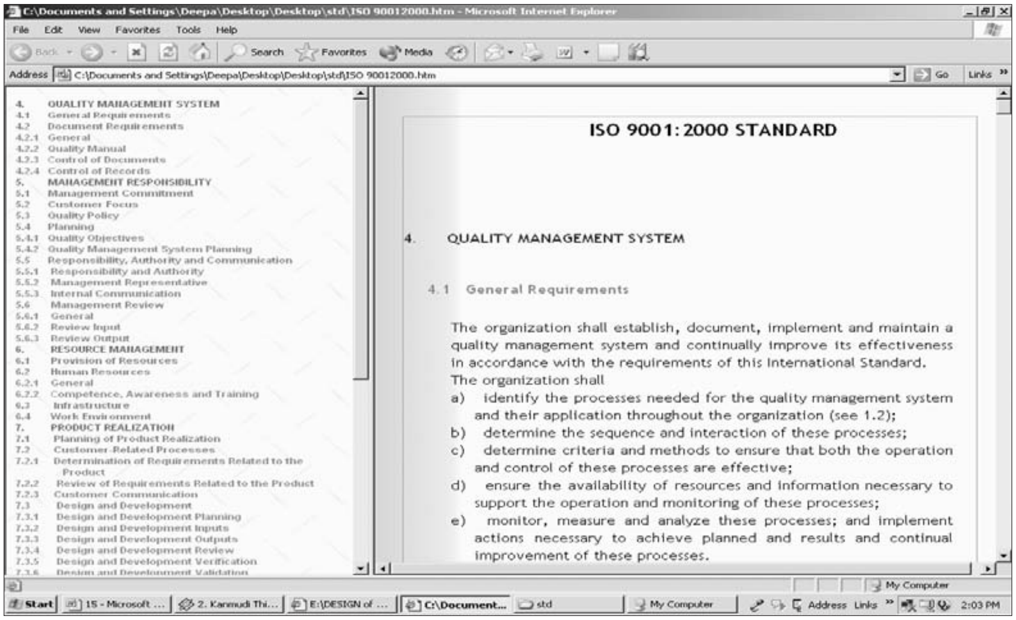


Table 5. Index of the ISO 9001:2000 standard

INDEX
Application 1
Availability of resources and information for processes 2
Continual improvement 2
Control of documents 3
Criteria and methods for processes 2
Documentation requirements 2
Monitor, measure and analyze of processes 2
Normative reference 1
Planned results 2
Process for QMS 2
Quality management systems 2
Quality manual 2, 3
Quality objectives 2, 3
Quality policy 2, 3, 4
Records 2
Scope 1
Scope of QMS 3
Sequence and interaction of processes 2
Terms and definitions 1

According to PMM-1 (see Table 3), an index of the keywords was prepared to access the page number of ISO 9001:2000 standard. A portion of the index is shown in Table 5. Furthermore, a sample of two FAQs has been prepared which is shown in Table 6. As the floor area of the company size is too small to accommodate the display boards containing all the stipulations of ISO

Figure 5. Front window of HTML file containing ISO 9001:2000 standard



4. QUALITY MANAGEMENT SYSTEM
4.1 General Requirements
4.2 Document Requirements
4.2.1 General
4.2.2 Quality Manual
4.2.3 Control of Documents
4.2.4 Control of Records
5. MANAGEMENT RESPONSIBILITY
5.1 Management Commitment
5.2 Customer Focus
5.3 Quality Policy
5.4 Planning
5.4.1 Quality Objectives
5.4.2 Quality Management System Planning
5.5 Responsibility, Authority and Communication
5.5.1 Responsibility and Authority
5.5.2 Management Representative
5.5.3 Internal Communication
5.6 Management Review
5.6.1 General
5.6.2 Review Input
5.6.3 Review Output
6. RESOURCE MANAGEMENT
6.1 Provision of Resources
6.2 Human Resources
6.2.1 General
6.2.2 Competence, Awareness and Training
6.3 Infrastructure
6.4 Work Environment
7. PRODUCT REALIZATION
7.1 Planning of Product Realization
7.2 Customer-Related Processes
7.2.1 Determination of Requirements Related to the Product
7.2.2 Review of Requirements Related to the Product
7.2.3 Customer Communication
7.3 Design and Development
7.3.1 Design and Development Planning
7.3.2 Design and Development Inputs
7.3.3 Design and Development Outputs
7.3.4 Design and Development Review
7.3.5 Design and Development Verification
7.3.6 Design and Development Validation

ISO 9001:2000 STANDARD

4. QUALITY MANAGEMENT SYSTEM

4.1 General Requirements

The organization shall establish, document, implement and maintain a quality management system and continually improve its effectiveness in accordance with the requirements of this International Standard.
The organization shall
a) identify the processes needed for the quality management system and their application throughout the organization (see 1.2);
b) determine the sequence and interaction of these processes;
c) determine criteria and methods to ensure that both the operation and control of these processes are effective;
d) ensure the availability of resources and information necessary to support the operation and monitoring of these processes;
e) monitor, measure and analyze these processes; and implement actions necessary to achieve planned and results and continual improvement of these processes.

9001:2000, a poster depicting the process-based QMS stipulated in ISO 9001:2000 was developed. In order to meet the specifications of I-1, the ISO 9001:2000 standard has been circulated among the target users, namely employees. Furthermore, the HTML file shown in Figure 6 would enable the display of the required stipulations of ISO 9001:2000 standard. For example, on pressing the link 5, the stipulations given under clause "Management Responsibility" shown in Figure 7 are displayed.

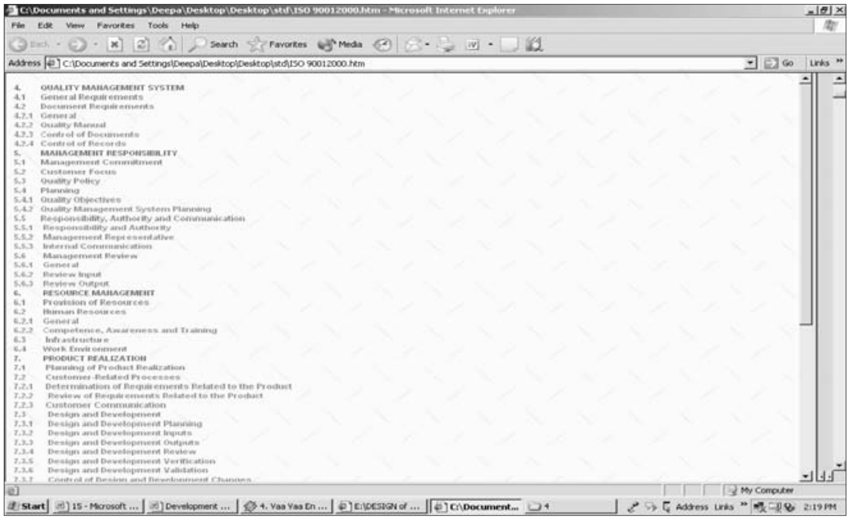
While referring to D-2 (see Table 2), it became necessary to list the processes needed for the QMS. Unlike in the case of D-1, it was possible to extract immediately and easily the list of processes shown in Table 7 from the quality manual of the company. After this, the task of preparing the QMIS handbook was started. According to the stipulations of DB-2 (see Table 2), the list of processes has been arranged according to the alphabetical ascending order of the process titles. This chronological ordering of the list of processes is shown in Table 8.

According to PMM-2, an index of titles of processes has been appended in the QMIS handbook. A portion of the page containing the index of titles is given in Table 9. According to I-2, the stipulation of processes has been circulated among the employees using circulars. Moreover, a poster facing the entry point of the company containing the list of processes was pasted. The photograph showing the pasted poster is presented in Figure 7. Furthermore, the HTML file has been developed to portray the "sequence and interaction of the process". The front page of this HTML file is shown in Figure 8. In a similar way, the QMIS has been developed according to its design specifications.

VALIDATION

In order to validate the QMIS, the managing partner was approached with a questionnaire. The questions asked and his responses in a Likert's scale of range from 0 to 10 are indicated in Table 9. As shown, the questions aimed to gather his assessment of a QMIS in achieving the requirements of the Clause 4 of ISO 9001:2000. Since his reactions ranged between 6 and 8, it is

Figure 6. Display of the ISO 9001:2000 standard



4. QUALITY MANAGEMENT SYSTEM
4.1 General Requirements
4.2 Document Requirements
4.2.1 General
4.2.2 Quality Manual
4.2.3 Control of Documents
4.2.4 Control of Records
5. MANAGEMENT RESPONSIBILITY
5.1 Management Commitment
5.2 Customer Focus
5.3 Quality Policy
5.4 Planning
5.4.1 Quality Objectives
5.4.2 Quality Management System Planning
5.5 Responsibility, Authority and Communication
5.5.1 Responsibility and Authority
5.5.2 Management Representative
5.5.3 Internal Communication
5.6 Management Review
5.6.1 General
5.6.2 Review Input
5.6.3 Review Output
6. RESOURCE MANAGEMENT
6.1 Provision of Resources
6.2 Human Resources
6.2.1 General
6.2.2 Competence, Awareness and Training
6.3 Infrastructure
6.4 Work Environment
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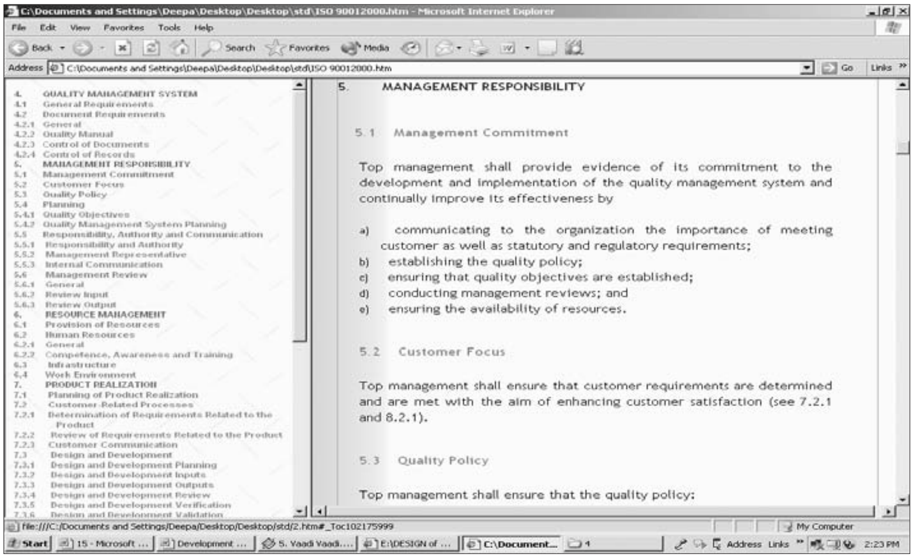
7.1 Planning of Product Realization
7.2 Customer-Related Processes
7.2.1 Determination of Requirements Related to the Product
7.2.2 Review of Requirements Related to the Product
7.2.3 Customer Communication
7.3 Design and Development
7.3.1 Design and Development Planning
7.3.2 Design and Development Inputs
7.3.3 Design and Development Outputs
7.3.4 Design and Development Review
7.3.5 Design and Development Verification
7.3.6 Design and Development Validation
7.3.7 Control of Design and Development Changes

Figure 7. Display of Clause 5 details



4. QUALITY MANAGEMENT SYSTEM
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7.3.1 Design and Development Planning
7.3.2 Design and Development Inputs
7.3.3 Design and Development Outputs
7.3.4 Design and Development Review
7.3.5 Design and Development Verification
7.3.6 Design and Development Validation

5. MANAGEMENT RESPONSIBILITY

5.1 Management Commitment

Top management shall provide evidence of its commitment to the development and implementation of the quality management system and continually improve its effectiveness by

a) communicating to the organization the importance of meeting customer as well as statutory and regulatory requirements;
b) establishing the quality policy;
c) ensuring that quality objectives are established;
d) conducting management reviews; and
e) ensuring the availability of resources.

5.2 Customer Focus

Top management shall ensure that customer requirements are determined and are met with the aim of enhancing customer satisfaction (see 7.2.1 and 8.2.1).

5.3 Quality Policy

Top management shall ensure that the quality policy:

Table 6. FAQs of the ISO 9001:2000 standard

1. **From where can I get the hard and soft copies of the ISO 9001:2000 standard?**
   It is available on the PC and management representative’s table.
2. **What are the processes that take place in our company?**
   Refer to pages 46 and 47 of the quality system manual.

Table 7. List of process needed for the QMS (Arranged in the order of process numbers and clause numbers)

Process Number	ISO 9001:2000 Clause Number	Process Description	Responsibility	Interacting Process
P01	4.2.3	Control of Documents	Management Representative	All Business Processes
P02	4.2.4	Control of Records	Management Representative	All Business Processes
P03	5.3	Quality Policy	Managing Partner	All Business Processes
P04	5.4.1	Quality Objectives		All Business Processes
P05	5.4.2	Quality Management System Planning	Managing Partner	All Business Processes
P06	5.5.3	Internal Communication		All Business Processes
P07	5.6	Management Review	Managing Partner	All Business Processes
P08	6.1	Provision of Resources		P07, P11, P12, P15, P18, P21
P09	6.2.1	Human Resources		P11, P12, P15, P17, P18
P10	6.2.2	Training	Managing Partner	P03, P04, P11, P15, P17, P18, P21, P22
P11	7.1	Planning for Product Realization (Refer Annexure-I and Process flow chart PFC Series for process description/ Sequence in detail)	Supervisor	P01, P02, P04, P08, P12, P13, P14, P15, P16, P18
P12	7.2	Determination & Review of requirements related to Product (Refer Process flow chart PFC-01)	Managing Partner	P11, P13, P14, P15, P16, P20
P13	7.2.3	Customer Communication		P02, P11, P12, P14, P15, P16, P19
P14	7.4	Purchasing Process (Refer Process Flow Chart PFC-02)		P11, P12, P13, P20
P15	7.5,	Production/Service Provision Process (Refer process Flow Chart PFC-03)	Managing Partner Supervisor	P06, P08, P11, P12, P14, P18, P20
	7.6	Control of monitoring & measuring devices		
P16	8.2.1	Customer Satisfaction	Managing Partner	P03, P04, P11, P12, P13, P20
P17	8.2.2	Internal Audit	MR	All Business Processes
P18	8.2.3	Monitoring & Measurement of Product/Processes	Managing Partner Supervisor	P11, P15, P20
P19	8.3	Control of Non conforming product		P13, P16, P17, P18, P20, P22
P20	8.4	Analysis of data		P07, P12, P14, P15, P16, P18, P19, P21, P22
P21	8.5.1	Continual Improvement	All employees	All Business Processes
P22	8.5.2 & 8.5.3	Corrective action & Preventive action	Managing Partner Supervisor	All Business Processes

Table 8. List of processes needed for the QMS (Arranged in the order of process description)

Process Number	ISO 9001:2000 Clause Number	Process Description	Responsibility	Interacting Process
P20	8.4	Analysis of data	Managing Partner Supervisor	P07, P12, P14, P15, P16, P18, P19, P21, P22
P21	8.5.1	Continual Improvement	All employees	All Business Processes
P01	4.2.3	Control of Documents	Management Representative	All Business Processes
P15	7.6	Control of monitoring & measuring devices	Managing Partner Supervisor	P06, P08, P11, P12, P14, P18, P20
P19	8.3	Control of Non conforming product	Managing Partner Supervisor	P13, P16, P17, P18, P20, P22
P02	4.2.4	Control of Records	Management Representative	All Business Processes
P22	8.5.2 & 8.5.3	Corrective action & Preventive action	Managing Partner Supervisor	All Business Processes
P13	7.2.3	Customer Communication	Managing Partner	P02, P11, P12, P14, P15, P16, P19
P16	8.2.1	Customer Satisfaction	Managing Partner	P03, P04, P11, P12, P13, P20
P12	7.2	Determination & Review of requirements related to Product (Refer Process flow chart PFC-01)	Managing Partner	P11, P13, P14, P15, P16, P20
P09	6.2.1	Human Resources	Managing Partner	P11, P12, P15, P17, P18
P17	8.2.2	Internal Audit	MR	All Business Processes
P06	5.5.3	Internal Communication	Managing Partner	All Business Processes
P07	5.6	Management Review	Managing Partner	All Business Processes
P18	8.2.3	Monitoring & Measurement of Product/Processes	Managing Partner Supervisor	P11, P15, P20
P11	7.1	Planning for Product Realization (Refer Annexure-I and Process flow chart PFC Series for process description/Sequence in detail)	Supervisor	P01, P02, P04, P08, P12, P13, P14, P15, P16, P18
P15	7.5,	Production/Service Provision Process (Refer process Flow Chart PFC-03)	Managing Partner Supervisor	P06, P08, P11, P12, P14, P18, P20
P08	6.1	Provision of Resources	Managing Partner	P07, P11, P12, P15, P18, P21
P14	7.4	Purchasing Process (Refer Process Flow Chart PFC-02)	Managing Partner	P11, P12, P13, P20
P05	5.4.2	Quality Management System Planning	Managing Partner	All Business Processes
P04	5.4.1	Quality Objectives	Managing Partner	All Business Processes
P03	5.3	Quality Policy	Managing Partner	All Business Processes
P10	6.2.2	Training	Managing Partner	P03, P04, P11, P15, P17, P18, P21, P22

Table 9. Index of the QMIS handbook

INDEX

Controls needed to ensure changes, the current revision status of documents,
relevant versions of applicable documents 2
Control of documents 9
Controls needed for approving documents 10
Controls needed to review, update and re-approve documents 11
Controls needed for documents of external region 12
Controls needed to prevent the unintended use of obsolete documents 12
List of processes (Annexure II) 46
    Interactions of processes 45
    Quality policy 14
    Quality objectives 14
    Documents containing the procedure 51
Quality Manual 8

Figure 7. Photograph showing the list of processes

inferred that the QMIS is practically compatible. Furthermore, he was asked an open question to write about his opinion on QMIS developed in his company. He reacted by writing the statement, "QMIS has improved the performance of the quality management system of my company". Thus the QMIS developed was validated for checking its effectiveness in a real-time environment.

RESULTS AND DISCUSSIONS

The advantages of developing QMIS are described here by referring to its two elements 1 and 2. As mentioned earlier, it was not even possible to locate the ISO 9001:2000 standard in the company before the development of QMIS. This indicates that there existed a danger that the quality system of the company would be dragged away from the ISO 9001:2000 standard. This means that

Figure 8. Sequence and interaction of the processes

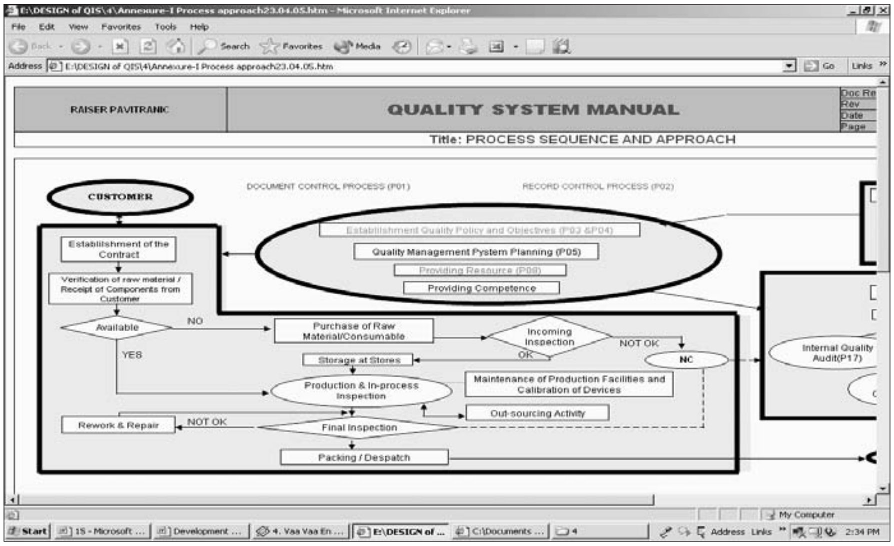

Table 9. Validation questionnaire and results

Question Number	Question	Managing partner's reactions in a Likert's scale of range 0-10. (0 - Not at all; 5 - Partially; 10 - Fully)
1	To what extent has QMIS leveraged in meeting the general requirements of QMS (as specified in Sub-Clause 4.1 of ISO 9001:2000)?	8
2	To what extent has QMIS leveraged in meeting the general documentation requirements of QMS (as specified in Sub-Clause 4.2.1 of ISO 9001:2000)?	7
3	To what extent has QMIS leveraged in meeting the objectives of developing quality manual in QMS (as specified in Sub-Clause 4.2.2 of ISO 9001:2000) ?	8
4	To what extent has QMIS leveraged in meeting the objectives of controlling documents in QMS (as specified in Sub-Clause 4.2.3 of ISO 9001:2000)?	6
5	To what extent has QMIS leveraged in meeting the objectives of controlling records in QMS (as specified in Sub-Clause 4.2.4 of ISO 9001:2000)?	7

the company was at the threshold of losing the benefits of implementing the ISO 9001:2000. As mentioned earlier, after the development of QMIS, the copies of ISO 9001:2000 standard are made available to all of the employees, and a soft copy is posted electronically using an HTML file. Likewise, before developing a QMIS pertaining to element 2, the list of processes was only available in the manual, which was not accessible to all employees. After the development of QMIS, the list of processes is made available in both document and electronic form. This activity enables the employees to be aware of the processes that take place in the company and, thereby, orients them toward attaining a higher degree of quality in totality and continually. Furthermore, the validation study conducted after developing a QMIS indicated its practical viability. As a whole, the development of a QMIS in the company led to an indication that the QIS would be a leveraging mechanism to enhance the performance of Clause 4 of ISO 9001:2000.

CONCLUSION

In order to face the ever-increasing degree of competition, companies have been striving to enhance the effectiveness of their work by adopting various approaches (Kaye & Anderson, 1999; Rho, Park, & Yu, 2001). When they are prescribed with completely new strategies, implementing them poses harder challenges. Moreover, the benefits of the heavy investment on strategies cannot be reaped back within the lifespan of the concerned projects. Hence, it is preferable that companies adopt leveraging actions by adopting the existing and proven strategies. In this direction, the leveraging action of information system management by adopting the widely installed ISO 9001:2000 based quality system draws the attention. In order to examine this proposal, a research project has been carried out in which the QMIS in accordance with Clause 4 of ISO 9001:2000 has been designed. This QMIS has been taken to an ISO 9001:2000 certified export oriented high technology machining based company. After getting the permission, the relevant data were collected. The analysis of the data indicated that this company has progressed toward data elements of QMIS to a good extent and database elements to a reasonably-satisfactory extent. However, the company has failed to incorporate the processing methodology and models and information elements of QMIS. In order to fill this gap, the QMIS elements missed in this company were developed. Finally, QMIS was validated by gathering the assessment of the company's managing partner. The experience of conducting the research project reported in this paper instigates us to postulate that QMIS can be implemented without any difficulty in companies in which ISO 9001:2000 based quality system is installed. Since this company is aspiring to move forward in the international market, this postulation may hold true for most of the modern companies situated in different parts of the world. Hence, it is a reasonable proposal that modern companies adopt the QMIS presented in this paper and gain the synergic benefits of information systems and ISO 9001:2000 standard.

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Chapter 2.10

Design and Analysis of Decision Support Systems

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ABSTRACT

Since their creation in the early 1960's, decision support systems (DSSs) have evolved over the past 4 decades and continue to do so today. Although DSSs have grown substantially since its inception, improvements still need to be made. New technology has emerged and will continue to do so and, consequently, DSSs need to keep pace with it. Also, knowledge needs to play a bigger role in the form of decision making. We first discuss design and analysis methods/techniques/issues related to DSSs. Then, the three possible ways to enhance DSSs will be explored.

INTRODUCTION

Over the 4 decades of its history, decision support systems (DSSs) have moved from a radical movement that changed the way information systems were perceived in business, to a mainstream commercial information technology movement that all organizations engage. This interactive, flexible, and adaptable computer based information system derives from two main areas of research: the theoretical studies of organizational decision making done at the Carnegie Institute in the 1950's and early 1960's, as well as the technical work on interactive computer systems which was mainly performed by the Massachusetts Institute of Technology (Keen & Morton, 1978).

DSSs began due to the importance of formalizing a record of ideas, people, systems, and technologies implicated in this sector of applied information technology. But the history of this system is not precise due to the many individuals involved in different stages of DSSs and various industries while claiming to be pioneers of the system (Power, 2003; Arnott & Pervan, 2005). According to Arnott (2006), the DSS field began in the early 1970s as a radical alternative to large-scale management information systems (MIS). Over time, major changes in information technology have enabled new decision support movements. In the late 1980s and mid-1990s, multidimensional modeling, OLAP technology, and advances in storage technology and data modeling led to the deployment of large-scale executive information systems, data warehousing, and business intelligence. Now DSSs have become very sophisticated and stylish since the early pioneering research. Many new systems have expanded the frontiers established by these pioneers, yet the core and basis of the system remains the same. Today, DSSs are used in the finance, accounting, marketing, medical, as well as many other fields.

BACKGROUND

The basic ingredients of a DSS can be stated as follows: the data management system, the model management system, the knowledge engine, the user interface, and the users (Donciulescu, Filip, & Filip, 2002). The database is a collection of current or historical data from a number of application groups. Databases can range in size from storing it in a PC that contains corporate data that has been downloaded, to a massive data warehouse that is continuously updated by major organizational transaction processing systems (TPSs). When referring to the model management system, it is primarily a stand-alone system that uses some type of model to perform "what if" and other kinds of analysis. This model must be easy to use, and therefore the design of such model is based on a strong theory or model combined with a good user interface.

A major component of a DSS is the knowledge engine. To develop an expert system requires input from one or more experts, this is where the knowledge engineers go to work, who can translate the knowledge as described by the expert into a set of rules. A knowledge engineer acts like a system analyst but has special expertise in eliciting information and expertise from other professionals (Laudon & Laudon, 2005).

The user interface is the part of the information system through which the end user interacts with the system, the type of hardware, and the series of on-screen command and responses required for a user to work with the system. An information system will be considered a failure if its design is not compatible with the structure, culture, and goals of the organization. Research must be conducted to design a close organizational fit, to create comfort and reliability between the system and user. In a DSS, the user is as much a part of the system as the hardware and software. The user can also take many roles such as decision maker, intermediary, maintainer, operator, and feeder. A DSS may be the best one in its industry but it still requires a user to make the final decision.

Power (2003) introduced a conceptual level of DSSs, which contains five different categories. These categories include model-driven DSS, communication-driven DSS, data-driven DSS, document-driven DSS, and knowledge-driven DSS. Defining DSS is not always an easy task due to the many definitions available. Much of this problem is attributed to the different ways a DSS can be classified. At the user level, a DSS can be classified as passive, active, or cooperative.

Essentially, DSS is a computer-based system that provides help in the decision making process. However, this is a broad way of defining the subject. A better way of describing DSS is to say it is a flexible and interactive computer-based system that is developed for solving non-structured management problems. Basically, the system uses information inputted from the decision maker (data and parameters) to produce an output from the model that ultimately assists the decision maker in analyzing a situation. In the following sections, we first discuss design and analysis methods/techniques/issues related to DSSs. Then, the three possible ways to enhance DSSs will be explored. At the end, future trends in DSSs will be discussed.

DESIGN AND ANALYSIS METHODS/TECHNIQUES/ISSUES RELATED TO DSSs

Design Methods

Today, DSSs hold a primary position in an organization's decision making by providing timely and relevant information to decision makers. It has become a key to the success or survival of many organizations. However, there is a high tally of failure in information systems development projects, even though they are a focal point of industrial concern (Goepp, Kiefer, & Geiskopf, 2006). Designing methods have become an important component that assures a successful information system design. This issue is in relevance to the design of a DSS.

There have been many different strategies employed for the design of a DSS, including the early decision-oriented design approach (Stabell, 1983). Current research on DDS design has witnessed the rapid expanding of object-oriented (OO) approach, which exploits object-oriented software engineering with unified modeling language (UML); knowledge management (KM) approach, which supports end-users by embedding declarative and/or procedural knowledge in software agents; structured modeling (SM) approach, which employs a hierarchically organized, partitioned, and attributed acyclic graph to represent models; and design science (DS) approach, which attempts to create artifacts that serve human purposes and solve organizational problems.

Object-oriented (OO) approach: The characteristic of OO approach is to use object-oriented software engineering with UML in the design and implementation of a DSS. OO design concepts are based on software engineering in that knowledge encapsulation present in a set of objects in an object-oriented system, where sub-classes show inheritance of the properties of the main class, is more compact and yet extensive compared to a logic-based system. Higher order logic is required to duplicate the performance of a simple object-oriented system (Pillutla & Nag, 1996). OO approach is considered a novel way of systems thinking. It provides designers and developers with easy analysis of complex systems and design of suitable software systems. It allows the developers and users to think in terms of objects and their behaviors instead of thinking about processes and process complexities. The main advantages are due to the features like data abstraction, encapsulation, inheritance, and polymorphism of OO approach (Nagarur & Kaewplan, 1999).

OO approach involves basically three major steps (Tian, Ma, Liang, Kwok, & Liu, 2005). The user's requirements are first captured by using a set of use case diagrams. These diagrams indicate all the functionalities of the system from the user's point of view. Then classes and their relationships are identified and described in class diagrams. Finally, sequence diagrams or collaboration diagrams are developed, which describe the interaction between objects (instances of classes). Tian et al. (2005) designed a DSS with the OO approach for an organization, which was implemented successfully.

Knowledge management (KM) approach: In some environments (non-preprogrammed applications), end-users, especially the less experienced end-users, need to have certain knowledge guiding them how to use the system. The KM design approach supports end-users by embedding declarative and/or procedural knowledge in software agents.

West Jr. and Hess (2002) used KM design approach to support end-users with spatially oriented decision-making by reporting on a specific spatial DSS that uses the approach. Procedural knowledge about performing spatial analysis was embedded in software agents that assist users with difficult and spatially oriented tasks. Because the system used a metadata repository, users were supported in some tasks by using the metadata repository directly and in others by using the software agents that access the metadata. According to West Jr. and Hess (2002), KM design approach provides better assistance to inexperienced users of spatial DSS, which requires a design approach that will prioritize knowledge support of the end-users' decision-making activities, and this approach, with the distribution of knowledge between metadata, agents, and end-users, has similar potential as a determinant of system success in any DSS (spatial or otherwise) where both declarative and procedural knowledge are needed to effectively accomplish the decision-making task. .

Structured modeling (SM) approach: SM (Geoffrion, 1987) approach "uses a hierarchically organized, partitioned, and attributed acyclic graph to represent models" (Srinivasan & Sundaram, 2000). It is a formal framework for describing models. SM identifies the basic components of models, the relationships among these components, and conditions under which a model may be termed structured (Lenard, 1993). It includes a language for describing a model schema and prescribes data tables for capturing the details of model instances.

SM decomposes a decision problem into genera and elements within genera in a hierarchic way, which forms a system that is sensitive to natural definitions of entities and objects in the problem (Pillutla & Nag, 1996). It consists of three levels: elemental structure, generic structure, and modular structure. The elemental structure intends to capture the definitional detail of a specific model instance. The generic structure targets at capturing the natural familial groupings of elements. The modular structure seeks to organize generic structure hierarchically according to commonality or semantic relatedness. The leveled structures allow the complexity of a model to be managed and ranked according to its hierarchies. The graph feature allows modelers and decision makers to understand the model better. A key advantage of SM is the ease with which structured models can be visualized (Srinivansan & Sundaram, 2000).

Srinivansan and Sundaram (2002) propose using SM in the design of model based DSS with the intention of solving existing design problems, such as lack of theory or design principles and domain specific issues, in other approaches. They select object relational database environment to implement SM, to be specific, they propose using SM to provide a systematic general framework for conceptual modeling and an object relational database management system (ORDBMS) to implement it. They believe an object relational platform for implementing structured models offers a development platform that is well suited to their needs. Such a platform is uniquely capable of meeting the conceptual requirements outlined by SM while satisfying many practical design concerns such as performance, persistence, and interoperability. They trust that their proposition of using SM approach for specific problem conceptualization and such a powerful environment as ORDBMS to implement it will provide design ideas that can potentially serve a very useful class of applications (Srinivansan & Sundaram, 2000).

Design science (DS) approach: Arnott (2006) defines design science as an alternative, or complement, to the natural science approach which has been a dominant research methodology in information systems field. Natural science tries to understand reality, but design science attempts to create things that serve human purposes (March

& Smith, 1995). In design science, researchers create and evaluate information technology artifacts that are intended to solve identified organizational problems (Hevner et al., 2004). Design science is especially relevant to information system research because it helps to address the role of the information technology artifact in information system research and the low professional relevance of many information system studies (Benhasat & Zmud, 1999; Orlikowski & Iacono, 2001).

The functionality of a DSS evolves over a series of development cycles where both the end-users and the systems analyst are active contributors to the shape, nature, and logic of the system (Arnott, 2004). Yet system developers have little guidance about how to proceed with evolutionary DSS development. DSS developers are facing the fact that insufficient knowledge exists for design purpose, and designers must rely on intuition, experience, and trial-and-error methods. Design science approach, on the other hand, can facilitate developers to create and evaluate information technology artifacts that are intended to solve identified organizational problems (Hevner, March, Park, & Ram, 2004). Vaishnavi and Kuechler (as in Arnott, 2006) proposed a design science methodology with the major process steps of awareness of problem, suggestion, development, evaluation, and conclusion. Arnott (2006) proposed a five steps approach, which was adapted from Vaishnavi and Kuechler, for designing evolutionary DSS: problem recognition, suggestion, artifact development, evaluation, and reflection. A research project by Arnott indicates that design science approach can tackle problems of both theoretical and practical importance.

DSS design model: DSS design model is the most recent DSS design approach developed by Klashner and Sabet and is worthy of a discussion. According to Klashner and Sabet (2007), DSS design model differs from any other models and approaches in that it is a more comprehensive design approach to address domain and nondeterministic complexities arising from real-world decision-making requirements. Incorporating morphogenetic principles, the model reflectively and concurrently informs its own evolution and directly impacts the design of the proposed DSS under development “although this new DSS design model appears simple and straightforward” (Klashner & Sabet, 2007).

The model consists of three major components: theory and analysis, simulation, and decision/design. Within the theory and analysis component, multiple data from system domain are fed into theory and analysis. A relation between the theory and domain is maintained to continuously exchange synchronous data and update the theory. The simulation component interacts with the theoretical components to integrate the data feed. As to the decision/design component, the design decision-making process will inevitably be influenced by the effect of theoretical analysis and simulation combined to the degree of not violating the decision-makers’ shared understanding of the design goals. Then the newly integrated design decisions immediately act on the relationship between the system domain and information infrastructure, thus completing the first full iteration since the general iterative flow of data.

Klashner and Sabet (2007) argue that in the early years of DSS research, design choices were intuitively understood in most cases because of the straightforward nature of the stakeholder’s requirements. But today, because stakeholder decisions have become highly subjective and complicated due to the increased problem complexity arising from various semi- to ill-structured problems (Nemati, Steiger, Iyer, & Herschel, 2002), a more comprehensive systems design approach is needed. Thus, the new DSS design model has been developed to address this issue. At present, the model application is domain specific, but it is currently being applied to another mission critical infrastructure design effort to test its generalizability to other domains where DSS plays a key role in daily operations (Klashner & Sabet, 2007).

Design Techniques

As we are advancing in information technologies, business decision makers can now have access to vast amount of information. On one hand, they may gain necessary and important information for making informed decisions, but on the other hand, they may also become overloaded by the information irrelevant to what they need. Thus, there is a pressing need for decision aiding tools that would effectively process, filter, and deliver the right information to the decision makers. Proper combination of DSSs and agent technologies could prove to be a very powerful tool for rendering decision support (Vahidov & Fazlollahi, Winter 2003-2004).

A software agent performs interactive tasks between the user and the system. The user instructs the system what he/she intends to accomplish. The software agent carries out the task. By analogy, a software agent mimics the role of an intelligent, dedicated and competent personal assistant in completing the user's tasks (Bui & Lee, 1999). In the DSS environment, software agents have been more formally described as autonomous software implementations of a task or goal that work independently, on behalf of the user or another agent (Hess, Rees, & Rakes, 2000). As the traditional, direct manipulation interface of our computing environment is much limited (Maes, 1994), software agents would seem to be a suitable and most needed solution for providing procedural assistance to end-users (West Jr. & Hess, 2002). "These 'robots of cyberspace' can be effectively utilized in automating many information processing tasks" (Vahidov & Fazlollahi, 2003-2004).

In some DSS environments, such as spatial DSS (Sikder & Gangopadhyay, 2002; West Jr. & Hess, 2002), Internet-based DSS (Bui & Lee, 1999) and Web DSS (Vahidov & Fazlollahi, 2003-2004), a multi-agent system should be designed and implemented in the DSS to facilitate the decision makers since decision making involves complex set of tasks that requires integration of supporting agents (Bui & Lee, 1999), and these agents should have behaviors to work in team (Norman & Long, 1994). Vahidov and Fazlollahi (2003-2004) developed architecture of multi-agent DSS for e-commerce (MADEC), in which intelligence team (agents), design team (agents), and choice team (agents) were composed. The multi-agent system was implemented in a prototype of MADEC, which received higher user satisfaction.

THREE POSSIBLE WAYS TO ENHANCE DSSs

Creating Knowledge Warehouses (KW)

Nemati (2002) proposed that a new generation of knowledge-enabled systems that provides the infrastructure required to capture, enhance, store, organize, leverage, analyze, and disseminate not only data and information but also knowledge (Nemati, 2002). Expanding data warehouses to encompass the knowledge needed in the decision making process is the creation of knowledge warehouses (KW). An important component of KW is a very complex process known as knowledge management. Knowledge management allows for knowledge to be converted from tacit to explicit through such processes as filtering, storing, retrieving, and so forth, thus allowing it to be utilized by decision makers.

The goal of KW is to give the decision maker an intelligent analysis standpoint that enhances all aspects of the knowledge management process. The main drawbacks of KW are the amount of time and money that need to be invested as well as some of the same problems that are found in successfully implementing DSSs. Among these factors are the users' involvement and participation, values and ethics, organization and political issues within the company, and other external issues. The development and implementation of KW still has much work to be done, however, DSSs seem to be headed toward knowledge enhancement in the future and KW looks to have a promising outlook in the upcoming years as a result.

Focusing on Decision Support

While knowledge management systems seem like a logical way to advance the shortcomings of DSSs, another view also exists. By removing the word "system" from DSSs and focusing on decision support, decision making might cause some interesting, new directions for research and practice. Decision support (DS) is the use of any plausible computerized or non-computerized means for improving sense making and/or decision making in a particular repetitive or non-repetitive business situation in a particular organization (Alter, 2004).

DS embodies a broader perspective that seems logical in environments where the user does not necessarily need the technical aspects of DSSs. This is based on the belief that most work systems of any significance include some form of computerized support for sense making and decision making (Alter, 2004). The difference between DSSs and DS is not too drastic but DS is a sensible option for many companies due to the increase in technology since the creation of DSSs; DSSs may not fit the needs of a business as it had in the past.

Integrating DSSs and KMSs

In line with Bolloju (2002), integrating decision support and knowledge management may correct some of the deficiencies of DSSs. The decision-making process itself results in improved understanding of the problem and the process, and generates new knowledge. In other words, the decision-making and knowledge creation processes are interdependent. By integrating the two processes, the potential benefits that can be reaped make the concept seem more worthwhile.

Integrating DSSs and KMSs seems to be the best choice out of the three possible ways to enhance DSS. The reasoning behind this selection is that integrating the two seems to provide a way for including both options without sacrificing one for the other. More importantly, while KW appears to have a very bright future, KW currently requires a great amount of time and money. The combination of both areas allows for a better overall utilization in the present. In time, KW may not be as time consuming and costly as it is now. However, to achieve a better balance of usefulness and efficiency, the integration of DSSs and KMSs appears to be the smartest choice.

FUTURE TRENDS

DSS in Business Analytics

The future of DSSs, Angus (2003) argued and supported by SAS (2004), is in the field of *business analytics* (BAs). BAs differ from that of the recently and previously more common business intelligence (BI). With the fast pace of business and life today it would only make sense for a shift to BA because it does focus on the many possibilities and the future outcomes for production and service.

BAs focus on the future of operations. Opposed to that of BI where it focuses on the past and what can be done to change the past if things were done wrong or repeat if things were done right. However, BAs let managers center on what future trends are developing, which allows them not to accumulate a surplus of inventory of outdated products. It also enables managers to change their prices before the market does, or introduce their new product before anyone else gets the chance to. This is known as first-to-market (Gnatovich, 2006). BAs give the companies that use it a tremendous advantage over their competitors in the market place.

Power-Hungry DSS

As everyone can see, the computing power is still accelerating. With its plan of "Itanium" processors, Intel is rushing towards its upcoming generation of 64 bit chips to support power-craving applications. Without any doubt, the power-hungry, large scale, integrated DSS application with dynamic calculation, background data mining, and high-end data visualization falls right into this end of the spectrum (Thomsen, 2003).

Web-Based DSS

The fast growing Internet and e-commerce have greatly impacted the way we conduct business. With the support of intelligent agents, DSS has been implemented for aiding decision makers in e-commerce. E-commerce combines transaction and decision support within an e-framework. Ultimately, the e-world is just another channel (Thomsen, 2003). If we can use the e-channels appropriately, integrate text engines within an overall DSS architecture, and provide for interoperability between DSS components, we may actually learn a few things about all this data we are collecting and make better decisions—without losing our humanity (Thomsen, 2003).

DSS in Retailing Business

In the retailing business sector, the competition over customers grows fierce. A customer's decision of buying from one retailer over another becomes the dividing factor in competition. Additionally, product mix between general and specialty retail is becoming homogenized. This expands the growth for more sophisticated and accurate decision support technology in the business (Rowen, 2005).

A few other trends in the retail business also call our attention. According to Rowen (2005), decision support solutions must interact with forecasting, allocation, and many other demand-chain applications from disparate vendors to increase margins. Additionally, we are being confronted with the coming onslaught of customer, events, and transactional data. Retailers are generating information at a volume that few can find significant use for today. Finally, forecasting and tracking anticipated sales has become another decision support trend within retail. Such technology enables a retailer to investigate the situation at hand, determining if a product is available.

Research in DSS

In terms of trends in DSS research, in the late 1980s and early 1990s, data warehouse and data mining was one of the focuses of research in DSS field. Since then software agents, also know as intelligent agents, emerged as an interdisciplinary area involving researchers from such fields as expert systems, DSS, cognitive science, psychology, databases, and so forth (Eom, 1999). Citations relevant to software agents in this chapter support such a proposition.

Studies of design science have shown a significant number in recent years in DSS research (Arnott & Pervan, 2005). This research stream has been rapidly expanding with a range of new topics encouraged by technological advances, methodological innovations, and increased expectations for theory development and empirical analysis of the new artifacts (Banker & Kauffman, 2004), such as the design of auction mechanisms (Bapna, Goes, & Gupta, 2003; Kelly & Steinberg, 2000) and optimal strategies for investment in knowledge by using a market mechanism (Ba, Stallaert, & Whinstone, 2001). It is likely that it will remain as a major topic in years to come.

According to Eom's (Eom, 1999) study, Web-based DSS is another emerging topic in the DSS area. Sikder and Gangopadhyay (2002) identified research issues on the design and implementation of a Web-base collaborative spatial decision support system. Vahidov and Fazlollahi (2003-2004) proposed architecture for a multi-agent DSS for e-commerce and described a prototype system for making online investment decisions with such a Web-based multi-agent DSS. In the pre-Web era, DSS was primarily used in an "island" mode. In e-commerce applications today, DSS can be an integral part of the digital environment and directly support the actions of the involved parties (Vahidov & Fazlollahi, 2003-2004).

CONCLUSION

Since their creation in the early 1960's, DSSs have evolved over the past 4 decades and continue to do so today. Although DSSs have grown substantially since its inception, improvements still need to be made. New technology has emerged and will continue to do so and, consequently, DSSs need to keep pace with it. Also, knowledge needs to play a bigger role in the form of decision making.

Shim (2002) emphasized that DSSs researchers and developers should (i) identify areas where tools are needed to transform uncertain and incomplete data, along with qualitative insights, into useful knowledge, (ii) be more prescriptive about effective decision making by using intelligent systems and methods, (iii) exploit advancing software tools to improve the productivity of working and decision making time, and (iv) assist and guide DSSs practitioners in improving their core knowledge of effective decision support.

The prior statement sums up the courses of action that need to be taken very well. The successful integration of DSSs and KMSs could revolutionize DSSs and propel it to even greater heights in the future. In closing, DSSs have a storied history that spans the course of 4 decades; however, the greatest mark may be made in the not so distant future as DSSs continue to evolve.

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KEY TERMS

Business Analytics (BA): A technological system that collects and evaluates all relevant data then scrutinizes it and puts it into different simulations to find out which one is the most appropriate.

Business Intelligence (BI): A system of technologies for collecting, reviewing, and hoarding data to assist in the decision making process.

Decision Support Systems (DSSs): An interactive, flexible, and adaptable computer-based information system, especially developed for supporting the solution of a non-structured management problem for improved decision making. It utilizes data, provides an easy-to-use interface, and allows for the decision maker's own insights

Interface (or User Interface): A component designed to allow the user to access internal component of a system, also known as the dialogue component of a DSS.

Knowledge Management: The distribution, access, and retrieval of unstructured information about human experiences between interdependent individuals or among members of a workgroup.

Sensitivity Analysis: Running a decision model several times with different inputs so a modeler can analyze the alternative results.

Software Agent: A software program that intelligently performs its duties without human inter-action.

Structured Modeling: A generic design strategy for representing complex objects that are encountered in modeling applications (Srinivasan & Sundaram, 2000).

Transaction Processing System (TPS): Computerized systems that perform and record the daily routine transactions necessary to conduct the business; they serve the organization's operational level.

Use Case: A complete sequence of related actions initiated by an actor; it represents a specific way to use the system.

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Chapter 2.11

Decision Making and Support Tools for Design of Machining Systems

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INTRODUCTION

The *design of manufacturing systems* is a wide open area for development and application of decision making and decision support technologies. This domain is characterized by the necessity to combine the standard decision making methods, sophisticated operational research techniques, and some specific rules based on expert knowledge to take into account principal technological constraints and criteria.

A promising trend in this area deals with the development of integrated software tools (Brown, 2004; Grieves, 2005; Stark, 2005). Their main idea consists in integrating product and manufacturing data into a common database. This enables product designers to consider the manufacturing processes constraints at the early product design stage. At the same time, all data of product design should be used directly for optimizing the corresponding manufacturing system. That is why the core of these software tools is a powerful extendable database, supported by a user friendly software environment. This database normally contains digital models of product and processes. In order to find an optimal manufacturing system configuration, a set of advanced decision making and decision support methods are used for data processing.

In this work we present the main principles and ideas of decision making by the example of decision and support soluton for machining systems used for mass production. The used approach is based on several techniques:

- Powerful database of standard solutions and
  efficient mecanisms to search the existing elements
- Expert system to choose better solutions from database;
- Line balancing model based on shortest path
  approach;
- Set of problem oriented rules; and
- User friendly software environment.

These techniques are combined in the decision support software tool for optimal process planning, line balancing, and equipment selection for optimal design of a transfer machine with rotary or mobile table.

BACKGROUND

The studing of line design problems began by considering the simple *assembly line balancing problem* (SALBP) (Baybars, 1986; Scholl & Klein, 1998). The SALBP consists in assigning a set of operations to identical consecutive stations minimizing the number of stations required, subject to *precedence constraints* between operations and *cycle time* constraints. Many exact and heuristic approaches for SALBP were suggested in literature: lagrange relaxation techniques (Aghezzaf & Artiba, 1995), branch and bound algorithms (van Assche & Herroelen, 1998; Ugurdag, Papachristou, & Rachamadugu, 1997; Scholl & Klein, 1998), and heuristics and meta-heuristics (Arcus, 1966; Helgeson & Birnie, 1961; Rekiek, De Lit, Pellichero, L'Eglise, Fouda, Falkenauer *et al*., 2001). This list is not exhaustive. A state-of-the-art can be found in (Baybars, 1986; Becker & Scholl, 2006; Erel & Sarin, 1998; Ghosh & Gagnon, 1989; Rekiek, Dolgui, Delchambre, & Bratcu, 2002).

The problem where line balancing is combined with equipment selection is often called *simple assembly line design problem* (SALDP) (Baybars, 1986; Becker & Scholl, 2006) or *single-product assembly system design problem* (SPASDP) (Gadidov & Wilhelm, 2000). SALDP considers the "high-level" logical layout design with equipment selection (one per station) from a set of alternatives. There are several equipment alternatives for each operation, and often a particular piece of equipment is efficient for some operations, but not for others (Bukchin & Tzur, 2000; Bukchin & Rubinovich, 2003). There is a given set of equipment types; each type is associated with a specific cost. The equipment cost is assumed to include the purchasing and operational cost. The duration of an operation depends on the equipment selected. An operation can be performed at any station, provided that the equipment selected for this station is appropriate and that precedence relations are satisfied. The total station time should not exceed the predetermined cycle time. The problem consists of selecting equipment and assigning operations to each station. The objective is to minimize the total equipment cost.

The *balancing of transfer lines and machines* (Dolgui, Guschinsky, & Levin, 2000) deals with grouping operations into a number of blocks (sets of operations performed by a spindle head) and assigning these blocks to stations. Each block requires a piece of equipment (a multi-spindle head), which incurs a purchase cost. Therefore, it is necessary to minimize both the number of stations and the number of blocks. To do it, all possible operations assignments to blocks and stations must be considered; otherwise the optimality of a solution cannot be guaranteed. The set of alternative blocks is not known in advance and the parameters of a block depend on the set of operations assigned to it. Therefore, the balancing of machining systems, as it was demonstrated in (Dolgui, Finel, Guschinsky, Levin, & Vernadat, 2006), is more complex than SALBP and SALDP.

MACHINE TOOL ENGINEERING

Transfer machines are dedicated to the mass production of a family of similar products and widely used in the automotive industry (Hitomi, 1996). Designing and balancing such machines is a very complex problem due to necessity to take into account the specific machining constraints. At the same time, to acquire a machine sell order, the manufacturers must provide their customers with the results of the preliminary design (general plans of the machine and an estimation of the price) as quickly as possible. Therefore, it is vitally important for manufacturers to have a decision making methodology and decision support system (Dolgui, Guschinskaya, Guschinsky, & Levin, 2005).

Thus, in order to help designers to find a high-quality (and if possible an optimal) architecture of transfer machine corresponding to the customer demand, we developed and implemented a methodology and a prototype of decision support system named "*machine tools engineering*" (MTE).

This decision support system deals with the optimization of the logical layout design of *transfer machines* and provides designers with an integrated design environment. We depicted the different design stages as well as the implemented in MTE software tool operational research and decision-aid methods.

A decision support system devoted to the design of transfer machines has to provide users with graphical tools to make the design process fast and easy. In addition, it must be capable to help designers to make decisions based on expert knowledge and technological requirements. To reach these objectives, MTE was developed in the design environment of popular commercial CAD system *AutoCad Mechanical Desktop 2006*. Its conceptual environment makes the creation, editing, and navigation of solids and surfaces simple and intuitive. The modules containing the developed optimization methods are plug-ins embedded to AutoCad Mechanical Desktop 2006. This system configuration enables designers to use the common data format at all preliminary design stages.

MTE is dedicated to the preliminary design of transfer unit head machines (machines composed from standard units) with the following configurations:

1. *Multi-positional machines with rotary table.*
   A part is sequentially machined on *m* working
   positions and is moved from one position to the next one using a rotary table. The rotary table is divided into *m*+ 1 sectors: *m* of them correspond to the working positions and one sector is served for loading the billet and unloading the part. Therefore, at each moment *m* parts are machined—one per working position. Each working position may be accessible for one or two (one vertical and one horizontal) spindle heads. The spindle heads of each working position are activated simultaneously. Thus, all spindle heads perform operations on parts in parallel.
2. *Machines with mobile table.* These machines are used for the fabrication of parts that cannot be produced on multi-positional machines with rotary table because of their dimensions (this type of machine has a lower productivity than rotary table machines since only one part can be machined within the *cycle time*). Here, a part is machined on *m* ($m \leq 3$) working positions and is moved from one position to the next one using a mobile table. Each working position has

one or two (one vertical and one horizontal, or two horizontal) spindle heads. The last working position may have three spindle heads (one vertical and two horizontal, or three horizontal). The spindle heads of each working position are activated simultaneously. At each moment only one position is active and the spindle heads of the active working position perform operations on the machined part. The first position is used also for unloading the part after machining and loading the billet.

DECISION MAKING METHODOLOGY

A design methodology for manufacturing systems can be defined as a set of procedures that analyzes and segregates a complex *manufacturing system design* task into simpler manageable sub-design tasks while still maintaining their links and interdependencies (Wilheim, Smith, & Bidanda, 1995). An illustration of *MTE decision support system* is given in Figure 1 and the corresponding decision making procedure is presented in Table 1 (Dolgui et al., 2005).

Product/Process Modeling

Part Modeling

The first step deals with the *modeling of a part* to be machined. The clients provide the machine tool manufacturer with the specifications of a part already designed, which they want to produce using a transfer machine. Usually, the manufacturing process includes milling, drilling, boring, and so forth, a set of part elements such as planes, facets, holes of different types (cylindrical, bevel, threaded, etc.). Each element concerns a certain side (or surface) of the part and is characterized by a set of technological parameters, like required tolerances and surface conditions. Figure 2 shows an example of a part that was modeled in the MTE system.

In order to use the same format for the geometric and technological data, the part is modeled with machining features. The concept of feature

Figure 1. MTE decision support system

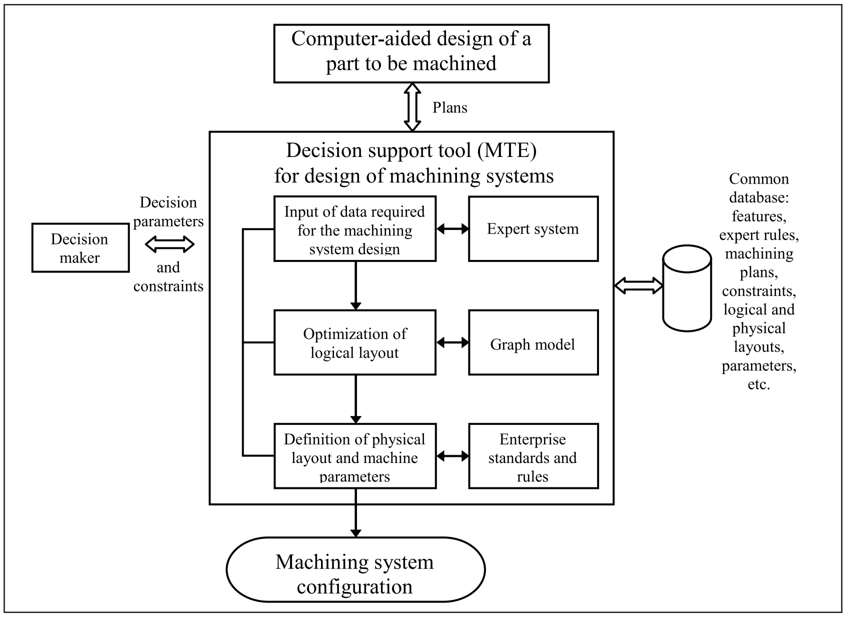


Table 1. General methodology of decision making for a machining system design

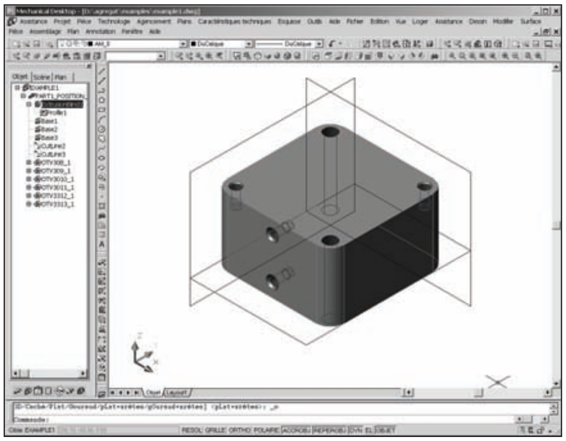
Stages and steps
Stage 1. Input of data required for the machining system design
Step 1.1. Part modeling with features
Step 1.2. Input of part and machine properties
Step 1.3. Process planning using an expert system
Step 1.4. Constraints generation based on machining data and user experience
Stage 2. Optimization of logical layout
Step 2.1. Finding all solutions minimizing the number of spindle heads and working positions while assigning operations to working positions and defining cutting modes for spindle heads
Step 2.2. Choice of a solution among the optimal ones (solution to be applied)
Stage 3. Definition of physical layout and machine parameters
Step 3.1 Working plan documentation
Step 3.2. Part positioning
Step 3.3. Equipment selection
Step 3.4. Preliminary 3D layout design
Step 3.5. Control equipment and additional devices selection
Step 3.6. Cost estimation

associates the technological characteristics of a machining element with its geometric parameters. Therefore, the part modeling step demands analyzing the part to be machined and identifying features, their geometric and topological relations.

To make the design of features easier and faster, we analyzed a certain number of standard elements. A graphic library of the most common parameterized features was developed and embedded to AutoCad Mechanical Desktop 2006. The corresponding technological characteristics are stored in the data fields associated with each feature.

When the part has been modeled, some additional characteristics of the part (for example, the material and its properties, the properties of the billet, etc.), and of the machine (for example, the desired productivity, the cooling method, the type of cooling liquid, etc.) must be defined as well as a desired type of machine (with rotary or mobile table) must be selected.

Figure 2. Part to be machined



Process Planning

At this stage, the machining operations, required tools and their parameters for each part feature are determined. The *process plan* of a part feature, that is, a set of operations to be performed in order to provide the required geometric and technological characteristics, is chosen using the following parameters: the condition of surface before machining, the diameter of machining holes, and the required precision for each machining element. These parameters are stored in the data fields associated with the features. Analyzing their values and using the expert system, all possible process plans for each feature can be chosen from the process plans database. This database contains also dependences between the feature parameters and the set of all possible operations that a machine equipped by standard spindle heads can process. Then, for each feature and each possible process plan the corresponding tolerances are calculated. The obtained values of tolerances are compared with those required and the plan providing the values nearest to the required is chosen. For this chosen plan, the parameters of operations (like cutting depth, machining length, type and material of cutting tool, working stroke, and cutting mode) are determined automatically. Cutting mode is defined by minimal, maximum, and recommended values of the following parameters: cutting speed, feed rates per minute and per revolution. Then, the user, who can replace or modify automatically chosen plans, analyzes the plans suggested by the decision support tool. New process plans can be stored in the database.

In order to establish a total process plan, the individual machining plans selected for the features must be completed by introducing the existing relations between the operations of different features. These relations are introduced using different types of constraints.

Generation of Constraints

The decision support tool MTE considers the following types of relations between machining operations:

a. *Precedence constraints* which define possible sequences of operations and are determined by a number of known technological factors (fixed sequences of operations for machining features, the presence of roughing, semi-finishing and finishing operations, etc.).
b. *Inclusion constrains* reflect the necessity to perform some operations on the same working position or even by the same spindle head. They are implied by the required precision (tolerance) of mutual disposition of machined features as well as a number of additional factors.
c. *Exclusion constrains* are used in the cases when it is impossible to assign some pairs of operations to the same working position (or to the same spindle head). It can be caused by a number of constructional and technological constraints: mutual influence of these operations, a forbidden tool location, and so forth. This type of constraint must be fulfilled also for operations executed on the different sides of the part because they cannot be performed by the same spindle head.

Some constraints are automatically generated by the decision support tool MTE. For this, all operations can be divided into four groups according to the finish state:

1. Milling operations
2. Roughing operations (boring, drilling with the
drill diameter more than 20 mm, countersinking
with the countersink diameter more than 30 mm)
3. All other operations except threading operations
4. Threading operations.

Usually, no operation of a group can be started before the end of all previous group operations, therefore the corresponding precedence constraints are generated automatically. Generally, the same equipment cannot perform operations of two different groups. Thus, they cannot be assigned to the same spindle head. Since all spindle heads of a working position are activated simultaneously, operations from different groups can not be assigned to the same working position; therefore the corresponding *exclusion constraints* are also generated automatically. In accordance with their expert knowledge or preferences users can introduce complementary constraints of any type or remove the constraints generated automatically.

The overall equipment dimensions limit the total number of working positions and the number of blocks at each working position by the values of the parameters $\overline{m}$ and $\overline{n}$ respectively. The values of $\overline{m}$ and $\overline{n}$ are obtained taking into account the available machine configuration and economical constraints.

The objective production rate is obtained, if the machine *cycle time* $T(P)$ does not exceed the maximum authorized value T_0.

Logical Layout Optimization

The manufacturing information as well as diverse constraints related to the design of spindle heads and working positions are used as input data for the second design stage, that is, *logical layout design* (Wilheim et al., 1995; Zhang, Zhang, & Xu, 2002). The quantity of equipment (spindle heads, working positions) required to produce a part with the given productivity rate defines the final cost of the *transfer machine*. Therefore, the goal of the logical layout optimization is to find a design variant that minimizes the number of working positions and the total number of spindle heads while satisfying all given technological and economical constraints (Dolgui, Guschinsky, Levin, & Proth, 2008).

Problem Statement

If the machining is organized on m working positions, then at the k-th working position $k=1, ..., m$, a subset N_k of the given set **N** of operations is performed. Each set N_k is uniquely partitioned into n_k subsets (N_{kl}, $l=1,...,n_k$), where the operations of each subset N_{kl} are performed by the same spindle head. Such a partition is unique due to the fact that each operation corresponds to one "side" of the part, and only the operations of the same side can be performed by one spindle head. Parameters of the kl-th spindle head and its execution time depend both on the set of operations N_{kl} and their cutting modes.

The logical layout optimization consist in determining simultaneously:

a. The number m of working positions;
b. The partitioning of the given set **N** of operations into subsets N_k, $k = 1,...,m$; and
c. The feed per minute X_{kl} for each N_{kl}, $l = 1,\ldots, n_k$.

Let $P=<P_1,...,P_k,...,P_m>$ is a design solution with $P_k = (P_{k1}, ..., P_{kl}, ...,P_{kn_k})$ and $P_{kl} = (N_{kl}, X_{kl})$. Let C_1 and C_2 be the relative costs for one working position and one block, respectively. Then the objective function of the considered design problem can be formulated as follows:

$$Min\ Q(P) = C_1 m + C_2 \sum_{k=1}^{m} n_k \qquad (1)$$

Cycle Time Calculation

Let $\lambda(i)$ be the given length of the working stroke for operation $i \in$ **N.** The execution time $\tau^b(N_{kl}, X_{kl})$ of the set N_{kl} of operations performing by the kl-th spindle head working with the feed per minute X_{kl} is equal to:

$$\tau^b(N_{kl}, X_{kl}) = L(N_{kl})/X_{kl}, \qquad (2)$$

where $L(N_{kl}) = max\{\lambda(i) \mid i \in N_{kl}\}$.

The execution time for all operations of the k-th working position (k=1,…,m) is equal to:

$$\tau^p(P_k) = max\ \{\ \tau^b(N_{kl}, X_{kl})\ |\ l=1,\dots,n_k\ \}. \quad (3)$$

The *cycle time* for *machines with a rotary table* is defined by the maximum value among the execution times of the working positions:

$$T(P)=\boldsymbol{\tau}'' + \max\{\tau^{\,p}(P_k)\ |\ k= 1, 2..., m\}, \quad (4)$$

where $\boldsymbol{\tau}''$ is a given constant, an additional time for loading the billet and unloading the part after machining.

The cycle time for *machines with a mobile table* is defined by the sum of the machining times of the working positions:

$$T(P)=\boldsymbol{\tau}'' + \sum_{k=1}^{m} \tau^p(P_k) \quad (5)$$

Let $\mu(i)$ be a constant that characterizes the tool life rate, $[s_1(i),s_2(i)]$ and $[v_1(i),v_2(i)]$ the ranges of the feasible values of feed per revolution $s(i)$ and spindle speed (cutting speeds) $v(i)$, respectively, for each operation $i\in\mathbf{N}$; $s_0(i)$, $v_0(i)$ are their "recommended" values:

$$\begin{aligned} x_0(i) &= s_0(i)v_0(i),\\ x_1(i) &= s_1(i)v_1(i), \qquad (6)\\ x_2(i) &= s_2(i)v_2(i). \end{aligned}$$

The interval of possible values of the feed per minute for the spindle head which executes the set N of operations $\mathbf{X}(N)= [\underline{X}(N), \overline{X}(N)]$ is calculated as follows:

$$\underline{X}(N)=\max(\max\{x_1(i)|i\in N\}, L(N)/(T_0\text{-}\tau'') \quad (7)$$
$$\overline{X}(N)=\min\{x_2(i)|i\in N\} \quad (8)$$

If the set $\mathbf{X}(N)$ is empty, then operations of the set N cannot be executed by one spindle head. Otherwise, a preliminary value $x\in\mathbf{X}(N)$ might be chosen in the following way:

$$x^*(N)=\min\{(L(N)/\lambda(i))^{\mu(i)}x_0(i)|i\in N\} \quad (9)$$
$$x^{**}(N)=\max\{\underline{X}(N), x^*\} \quad (10)$$
$$x(N)=\min\{x^{**}, \overline{X}(N)\} \quad (11)$$

In this case, the feed per revolution for operation i is equal to $s(i,x)=\min[s_2(i),x/v_1(i)]$, and the cutting speed is equal to $v(i,x)=x/s(i,x)$.

Modeling of Constraints

We assume that the given productivity is achieved, if the cycle time $T(P)$ (calculated) does not exceed the maximum value T_0.

$$T(P) \le T_0 \quad (12)$$

The *precedence constraints* can be specified by an acyclic digraph $G^{OR}=(\mathbf{N},D^{OR})$ where an arc $(i,j)\in D^{OR}$ if and only if the operation i has to be executed before the operation j. Thus, for each operation $j\in\mathbf{N}$, a set $Pred(j)$ of its immediate predecessors is determined.

The *inclusion constraints* can be given by undirected graphs $G^{SH}=(\mathbf{N},E^{SH})$ and $G^{SP}=(\mathbf{N},E^{SP})$ where the edge $(i,j)\in E^{SH}$ if and only if the operations i and j must be executed by the same spindle head, the edge $(i,j)\in E^{SP}$ if and only if the operations i and j must be executed on the same working position.

The *exclusion constraints* can also be defined by undirected graphs $G^{DH}=(\mathbf{N},E^{DH})$ and $G^{DP}=(\mathbf{N},E^{DP})$ where the edge $(i,j)\in E^{DH}$ if and only if the operations i and j cannot be executed by the same spindle head, the edge $(i,j)\in E^{DP}$ if and only if the operations i and j cannot be executed on the same working position.

Since for this type of machine the set N_k is partitioned into subsets for spindle heads uniquely, we can define a function $O(N_k)$ whose value is equal to the number of obtained spindle heads. We assume also that this function takes a sufficiently large value if the operations of the set N_k cannot be partitioned into subsets with regard to precedence, inclusion and exclusion constraints, that is, where one of the following conditions holds:

$$\{i,j\} \subseteq N_k,\ \ (i,j) \in (D^{OR} \cup E^{DP}) \qquad (13)$$

$$|\ \{i,j\} \cap N_k| = 1,\ (i,j) \in E^{SP} \qquad (14)$$

$$\{i,j\} \subseteq \mathrm{N}_{kl},\ (i,j) \in E^{DH},\ l=1,\ldots,\ n_k \qquad (15)$$

$$|\{i,j\} \cap N_{kl}| = 1,\ l = 1,\ldots,n_k,\ (i,j) \in E^{SP} \qquad (16)$$

$$\boldsymbol{X}(N_{kl}) = \emptyset,\ l = 1,\ldots,n_k$$
(17)

Optimization Model

The optimization model of the considered decision making problem for *logical layout design* can be formulated as follows:

$$Minimize\ Q(P) = C_1 m + C_2 \sum_{k=1}^{m} O(N_k), \qquad (18)$$

subject to:

$$T(P) \le T_0 \qquad (19)$$

$$\bigcup_{k=1}^{m} N_k = \mathbf{N} \qquad (20)$$

$$N_{k'} \cap N_{k''} = \emptyset,\ \forall\ k',\ k'' = 1,\ldots,m \text{ such that } k' \neq k'' \qquad (21)$$

$$O(N_k) \le \bar{n},\ \ \text{for all } k=1,\ldots,m \qquad (22)$$

$$X_{kl} \in \boldsymbol{X}(N_{kl}),\ \text{for all } k=1,\ldots,m;\ l=1,\ldots,n_k \qquad (23)$$

$$m = m(P) \le \bar{m} \qquad (24)$$

The objective function (18) is the estimation of the equipment cost; constraint (19) provides the required productivity rate; constraints (20-21) ensure the assignment of all the operations from **N**, each operation to one and only one working position; (22) provides precedence constraints for operations, inclusion and *exclusion constraints* for spindle heads and working positions; (23) chooses feasible values of the feed per minute for each spindle head; and (24) is the constraint on the number of working positions.

The values $\bar{m}$ and $\bar{n}$ are defined by the type of the machine: for machines with rotary table $\bar{m} \le 15$ and $\bar{n} = 2$, for machines with mobile table $\bar{m} \le 3$ and $\bar{n} \le 3$. For machines with mobile table the expression (22) is replaced by (22'):

$$O(N_k) \le 2,\ \ k=1,\ldots,m\text{-}1;\ O(N_m) \le 3 \qquad (22')$$

Optimization algorithms are based on the shortest path approach (Dolgui et al., 2000; Dolgui et al., 2008). They find all optimal solutions corresponding to the different machine configurations with different operations' assignment or allocation of spindle heads to working positions. In order to choose a solution to be applied, these solutions can be evaluated by user with other criteria and user's preferences. If the results of the optimization do not satisfy user, it is possible to return to previous stages and make the necessary modifications of constraints and input data.

3D-MODEL AND COST ESTIMATION

The obtained logical layout defines the general configuration of a *transfer machine* and enables designers to complete this logical architecture by selecting the corresponding modular equipment from the library of standard units of *MTE*. At first, designers specify the overall dimensions of the movable table and place the part to be machined on it. The part position defines the angles and positions of the spindle heads.

Then, designers define the dimensions and the specifications of the required equipment that will automatically be designed using the graphical library of standard units. Finally, designers can obtain a preliminary 3D-model of the machine. Figure 3 illustrates a machine with rotary table which consists of six working positions and

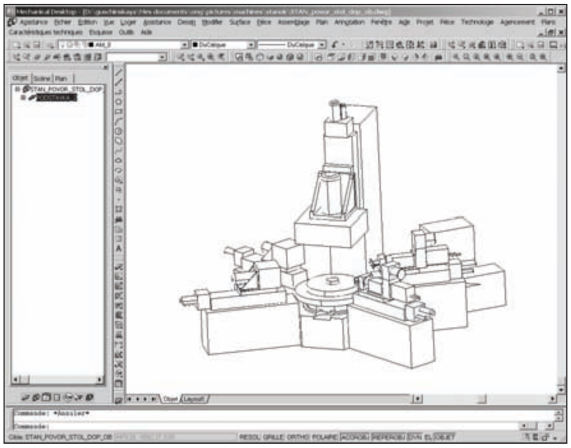


Figure 3. 3D-model of a machine with rotary table

equipped by one vertical spindle head. Figure 4 shows a machine with mobile table, which consists of two working positions.

In order to estimate the total machine cost, additional devices are to be selected, like control, tool storage, and loading-unloading systems. This choice is guided by some automatically generated suggestions and accompanied by the verification of compatibility with all previous decisions. The costs of all selected devices are obtained from the database which contains market prices of standard units (spindle heads and other machine elements). The total cost estimation enables designers to formulate a commercial offer for customers. Therefore, using the decision support system MTE, machine tools manufacturers can provide their clients with technological plans and a commercial offer in really short times. If clients accept this offer then the detailed design of the machine with the chosen configuration is to be prepared in order to establish a manufacturing plan. At this stage more detailed analysis of machine properties is needed, the manufacturability of parts can be verified using, for example, the finite elements model and simulation (Daschenko, 2003).

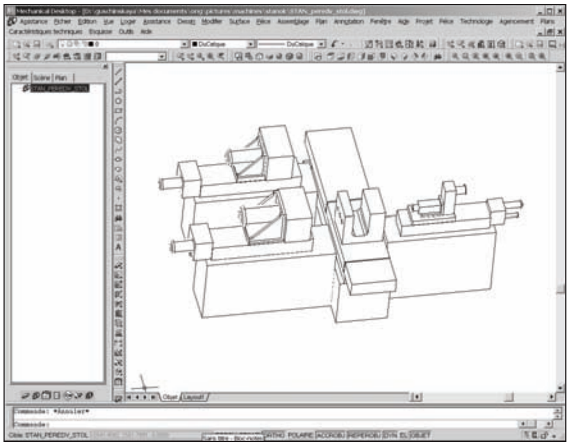


Figure 4. 3D-model of a machine with mobile table

CONCLUSION AND FURTHER RESEARCH

A novel and promising applied area for decision making methods and decision support technologies is the development of decision-aid software tools for manufacturing system design. It is necessary to use conjointly advanced operational research methods, standard decision making approaches, decision support technologies and problem oriented specific rules. We have presented an example of such a decision support system for preliminary *design of machining systems* for mass production.

The integrated *decision support system* MTE was developed to help machine tool designers to obtain a high-quality (and if possible optimal) architecture of *transfer machines*. The system supports the different stages of the logical layout design of a transfer machine: modeling of a part to be machined, process planning, optimization of the machine configuration, its preliminary 3D layout, and cost estimation. The optimization problem of the logical layout is to find the number of working positions and the number of spindle heads, to assign the manufacturing operations to positions, and to choose the cutting modes for each spindle head while minimizing the total equipment cost.

The perspectives of this research consist in the improvement and extension of the suggested approach for a larger class of manufacturing systems: linear *transfer machines*, transfer lines with buffers, multi-flow transfer lines, assembly lines, and so forth. Another promising approach is the integration of the process planning and logical layout steps in a common optimization model using heuristics and meta-heuristics.

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KEY TERMS

Feature: A standard element characterized by both technological and geometrical parameters that have meaning in the definition and machining of a part.

Integrated Decision Support Tool for Design of Machining System: A software tool, which includes the functions of part modeling, process planning, logical and physical layouts optimization, and machining system cost estimation. It is used for the preliminary design of the machining systems.

Logical Layout: An assignment of all operations to be executed to pieces of equipment; usually an optimal logical layout is obtained by solving the corresponding line balancing problem.

Physical Layout: An arrangement of pieces of equipment in the production area.

Process Planning: The activity of taking the product design or specification, which is defined in terms of size, shape, tolerances, finish, material properties, and so forth, and transforming it into detailed list of manufacturing instructions such as specifications for materials, processes, sequences, and machining parameters.

Spindle Head (Spindle Box): A device where several tools are fixed to perform several operations in parallel; all tools of the same spindle head have the same parameters (working stroke, feed per minute) and are activated simultaneously.

Transfer Machine: A machine tool used in the mass production of a unique product or a family of similar products by processing the drilling, boring, milling, and other machining operations in a given order on each part machined.

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Chapter 2.12

Context in Decision Support Systems Development

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INTRODUCTION

Finding appropriate decision support systems (DSS) development processes and methodologies is a topic that has kept researchers in the decision support community busy for the past three decades at least. Inspired by Gibson and Nolan's curve (Gibson & Nolan 1974; Nolan, 1979), it is fair to contend that the field of DSS development is reaching the end of its expansion (or contagion) stage, which is characterized by the proliferation of processes and methodologies in all areas of decision support. Studies on DSS development conducted during the last 15 years (e.g., Arinze, 1991; Saxena, 1992) have identified more than 30 different approaches to the design and construction of decision support methods and systems (Marakas, 2003). Interestingly enough, none of these approaches predominate and the various DSS development processes usually remain very distinct and project-specific. This situation can be interpreted as a sign that the field of DSS development should soon enter in its formalization (or control) stage. Therefore, we propose a unifying perspective of DSS development based on the notion of context.

In this article, we argue that the context of the target DSS (whether organizational, technological, or developmental) is not properly considered in the literature on DSS development. Researchers propose processes (e.g., Courbon, Drageof, & Tomasi, 1979; Stabell 1983), methodologies (e.g., Blanning, 1979; Martin, 1982; Saxena, 1991; Sprague & Carlson, 1982), cycles (e.g., Keen & Scott Morton, 1978; Sage, 1991), guidelines (e.g., for end-user computer), and frameworks, but often fail to explicitly describe the context in which the solution can be applied.

BACKGROUND

A DSS is broadly considered as “a computer-based system that aids the process of decision making” (Finlay, 1994). Sprague uses a definition that indicates key components of the DSS architecture. A DSS is a “computer-based system which helps decision makers confront ill-structured problems through direct interaction with data and analysis models” (Sprague, 1980). In a more detailed way, Turban (1995) defines it as “an interactive, flexible, and adaptable computer-based information system, especially developed for supporting the solution of a non-structured management problem for improved decision making. It utilizes data, provides an easy-to-use interface, and allows for the decision maker’s own insights.” This second definition gives a better idea of the underlying architecture of a DSS. Even though different authors identify different components in a DSS, academics and practitioners have come up with a generalized architecture made of six distinct parts: (a) the data management system, (b) the model management system, (c) the knowledge engine, (d) the user interface, (e) the DSS architecture and network, and (f) the user(s) (Marakas, 2003;Power, 2002).

One section this article, Key Terms, briefly defines nine DSS development methodologies popular in the DSS literature. A typical methodology is represented by the steps in Table 1.

The exact number of steps can vary depending on the aggregation level of each phase. Moreover, steps are usually sequenced in an iterative manner, which means the process can iterate to an earlier phase if the results of the current phase are not satisfactory. Even though these processes are useful from a high-level perspective, we argue that they poorly support the DSS designers and builders to cope with contextual issues. The next paragraphs provide a couple of examples to illustrate this argument. The first example is related to the user interface. The DSS community widely recognizes that the user interface is a critical component of a DSS and that it should be designed and implemented with particular care. But how critical is this component? On the one hand, if we consider a DSS that is intended to be used by a wide range of nontechnical users (for example, a medical DSS for the triage of incoming patients in an emergency room that will be used by nurses and MDs working under pressure), then the user interface is indeed the single most critical component of the DSS, at least from a usability/acceptability point of view. In this context, the human-computer interaction (HCI) literature tells us that usability must definitely be considered before prototyping takes place, because the earlier critical design flaws are detected, the more likely they can be corrected (Holzinger, 2005). There are techniques (such as usability context analysis) intended to facilitate such early focus and commitment (Thomas & Bevan, 1996). On the other hand, if we consider a highly specific DSS that will be handled by a few power-users with a high level of computer literacy (sometimes the DSS builders themselves), then the user interface is less critical and usability considerations can be postponed until a later stage of the development process without threatening the acceptability of the system. This kind of decision has an impact on the entire development process but is rarely considered explicitly in the literature.

Table 1. Phases of the DSS design and development life cycle (Sage, 1991)

1. Identify requirements specifications
2. Preliminary conceptual design
3. Logical design and architectural specifications
4. Detailed design and testing
5. Operational implementation
6. Evaluation and modification
7. Operational deployment

The second example deals with the expected lifetime of the DSS. On the one hand, some DSS are complex organizational systems connected to a dense network of transaction information systems. Their knowledge bases accumulate large quantities of models, rules, documents, and data over the years, sometimes over a few decades. They require important financial investments and are expected to have a long lifetime. For a computer-based system, a long lifetime inevitably implies maintenance and legacy issues. The legacy information systems (LIS) literature offers several approaches to deal with these issues, such as the big bang approach (Bateman & Murphy, 1994), the wrapping approach (Comella-Dorda, Wallnau, Seacord, & Roberts, 2000), the chicken little approach (Brodie & Stonebraker, 1995), the butterfly approach (Wu et al., 1997), and the iterative re-engineering approach (Bianchi, Caivano, Marengo, & Vissagio, 2003). Some authors also provide methods fostering the clear separation between the system part and the knowledge base part, in order to maximize reusability (Gachet & Haettenschwiler, 2005). On the other hand, some DSS are smaller systems used to deal with very specific—and sometimes unique—problems, that do not go past the prototyping stage, that require minimal finances, and use a time-limited knowledge base. Maintenance and legacy issues are less salient for these systems and their development follows a different process.

We describe in the coming sections of this article a unifying approach to DSS development allowing DSS designers to explicitly take these contextual aspects into considerations in order to guide the development process of a DSS. This new approach is based on the concept of value-based software engineering.

VALUE-BASED SOFTWARE ENGINEERING

Suggesting that the DSS community never considered the context of a DSS prior to its development would be unfair. Several authors acknowledge that a systems design process must be specifically related to the operational environment for which the final system is intended (Sage, 1991; Wallace et al., 1987). For example, Sprague and Carlson (1982) explicitly specified in their "DSS action plan" a phase consisting of steps to develop the DSS environment. The purpose of this phase is to "form the DSS group, articulate its mission, and define its relationships with other organizational units. Establish a minimal set of tools and data and operationalize them." (p. 68). Nevertheless, how these tasks should be carried out is not specified. In this section, we propose an approach allowing DSS designers to model contextual value propositions and perform feedback control of a DSS project. This approach is inspired by the concept of value-based software engineering (Boehm & Guo Huang, 2003).

Two frequently used techniques in value-based software engineering are the benefits realization approach and the value-realization feedback process. The benefits realization approach (Thorp, 2003) allows developers to determine and reconcile the value propositions of the project's success-critical stakeholders. The centerpiece of this approach is the results chain (Figure 1). This chain establishes a framework linking initiatives that consume resources, such as implementing a new DSS, to contributions (describing the effects of the delivered system on existing operations) and outcomes (which can lead either to further contributions or to added value, such as increased profit). A results chain links to goal assumptions, which condition the realization of outcomes. Once the stakeholders agree on the initiatives of the final results chain, "they can elaborate them into project plans, requirements, architectures, budgets, and schedules." (Boehm & Guo Huang, 2003, p. 36)

Once the benefits-realization approach is completed, stakeholders can monitor the development of the project using the value-realization feedback process (Figure 2). As explained by Boehm and Guo Huang (2003):

The results chain, business case, and program plans set the baseline in terms of expected time-

Figure 1. Benefits-realization approach results chain (adapted from Boehm & Guo Huang, 2003)

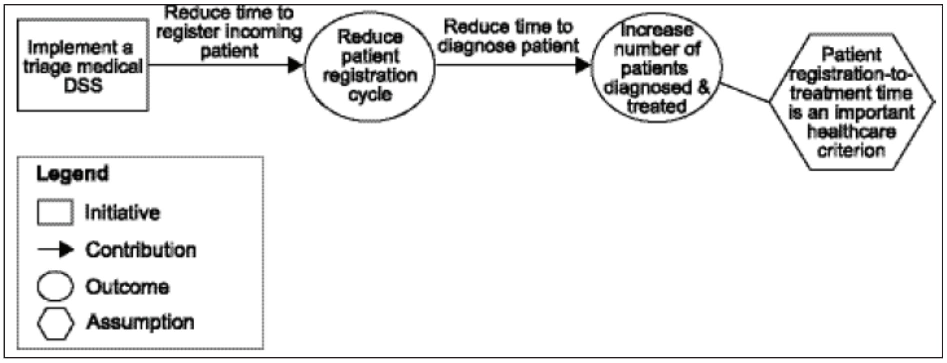
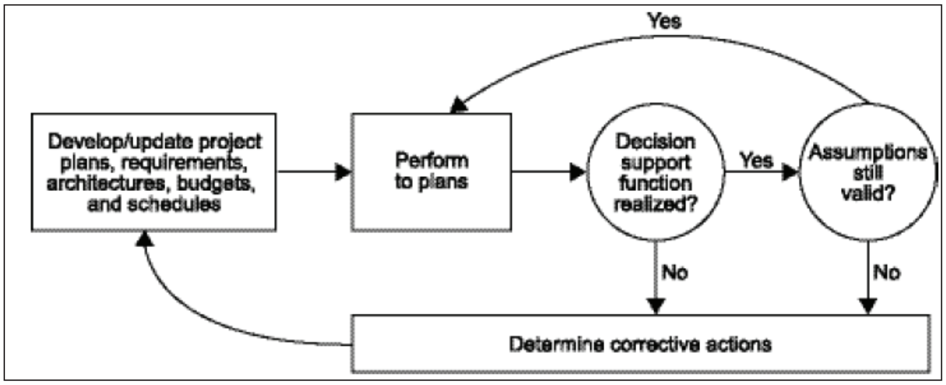


Figure 2. The realization feedback process (adapted from Boehm & Huo Huang, 2003)

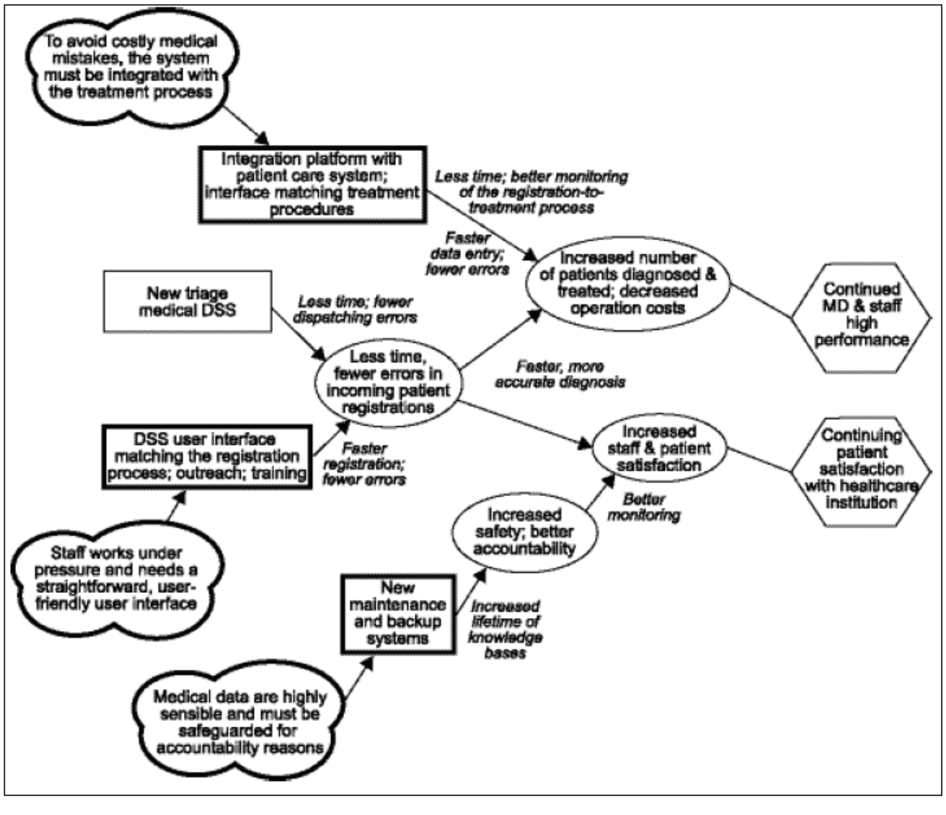


phased costs, benefit flows, returns on investment, and underlying assumptions. As the projects and program perform to plans, the actual or projected achievement of the cost and benefit flows and the assumptions' realism may become invalid, at which point the project team will need to determine and apply corrective actions by changing plans or initiatives, making associated changes in expected cost and benefit flows. (p. 37)

One obvious advantage of this feedback process is its ongoing consideration of the goal assumptions' validity. The development of an organizational DSS can take time and the project's plan can change several times during the whole process. It is therefore important to regularly monitor the process to be sure that the system still meets the local needs and helps answer the right questions (the popular "do the right thing" proposition). Otherwise, a DSS can be seen as very successful in terms of cost oriented earned value, but a complete disaster in terms of actual organizational value. The feedback process used in value-based software engineering focuses on value realization. Assessing the value of a transaction information system is a difficult task (Tillquist & Rodgers, 2005). However, assessing the value of a DSS is even more difficult, since its main function (supporting decision-makers) leads to effects that are very difficult to measure in isolation from the complementary processes and activities in which the DSS is embedded. Even worse, measuring the value of a DSS during its development is almost impossible. Therefore, the feedback process that we propose in Figure 2 focuses more of the realization of the decision support function of the DSS ("do the thing right") rather than on an objective measure of value realization. Another advantage of this process is that it clearly identifies the design and implementation feedback cycles of a DSS project. First, the upper loop where the two questions are answered positively represents the implementation cycle during which the DSS is gradually built by the DSS builder according to design plans. Second, the lower loop where either one of the two questions is answered negatively represents the design feedback cycle, during which the DSS design must be overhauled by the DSS designer to make sure that the DSS will "do the right thing right." This clear identification of both cycles is important because it overcomes a problem found in many DSS development processes that make an abundant use of feedback loops between their various phases, but fails to explain how the DSS designer and builder can go back to a previous stage in case of a goal failure at a later stage. Finally, another advantage of this feedback process is that it emphasizes the fact that context is not simply a state, but part of a process: "it is not sufficient for the system to behave correctly at a given instant: it must behave correctly during the process in which users are involved" (Coutaz, Crowley, Dobson, & Garlan, 2005, p. 50). Even though Coutaz et al. (2005) are mostly interested in the context of a system in use, we argue that the statement remains valid for the entire development process of a system.

Modeling the context-based development of a DSS consists in defining the initiatives, contributions, outcomes, and goal assumptions of a results chain. For the purpose of this article, Figure 3 uses the example scenario of a medical DSS for the triage of patients in an emergency room and extends the results chain of Figure 1 by adding new initiatives explicitly dealing with the two issues we

Figure 3. Extended results chain for a triage medical DSS. Stakeholders and contextual information are explicitly considered



mentioned in Section 2, namely the user interface and the maintenance and legacy issues. A third issue, integration with the patient care system, is also considered. These additional initiatives are shown with bold borders. Needless to say, a realistic and complete results chain for a triage medical DSS would be much more complicated than Figure 3, with many more initiatives, outcomes, and goal assumptions related to other value propositions. For the sake of simplicity, however, we decided to limit the scope of the results chain in order to improve its readability. The ultimate purpose of the figure is to show how the benefits realization approach allows DSS designers to dynamically identify the project's success-critical stakeholders and to determine their propositions in terms of decision support.

Figure 3 also introduces a new kind of symbol, graphically represented as a cloud, which identifies contextual requirements. A contextual requirement is defined as a specification of a contextual imperative. The three contextual requirements of Figure 3 describe three imperatives related to the DSS integration with the rest of the patient care system, the DSS user interface, and the DSS maintenance, respectively.

Contextual requirements adequately supplement functional requirements. Traditional techniques to capture functional requirements (for example, UML use case diagrams in the object-oriented community at large) focus on describing how to achieve business goals or tasks. As such, they help define the inner environment of the target system. Defining the inner environment of the system, however, is only one part of the design phase. The DSS designer also needs to define the conditions for goal attainment, which are determined by the outer environment of the system. This is where contextual requirements come into play. The importance of contextual requirements to model the outer environment of the DSS can not be overemphasized. As Simon (1996) indicates, "in very many cases whether a particular system will achieve a particular goal of adaptation depends on only a few characteristics of the outer environment" (p. 11). For example, our example triage DSS is most likely to fail, independently from its intrinsic qualities (the inner environment), if it does not consider the working conditions of the medical staff, the sensitivity of medical data, and the tremendous risk associated with medical mistakes (three characteristics of the outer environment).

Obviously enough, functional requirements are driven by the contextual requirements. For example, the first contextual requirement in Figure 3 (in the top left corner) considers the legal environment of the system (medical mistakes can lead to costly malpractice lawsuits) and indicates how important it becomes to tightly integrate the triage DSS with the rest of the patient care system, to ensure patients are being given the drugs corresponding to the diagnosis. This integration also leads to an increased number of patients diagnosed and treated and keeps up the performance of the medical staff. Based on this contextual requirement, the DSS builder can derive a set of functional requirements to attain this integration goal.

The second contextual requirement in the results chain (in the middle left part of Figure 3) explicitly considers the work environment of the medical staff and shows that MDs, nurses, staff, and patients are considered as important stakeholders in the initiatives. Their satisfaction and acceptance of the new system are deemed critical for the DSS success and depend on a straightforward, user-friendly user interface. Expected outcomes such as the increased staff and patient satisfaction, or initiatives focusing on user and system interfaces acknowledge this fact.

Finally, the initiative to include maintenance and backup systems because medical data are highly sensible (last contextual requirement in Figure 3) illustrates the necessity to safeguard the data and knowledge bases of the entire infrastructure, for increased safety and better accountability.

With DSS more than with any other kind of IS, working on functional requirements that are not driven by contextual requirements is like shooting in the dark. You may end up with a great functionality from a technical point of view, but still be completely off target in the context of the target system. In short, contextual requirements are used by the DSS designer to define the outer environment of the system, which determines the conditions for goal attainment. Contextual requirements drive the functional requirements used by the DSS builder to define an inner environment capable to achieve these goals.

Once the contextual requirements and the initiatives of the results chain are set, the DSS designer can turn them into plans, architectures, budgets, and schedules. At that stage, traditional DSS development processes and methodologies (see the section on Key Terms for examples) can be used with a context-based flavor. Instead of focusing on traditional performance issues, the context-aware DSS designer can focus on the most salient and relevant aspects of the target system. In our example DSS for medical triage, the requirements specification phase should focus on user interface requirements (to guarantee the system acceptability) and on data integration and workflow activities (to prepare a smooth integration with the global patient care system). Maintenance and backup considerations are traditionally postponed until the last step of the process (operational deployment). In our example, however, we clearly identified maintenance and backup as critical value propositions for the DSS. Therefore, it is wise to move the corresponding requirements to the first step of the process. Traditional methodologies defined in the Key Terms section, such as functional mapping (Blanning, 1979), decision graph (Martin, 1982), and descriptive and normative modeling (Stabell, 1983), can be used to identify functional requirements specifications.

CONCLUSION

In this article, we have described a unifying approach to formalizing the notion of context in the study of DSS development. The proposed solution relies on the concepts of value-based software engineering and contextual requirements. It provides DSS designers and builders with the appropriate techniques to explicitly consider the context of the target DSS during the entire development process.

The first technique is the benefits realization approach, which uses diagrams called results chains to determine and reconcile the value propositions of the project's success-critical stakeholders. The results chain establishes a framework linking contextual requirements to initiatives, contributions, and outcomes. The results chain also links to goal assumptions, which condition the realization of outcomes.

The second technique is the realization feedback process, which regularly monitors the realization of the expected decision support functionalities and the validity of the goal assumptions. If the decision support functionalities are not realized, or the assumptions' realism becomes invalid, the DSS designers need to determine and apply corrective actions by changing plans or initiatives.

Contextual requirements are used by the DSS designer to define the outer environment of the system, which determines the conditions for goal attainment. Contextual requirements then drive the functional requirements used by the DSS builder to define an inner environment capable of achieving these goals.

We provided an example to illustrate how a somewhat impractical, context-free DSS development life cycle can be turned into a context-based life cycle focusing on the most success-critical aspects of the target DSS, without overwhelming the DSS designers with long checklists that are not necessarily relevant in the context of the target system.

The inability of the DSS community to come up with unified and standardized methods to develop decision support systems is a recurring topic that has kept researchers and practitioners busy for the past three decades. We strongly believe that our approach finds a partial answer to the problem by explicitly acknowledging the fact that DSS can be widely different in their goals, scope, depth, lifetime, and costs. Rather than looking for an elusive context-free, one-size-fits-all solution, we propose a context-based set of tools able to formalize the DSS environment and context before choosing the appropriate development methodology. It is not our intention to define yet another solution in the existing proliferation of processes and methodologies for DSS development. Quite the opposite, we believe that our approach can help the field of DSS development enter in a formalization, or control, stage. Finally, it is our hope that the approach described in this article provides a vehicle for researchers and practitioners to develop better and more successful DSS.

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KEY TERMS

Design Cycle: DSS development methodology introduced by Keen and Scott Morton in 1978 (Keen & Scott Morton, 1978) which can be considered as the ancestor of most of the other DSS development processes and as an authoritative model. The global cycle is made of several steps focusing both on the decision support functionalities and their implementation in the actual system.

Decision Graph: DSS development methodology introduced by Martin in 1982 (Martin, 1982) as a modification of the descriptive system dynamics model. The methodology emphasizes graphic rather than computer simulation results, changes terminology from an engineering to a decision oriented context, and allows the use of a standard computer template. The methodology is purely graphical and uses symbols inspired by system dynamics structures. Decision graphs are used to create the decision model, with the purpose of identifying pertinent decisions.

Decision-Oriented DSS Development Process: DSS development process introduced by Stabell in 1983 (Stabell, 1983) in reaction to the technocentric, system oriented development methodologies proposed at the beginning of the 1980s. The development process relies on interrelated activities collectively labelled decision research. Emphasis in this decision-oriented, normative methodology is placed on changing the existing decision process to increase decision-making effectiveness.

Decision Support Engineering: DSS development methodology proposed by Saxena (1991) as a comprehensive methodology based on a life cycle model of DSS development, which encompasses an engineering approach to DSS analysis and design. Prototyping is also an important part of the methodology.

DSS Development Phases: DSS development methodology proposed by Sprague and Carlson in 1982 (Sprague & Carlson, 1982). The methodology can be broken down into two broad parts: an action plan and the ROMC methodology, a processing dependent model for organizing and conducting systems analysis in DSS.

DSS Prototyping (also known as evolutive approach): DSS development methodology defined by Courbon in 1979 (Courbon et al., 1979, 1980) as a methodology based on the progressive design of a DSS, going through multiple short-as-possible cycles in which successive versions of the system under construction are utilized by the end-user.

DSS Design and Development Life Cycle: DSS design and development methodology proposed by Sage in 1991 (Sage, 1991) as a phased life-cycle approach to DSS engineering. Its basic structure is very close to the software development life cycle (SDLC) methodology. However, it tries to avoid the drawbacks of the SDLC by embedding explicit feedback loops in the sequential life cycle and by promoting prototyping during system implementation in order to meet the iterative requirements of a DSS development process.

End-User DSS Development: Refers to people developing decision support applications for themselves or for others even though they are not trained IS professionals.

Functional Mapping (sometimes referred to as functional category analysis): DSS development methodology introduced by Blanning in 1979 (Blanning, 1979) as a DSS design approach mapping the functions of a DSS with the organizational units of the company. The methodology clearly identifies the responsibilities and/or benefits of the various organizational units vis-a-vis the DSS.

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Chapter 2.13

Flexible Spatial Decision-Making and Support: Processes and Systems

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ABSTRACT

Spatial decision-making is a key aspect of human behaviour. Spatial decision support systems support spatial decision-making processes by integrating required information, tools, models, and technology in a user-friendly manner. While current spatial decision support systems fulfill their specific objectives, they fail to address many of the requirements for effective spatial problem solving, as they are inflexible, complex to use, and often domain-specific. This research blends together several relevant disciplines to overcome the problems identified in various areas of spatial decision support. We proposed a generic spatial decision-making process and a domain-independent spatial decision support system (SDSS) framework and architecture to support the process. We also developed a flexible SDSS to demonstrate an environment in which decision-makers can utilize various tools and explore different scenarios to derive a decision. The use of the system is demonstrated in a number of real scenarios across location, allocation, routing, layout, and spatio-temporal problems.

INTRODUCTION

Decision-making is an essential element of our lives and critical for business success, because many natural phenomena and socio-economic activities take place in a spatial context. Spatial decision-making (SDM) becomes one of the important aspects of human behaviour. SDM activities are either dependent or influenced by geographical information. They are based on spatial problems that are normally semi-structured or ill-defined. Spatial problems are also multi-dimensional as they contain both spatial and non-spatial aspects.

It is not easy to measure or model all the aspects of a spatial problem in a single step. Therefore, a sophisticated modelling process is needed for solving these spatial problems.

Spatial decision-making usually involves a large number of alternative solutions, and these alternatives need to be managed using an appropriate scenario management facility. The multi-criteria decision-making (MCDM) method helps the decision-maker to select a solution from the many competitive alternatives. It facilitates the evaluation and ranking of the alternative solutions based on the decision- maker's knowledge or preference with respect to a set of evaluation criteria.

Decision support systems (DSS) have been proposed to support decision-making. Silver (1991) broadly defines a decision support system as a computer-based information system that affects or is intended to affect the way people make decisions. A focused DSS definition given by Sprague and Carlson (1982) states that a decision support system is an interactive computer-based system that helps decision-makers to solve unstructured problems by utilising data and models. To support spatial decision-making, a variety of systems have been developed: These include geographic information systems (GIS) and spatial decision support systems (SDSS). Our focus is on SDSS in this research. Peterson (1998) defines a spatial decision support system as an interactive and computer-based system designed to support a user or a group of users in achieving higher effectiveness for solving semi-structured or non-structured spatial decision problems.

As technology progresses, there is increasing opportunity to use SDSS in a variety of domains. Flexible support of decision-making processes to solve complex, semi-structured or unstructured spatial problems can offer advantages to individuals and organisations. We synthesise ideas, frameworks, and architectures from GIS, DSS, and SDSS. In addition, concepts from spatial modelling, model life cycle management, scenario life cycle management, knowledge management, and MCDM methodology are explored and leveraged in the implementation of a flexible spatial decision support system using object-oriented methodology and technology.

BACKGROUND

Moloney, Lea, and Kowalchek (1993) observe that about ninety percent of business information are geographically related and cover diverse domains, for example, resource management, environmental modelling, transportation planning, and geo-marketing. Spatial problems are normally categorised into allocation, location, routing, and layout problems based on their geographical features. The primary goal of SDSS is to support decision-making activities using its flexible modelling capabilities and spatial data manipulation functions. SDSS encompass spatial analytical techniques and enable system output in a variety of spatial forms. The characteristics of the spatial data, models, and operations as well as the integration processes of non-spatial systems with spatial systems make SDSS more complex. Currently- available SDSS frameworks and architectures are suitable for their specific objectives. However, they fail to properly address many of the requirements of a generic, flexible, and easy-to-use SDSS. As we have noted earlier, incorporating a GIS with a DSS develops some of SDSS frameworks and architectures. However, the existing SDSS frameworks and architectures are neither comprised of all the DSS components, nor are they generic. Fedra's (1995) framework is good for analytical modelling, but the solver is tightly integrated within the model, which does not provide flexibility in using a solver with different models. It does not provide any mapping instrument for flexible integration of model and data; rather it uses a pre-customised integration system that is limited to a specific domain. The model management framework of Yeh and Qiao

(1999) supports the modelling life cycle but overlooks spatial presentation functionalities. The dynamic environmental effects model (DEEM) is a software framework that provides optimal interoperability among environmental models, supports flexible decision-making, but fails to address scenario development and run-time model generation. The SDSS framework proposed by Armstrong and Densham (1990) does not separate model and solver. The knowledge management system framework of Mennecke (1997) does not pay attention to spatial visualisations, but rather focuses on the queries and reports. Some implemented SDSS are good in modelling systems, for example, Illinois River Decision Support System (ILRDSS) and Environmental Decision Support System (EDSS). Some are good in spatial data analysis and visualisation, for example, GRASSLAND, but none of these systems is generic and domain-independent.

The scenario-based SDSS architecture of Hall, Bowerman, and Feick (1997) is the only one that supports scenario management and facilitates the multiple scenario development. The system allows the decision-makers to generate, save, and recall solutions and supports comparing different scenarios. It is well developed for solving domain specific spatial problems, but the scenario evaluation has not been fully explored in this system as a non-spatial model; for example, the evaluation model has been absent in this framework. None of these frameworks and architectures addresses multi-criteria decision-making.

ISSUES, CONTROVERSIES, PROBLEMS

Though significant progress has been made in the context of decision-making and decision support systems, there has not been sufficient emphasis on SDM nor on SDSS. Densham (1991) argues that the main objective of a SDSS is to support decision-makers to make well-informed decisions based on complex spatial tasks. The processes and the various mechanisms used for solving spatial problems are also complex. The available technologies related to spatial decision-making are neither quite sufficient nor easy-to-use for managing this complexity.

Decision-makers often perceive the decision-making process adopted to solve complex multi-dimensional spatial problems as unsatisfactory. Decision-makers have been using the decision-making frameworks and processes for many years, but the general approaches proposed by Simon (1960) and others were not particularly developed for solving spatial problems; rather they provide a guideline for development of decision-making processes. Though Malczewski (1999) has proposed a multi-criteria decision-making framework, the implementation of the process has not been fully explored in the spatial context. A generic process to guide decision-makers to solve spatial problems is lacking. Decision-makers have to rely on their own processes and experience for spatial decision-making.

On the other hand, existing GIS, DSS, and SDSS that support decision-makers have their limitations in solving spatial problems. GIS do well in managing spatial data, but lack flexible modelling capacity. DSS are typically used in the non-spatial domain. SDSS encompass analytical techniques inherited from DSS and spatial modelling and various spatial input and output mechanisms provided by GIS to support decision-makers to make well-informed decisions. Densham (1991) argues that SDSS should facilitate a number of functions such as spatial data input, model-based analyses, and powerful visual presentations. Furthermore, these systems generally do not facilitate flexible spatial data manipulation mechanisms and lack output facility for presentation of the result of the decision-making process. They do not provide knowledge storage facility and lack a process-oriented user interface, thus enlarging the complexity of using the systems. A review of SDSS frameworks and architectures led us to conclude that current approaches fulfill their specific objectives, but fail to address many of the requirements of a generic, flexible, and easy-to-use SDSS.

In addition, model and scenario management processes have not been well developed in SDSS. The modelling process is ad hoc rather than generic and does not address the need of separation and integration of spatial and non-spatial models. Research indicates that the difficulties in synthesising various decision alternatives are primary obstacles to spatial problem-solving (Ascough II et al., 2002). Some SDSS support the development of single spatial or non-spatial scenario at one time, but few systems support integration of spatial and non-spatial scenarios to develop numerous multi-attribute spatial scenarios simultaneously. And also, spatial problems often have numerous alternative solutions, and use multiple criteria upon which they are evaluated. These complex spatial problems can be solved efficiently by incorporating the analytic modelling capabilities of the application specific spatial decision support system. The multi-criteria decision-making helps in screening alternatives and identifying the best solution. At this point many strategic requirements of SDSS have not been implemented completely. Their capability to solve complex multi-dimensional spatial problems is very limited.

Based on the problem areas identified in the field of spatial decision-making, we believe that a generic process for solving complex spatial problems is needed for achieving high effectiveness in spatial decision-making. The ideas from related disciplines (i.e., spatial modelling, model and scenario life cycle management, knowledge management and MCDM) need to be addressed in this process. Current SDSS frameworks and architectures address or implement one or a combination of requirements that are needed for complex spatial problem-solving, but they are incapable of managing all the issues required in a single coherent way. Synthesising ideas, frameworks, and architectures from related disciplines helps to overcome some of the problems identified in spatial decision support systems. A generic spatial decision-making process and a domain-independent SDSS framework and architecture will improve spatial decision quality and provide more opportunities for the use of SDSS.

SOLUTIONS AND RECOMMENDATIONS

To address the issues of spatial decision-making and spatial decision support systems, we first propose a spatial decision-making process that allows the decision makers to better use SDSS to solve spatial problems in a generic way, thus resulting in a better decision. We then develop a flexible spatial decision support system (FSDSS) framework and architecture to support this spatial decision-making process. The FSDSS provides flexible spatial data manipulation facility and supports integration of spatial and non-spatial data; it also facilitates the entire model and scenario management life cycle process, as well as support for multi-criteria spatial problem solving. We further implement a prototypical FSDSS that acts as a proof-of-concept for these proposals.

Spatial Decision-Making Process

Malczewski (1997) identifies *complexity*, *alternatives*, and *multi-criteria* characteristics as key features of spatial problems. Spatial problems are complex because they are semi-structured or ill-defined in the sense that the goals and objectives are not completely defined. Spatial problems are multi-dimensional and often related to non-spatial information. Each spatial problem can have a large number of decision alternative solutions. These alternative solutions to the spatial decision problems are normally characterised by multiple criteria upon which they are judged.

Model building is critical in decision-making as it clarifies thinking and improves the decision-making quality (Georgantzas & Acar, 1995). Spatial modelling techniques are used for finding relationships among geographic features and helps decision-makers to address the spatial problem clearly and logically. Spatial aspects and non-spatial aspects can be coexistent in a spatial problem, so that we need to consider both aspects at the same time. It is difficult to model a complex spatial problem in a single step, but it is possible to model one aspect of a complex problem at a time. For example, create a spatial model to deal with spatial aspects and a non-spatial model that caters to the non-spatial aspects of the problem, and then integrate them.

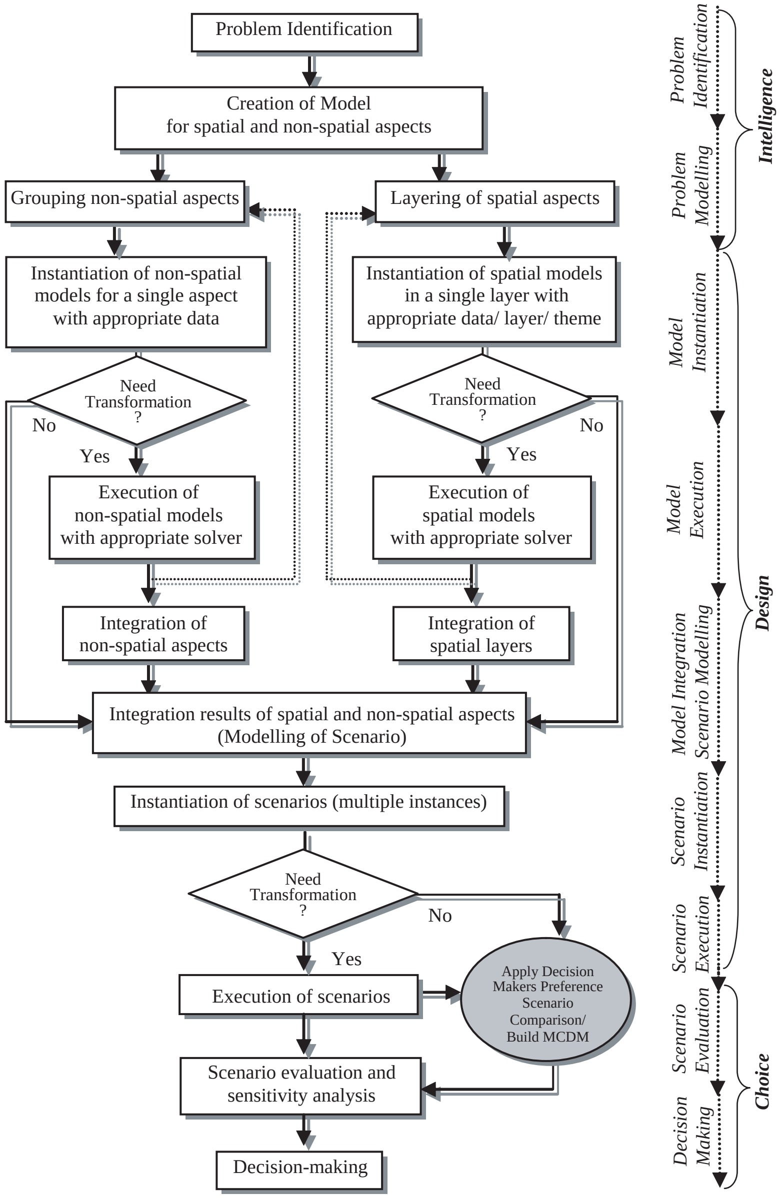
A spatial model contains spatial parameters that refer to the geographical features of a spatial problem. Vector-based spatial data can be categorised into three major groups, that is, spatial objects, spatial layers, and spatial themes. A spatial object represents a single spatial item, for example, a point, a line, or a polygon. A spatial layer contains a collection of spatial objects similar in nature, and every spatial object belongs to a certain layer. A spatial theme comprises a number of spatial objects and/or spatial layers that represent a particular meaning to a particular spatial problem. Vector data is linked to non-spatial domain data through a spatial reference system; a point could be associated with a residential location, and a line may represent a running path. Each aspect of a spatial problem can be modelled in one layer. These layers are then integrated into a complex model that represents the many facets of the problem.

We propose a spatial decision-making process (Figure 1) by synthesising ideas of decision-making processes (Simon, 1960) and the multi-criteria decision-making process (Malczewski, 1999). It also integrates concepts from spatial modelling, model, scenario, and knowledge management. The process contains nine specific steps, namely, problem identification, problem modelling, model instantiation, model execution, model integration, scenario instantiation, scenario execution, scenario evaluation, and final decision-making.

The decision-making process begins with the recognition of a real-world problem that involves searching the decision environment and identifying comprehensive objectives that reflect all concerns relevant to a decision problem. The problem is then put into a model by specifying the relevant attributes and behaviours. The parameters in a model structure are instantiated with appropriate data. Decision-makers select a solver for execution of a model instance and generate a result, that is, the scenario. A scenario improves cognition by organising many different bits of information (De Gues, 1997). Multiple scenarios are needed to explore different ways of seeing problems and enhancing the decision-making quality (Forrester, 1992). The scenario evaluation process evaluates many competitive alternatives simultaneously and helps to identify the best solution.

The process is iterative in nature so that multiple scenarios instances can be generated using the same scenario structures. The scenario integration process enables the decision-maker to combine both spatial and non-spatial scenarios to create a complex multi-criteria spatial scenario that addresses all the requirements of a complex spatial problem. When required, the instantiated scenarios are called for execution using different solvers. The execution of the scenario allows the decision-maker to further develop a more desirable solution to a particular problem. Scenario evaluation ranks the many alternative scenarios based on decision-makers' preferences. Sensitivity analysis is employed as a means for achieving a deeper understanding of the structure of the problem by changing the inputs, for example, data, solver, or evaluation model. This helps decision-makers learn how the various decision elements interact and allows them to determine the best solution. In completing the above processes, the best-evaluated scenario is selected. As there is no restriction on how the user chooses to solve a problem, decision-makers can select the phases to follow based on the nature of the specific problem and their specific purposes.

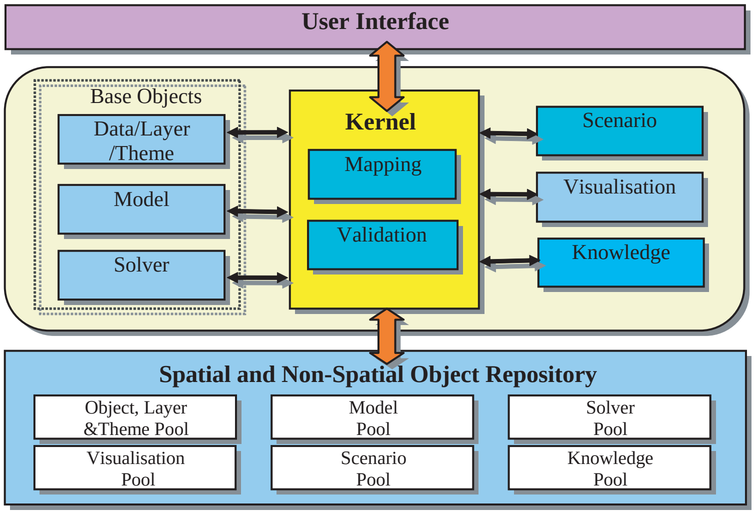
Figure 1. Spatial decision-making process



THE FSDSS FRAMEWORK

We propose a flexible spatial decision support system (FSDSS) framework (Figure 2) to support the decision-making process and overcome the problems identified earlier. The FSDSS framework is comprised of six major DSS objects or components namely, data, models, solvers, visualisations, scenario, and knowledge. These objects are stored in the object repository independently, and they communicate through the kernel, the programmatic engine that makes the system run. The framework accommodates spatial data (spatial objects, layers, and themes) and non-spatial data. It contains both spatial and non-spatial models, solvers, scenarios, and visualisations. The knowledge is the output of the decision-making process and can be stored in the system for future reference.

Figure 2. The FSDSS framework



The decision-maker interacts with the system through the user interface. Different data, model, and solver can be selected from the object repository and mapped together to generate a scenario, or a specific decision support system that is tailored for a particular problem domain.

This framework allows generating multiple scenarios at one time and stores them in the scenario pool. The framework supports the integration of several simple scenarios into a complex multi-attribute scenario that contains both spatial and non-spatial aspects through the scenario integration process. The multiple scenarios and the evaluated scenarios can be presented using the appropriate visualisation component. The output of the decision-making process can be saved in the object repository as knowledge.

The FSDSS Architecture

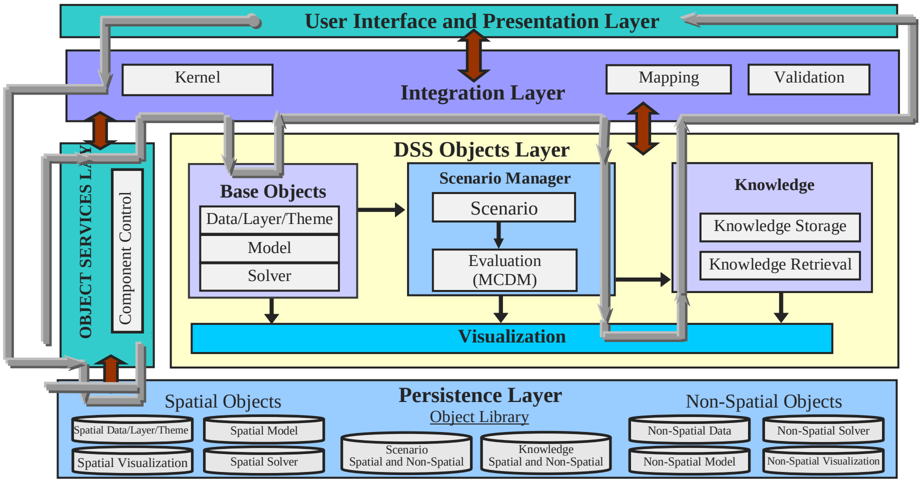
We propose an architecture that implements the FSDSS framework and supports the proposed decision-making process, as shown in Figure 3. The FSDSS architectural components are organised into five distinct layers; these are persistence layer, object services layer, DSS objects layer, integration layer, and presentation layer. These layers and their components are briefly described as follows.

The *persistence layer* contains the object library used to store the system objects. This includes the storage of non-spatial data and a variety of spatial data (objects, layers, themes, and map). It is also responsible for the storage of models, solvers, visualisations, scenarios, and knowledge, either spatial or non-spatial in nature, using the object-oriented database management system.

The *object services layer* manages the system objects through the component control that contains several parameters and methods to coordinate the component pool and the application. It exports objects from the object library to the DSS objects layer, as well as importing the resulting scenarios and knowledge from the DSS objects layer back to the object library. It also facilitates dynamic creation, updating, and deletion of the objects.

The *DSS objects layer* supports independent development and use of the decision-support components including spatial and non-spatial data, models, solvers, and visualisations, for generating basic spatial and non-spatial scenarios. It is responsible for integrating scenarios to develop complex spatial scenarios. It supports the evaluation and

Figure 3. The FSDSS architecture



ranking of multiple scenario instances using the evaluation model. This layer also facilitates the storage and reuse of the result from the decision-making process. It also provides graphical and map-based presentation of data, scenarios, and knowledge. The data component includes non-spatial and spatial data, that is, spatial objects, layers, themes, and maps. The model can be of the primitive type or the compound type (Geoffrion, 1987). Primitive type model parameters are directly derived using base data type variables or executed model values of the base models. The compound type parameters inherit and/or aggregate the base models as well as adding some other user-defined parameters. The non-spatial model handles non-spatial problems or non-spatial aspects of a spatial problem. Spatial models cater to spatial problems. The evaluation model is made of different parameters as well as the weights for each of these model parameters. The FSDSS architecture has a number of spatial-oriented solvers and generalised solvers that can be used to solve/execute both spatial and non-spatial models. The scenario combines data, model, solver, and other relevant information. The scenario structure and its multiple instances can be stored in the database. The FSDSS supports three types of visualisation: spatial, non-spatial, and map-based. Spatial visualisation is used to represent spatial data, scenarios, and knowledge. Non-spatial visualisation, for example, 3D graphs, are used to present the output of analytical results. In addition to the general graphical report functions, the FSDSS visualisation is particularly important when used with maps. Different spatial objects, layers, or themes are overlaid to generate a new map. The knowledge component contains the final results of the decision-making process, including information about the decision-maker, the rules that were applied, alternative scenarios, the final decision, as well as the system components used in reaching a particular decision.

The *integration layer* contains the communication components, that is, kernel, mapping, and validation components. In addition to activating and using the component functions, the kernel works as a user interface and is responsible for the communication and integration of system components. Mapping enables the model component to communicate with data and solver components properly through model-data and model-solver mapping processes. The model parameter or attributes are fixed; the user selects the data attributes for model-data mapping and selects the solver name and solver attributes for model-solver mapping. Validation enables proper communication between system components. The validation module is responsible for checking the input data type to the model and to the solver during the mapping process. The model-data validation tests whether the data type of the model attributes is similar or convertible to the data attributes, while model-solver validation checks whether the data types of the attributes of the model instance are similar or convertible to the data type of the solver attributes.

The *presentation layer* or user interface supports all the interactions between users and the system. It provides a flexible environment where spatial and non-spatial components are used together to solve complex spatial problems. The architecture as a whole is technology independent so that it can be implemented using commonly-available platforms.

A simple decision-making flow in Figure 3 illustrates how the FSDSS architecture supports the decision-making process. The decision-maker initiates the decision-making process at the interface layer and interacts with the system through the kernel. The component control picks up the relevant components from the persistence layer. The selected data, models, and solvers are combined in the integration layer to develop scenarios using the mapping component. The scenario manager manages these scenarios, and the evaluated scenarios can be presented using the appropriate visualisation component. The interaction between the DSS objects layer and the persistence layer are bi-directional. On the one hand, the architecture allows flexible selection of objects from the object library. On the other hand, the executed results (e.g., scenarios generated) can be stored back to the object library.

The FSDSS Implementation

A prototypical FSDSS was implemented to prove the validity of the proposed spatial decision-making process as well as the FSDSS framework and architecture. Object-oriented concepts, object-oriented database management system, and the object-oriented programming language were the tools and technologies used to develop the FSDSS prototype. *Jade* (www.jadeworld.com), a fully integrated development environment (Post, 2000) with its own object-oriented database and programming language, was selected as the implementation platform. The complete prototype was developed within Jade without recourse to any other tool. The proposed spatial decision-making process and the implemented FSDSS were evaluated through five scenarios across different spatial decision problem domains including location, allocation, routing, and/or layout. Table 1 details of the type of spatial problems and the specific domains where we tested the prototype. The same environment was used in the testing, but with different data, model, and solver sets.

Table 1. Spatial problems and implementation domains

Spatial Problem	**Application Domain**	**Example Spatial Problems**
Allocation	Geo-Marketing	Find geographical distributions
Layout	Running	Design and select best running path
Routing	Delivery	Identify the fastest route
Location	Housing	Search the most suitable house
Spatio-Temporal	Health	Trace the spread of a disease over space and time

Sample Sessions with the FSDSS

In the following sections, we explore the interaction with the FSDSS to solve three of the spatial problems mentioned above. We first use the problem of the design of a running track to introduce some of the core spatial modelling concepts such as objects, layers, and themes. The second example explores in detail the use of the FSDSS, following the proposed spatial decision-making process, in the context of the purchase of a house. To highlight the generic applicability of the system we show its use in the context of solving a spatio-temporal problem in health care.

Design of a Running Track

The first scenario we explore is the design of a path for a particular running event that takes into consideration the required amenities like drink points and toilets, as well as the distance. This example introduces some of the basic spatial concepts and functionality of the system. The decision-makers can plot a number of paths by clicking points on the map. These paths are then saved in the database as *running path 1* and *running path 2* (see Figure 4).

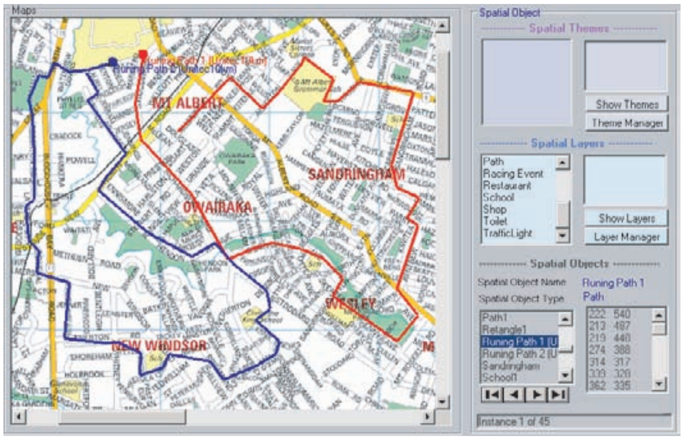
In addition to these two paths, the decision-makers need to consider other facilities that might be useful to this event, for example, drink points and toilets. These objects are stored in the database as individual objects or as a layer. The spatial layer manager manages these layers. As we can see from Figure 5, there are four drink points in the *drink point* layer.

Figure 6 presents the map layout of the two paths (running path 1, running path 2) and the relevant layers, that is, the four toilets in the toilet layer and four drink points in the drink point layer.

It also shows that some of the facilities are not useful for the event, for example, *toilet 4*, as it is far away from these paths. Further observation indicates that *toilet 1, toilet 2, drink point 1,* and *drink point 2* are particularly useful for running *path 1*, while *toilet 3, drink point 3,* and *drink point 4* are useful to *running path 2*. Based on these observations, the system enables the decision-maker to further group these objects or layers into spatial themes.

A spatial theme contains a group of spatial objects and/or spatial layers and presents a particular meaning to the decision-maker. In this illustration, *running path 1, toilet 1, toilet 2, drink point 1,* and *drink point 2* are grouped together to form a theme, that is, *running theme 1*. Similarly, *running path 2* along with *toilet 3, drink point 3,* and *drink point 4* forms *running theme 2*. The spatial

Figure 4. The two alternative paths for running event

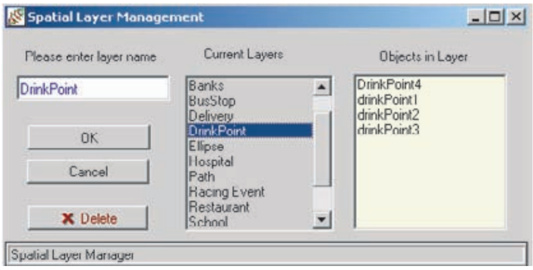


Spatial Object Name Runing Path 1
Spatial Object Type Path

222 540
213 487
219 440
274 388
314 317
339 320
362 335

Instance 1 of 45

Figure 5. Spatial layer manager

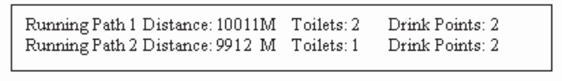


objects and layers used for creation of *running theme 1* are presented in Figure 7. Integration of these spatial items from different layers through map overlay allows viewing the whole picture of a spatial problem from different perspectives.

The spatial theme manager provided by the FSDSS manages the spatial themes. It allows the decision-makers to save themes to the database and retrieve themes from the database. The interface for the spatial theme manager is given in Figure 8.

The spatial theme manager facilitates the creation and deletion of themes as required. In addition, it facilitates the updating of themes, for example, add new objects or layers to the theme, or delete spatial objects or spatial layers from the theme. Figure 9 shows the map presentation of *running theme 1* and *running theme 2*.

Decision makers can also perform other tasks using appropriate models and solvers to further investigate the problem, for example, calculate the distance of each of these running paths using the *path* model and *distance* solver. The following illustration shows two different scenarios for the above-mentioned themes. These scenarios are compared with each other to decide the best path for this running event.



```
Running Path 1 Distance: 10011M   Toilets: 2    Drink Points: 2
Running Path 2 Distance: 9912 M   Toilets: 1    Drink Points: 2
```

In this case, *running path 1* is better than *running path 2* for two reasons. Firstly, *running path 1* has additional facilities (one more toilet) along its path compared with *running path 2*. Secondly and most importantly, the geographical layout of *running path 1* is better than *running path 2* since all available facilities are more evenly distributed along the track.

Purchase of a House

This section illustrates the implemented FSDSS to solve a location problem using the proposed spatial decision-making process. The application

Figure 6. Spatial layers (toilet and drink point layer)

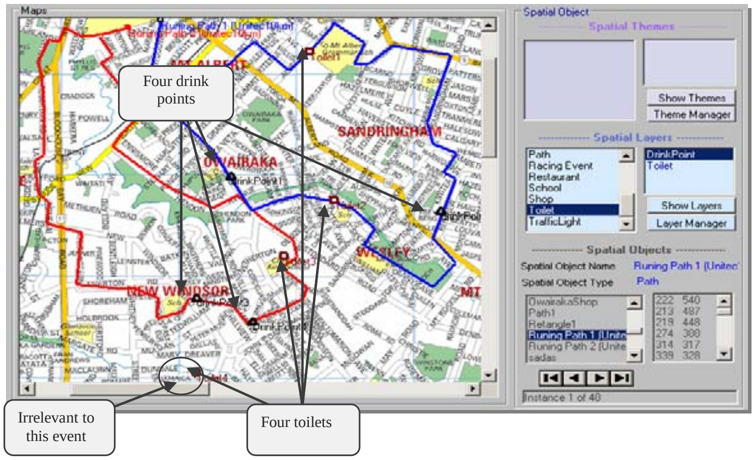


Figure 7. Implementation of spatial modelling

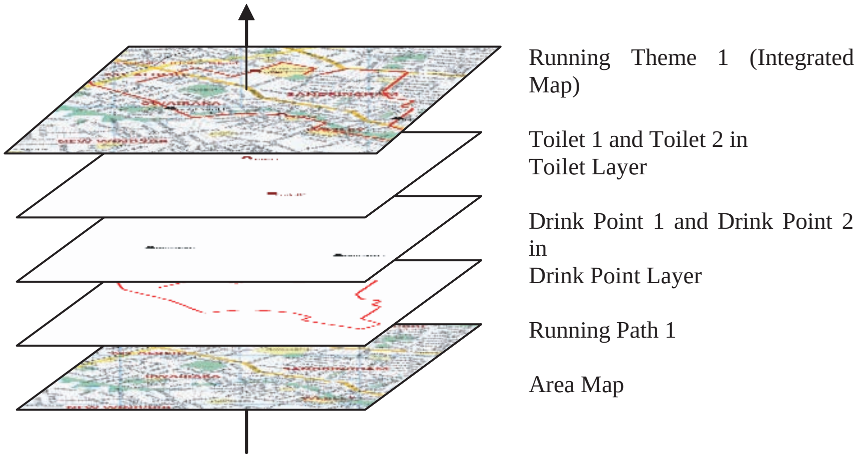
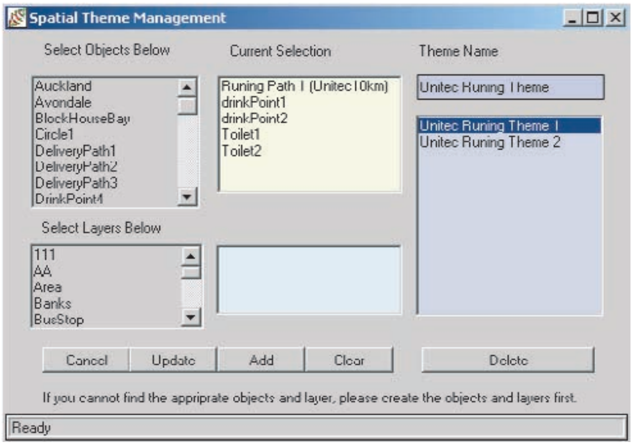


Figure 8. Spatial theme manager



Auckland
Avondale
BlockHouseBay
Circle1
DeliveryPath1
DeliveryPath2
DeliveryPath3
DrinkPoint4

Runing Path 1 (Unitec10km)
drinkPoint1
drinkPoint2
Toilet1
Toilet2

Unitec Huning Theme

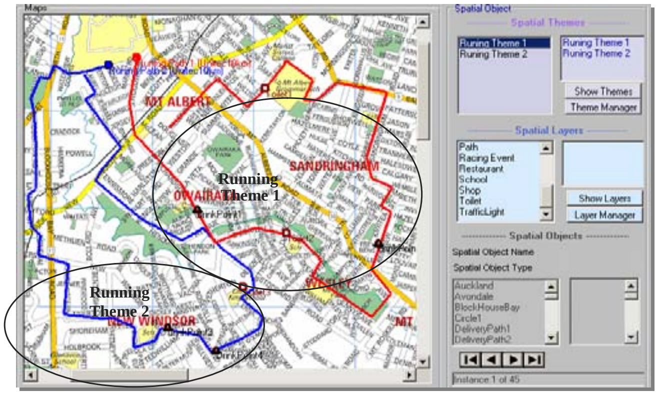
Unitec Runing Theme 1
Unitec Runing Theme 2

111
AA
Area
Banks
BusStop

If you cannot find the appriprate objects and layer, please create the objects and layers first.

Ready

Figure 9. Spatial themes (Running theme 1 and running theme 2)



Runing Theme 1
Runing Theme 2

Runing Theme 1
Runing Theme 2

Path
Racing Event
Restaurant
School
Shop
Toilet
TrafficLight

Auckland
Avondale
BlockHouseBay
Circle1
DeliveryPath1
DeliveryPath2

Instance 1 of 45

of each step of the process shown in Figure 1 is described in detail.

Step 1: Problem Identification

The problem presented in this session is to identify the optimal location of a property that maximises "return," that is, the satisfaction level that is measured on the basis of the following three criteria. The value tree of after-analysis of the problem is presented in Figure 10.

- **Quality criteria:** for example, construction material, year built, size, function, and number of rooms
- **Economic criteria:** such as market price or rental cost
- **Location:** for example, property accessibility, vicinity, and environmental conditions

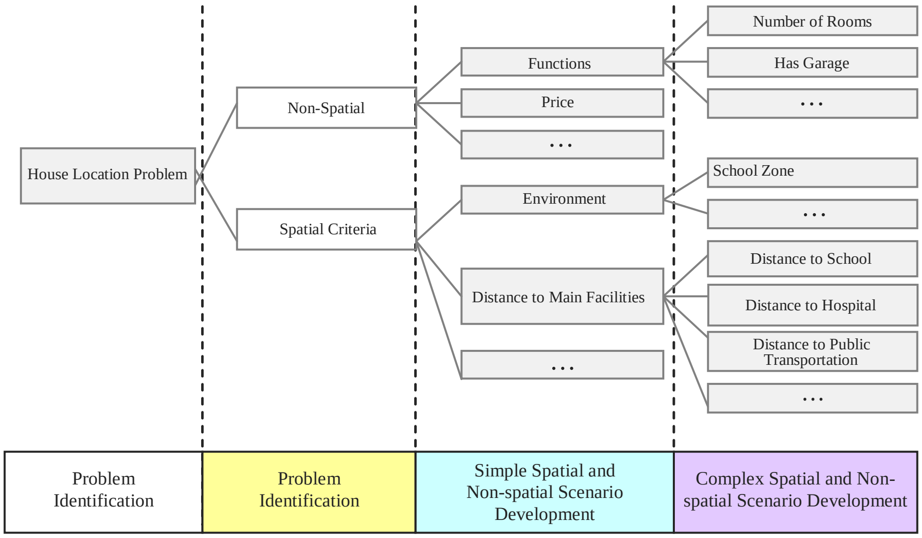
Some of these factors are difficult to evaluate or predict, as relative impacts for some of these factors on return remain unknown. It is hard to structure the problem in its entirety at one time, that is, precisely define and measure the objective for every possible solution. In the next step, the decision-maker models this problem using the proposed modelling approach by separating the spatial and non-spatial aspects of a complex spatial problem.

Step 2: Problem Modelling

The problem modelling involves both spatial and non-spatial aspects. Quality and economic factors are non-spatial in nature whereas accessibility criteria are of a spatial nature. On the non-spatial side, cost and quality of the property can be analysed using non-spatial models and solvers. The spatial aspect of the problem focuses on the location of the property, as it is an important criterion when people rent or buy a house. Location is a complex criterion that has multiple spatial dimensions, for example, environment and distance to important facilities. These spatial dimensions need to be analysed one by one in order to find a best location.

In this illustration, the decision-maker broadly selects a target area and then carries out accessibility analysis. The analysis involves both the non-spatial and spatial models, and it uses both non-spatial and spatial solvers. The problem is

Figure 10. Value tree of location problem



solved iteratively by first, considering spatial and non-spatial data, models, solvers, and scenarios; second, applying spatial and non-spatial criteria; and last, using goal-seeking and sensitivity analysis.

Step 3 and 4: Scenario Development

The decision-maker now needs to load relevant decision-making components. These include the property table and relevant map in which the properties are located, the various models, solvers, and visualisations to be used for building the different scenarios. A simple non-spatial scenario and a simple spatial scenario are developed separately at first; they are then integrated into a combined scenario. These scenarios are then transformed into a complex multi-criteria scenario through a structural integration process. The scenario development process is illustrated as follows:

Simple Non-Spatial Scenario

The non-spatial scenario is created using the non-spatial *filtering* model and the *range* solver. In this example, we have specified that we need a 3-bedroom flat with a price range between $300,000 and $400,000. Several properties are identified through this filtering process (see Figure 11). These are then stored in the database as *scenario 1* (4 instances).

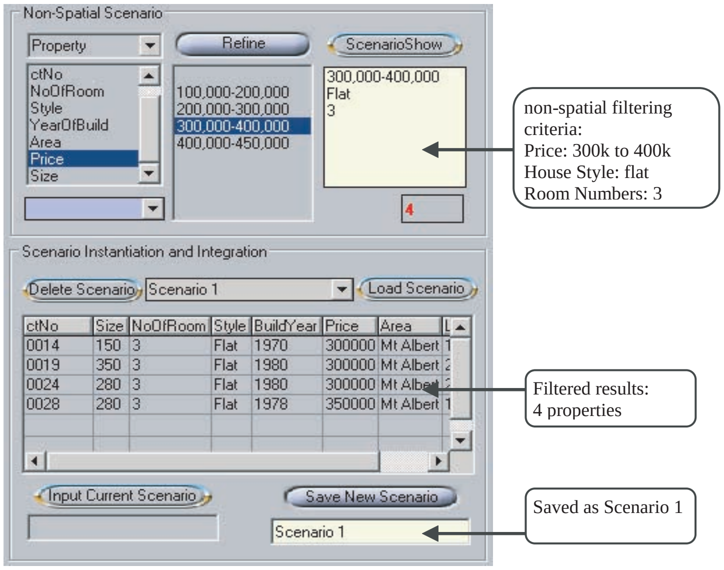
Simple Spatial Scenario

The decision-maker has selected a buffer zone (a 500-meter radius circle) around a particular location (e.g., x, y coordinates: 200,200). The *filtering* model is instantiated with the *property* data and executed using the *distance* solver to find the properties within the defined circle. This process develops many scenario instances as shown in Figure 12. These scenario instances are then stored in the database as *scenario 2* (14 instances).

Combined Scenario (Pipelining Integration)

Pipelining integration of spatial and non-spatial scenarios can be done in two ways. The first way is to create non-spatial *scenario 1* and then execute the geographical filtering model using

Figure 11. Simple non-spatial scenario creation



300,000-400,000
Flat
3

4

Scenario 1

ctNo	Size	NoOfRoom	Style	BuildYear	Price	Area	L
0014	150	3	Flat	1970	300000	Mt Albert	1
0019	350	3	Flat	1980	300000	Mt Albert	2
0024	280	3	Flat	1980	300000	Mt Albert	2
0028	280	3	Flat	1978	350000	Mt Albert	1

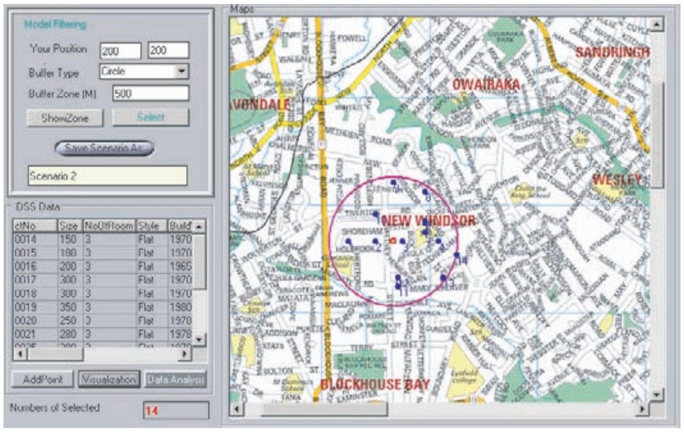
Scenario 1

non-spatial filtering criteria:
Price: 300k to 400k
House Style: flat
Room Numbers: 3

Filtered results:
4 properties

Saved as Scenario 1

Figure 12. Simple spatial scenario creation



Your Position: 200 200

Buffer Type: Circle

Buffer Zone (M): 500

Scenario 2

ctNo	Size	NoOfRoom	Style	Build
0014	150	3	Flat	1970
0015	180	3	Flat	1970
0016	200	3	Flat	1965
0017	300	3	Flat	1970
0018	300	3	Flat	1970
0019	350	3	Flat	1980
0020	250	3	Flat	1970
0021	280	3	Flat	1978

Numbers of Selected: 14

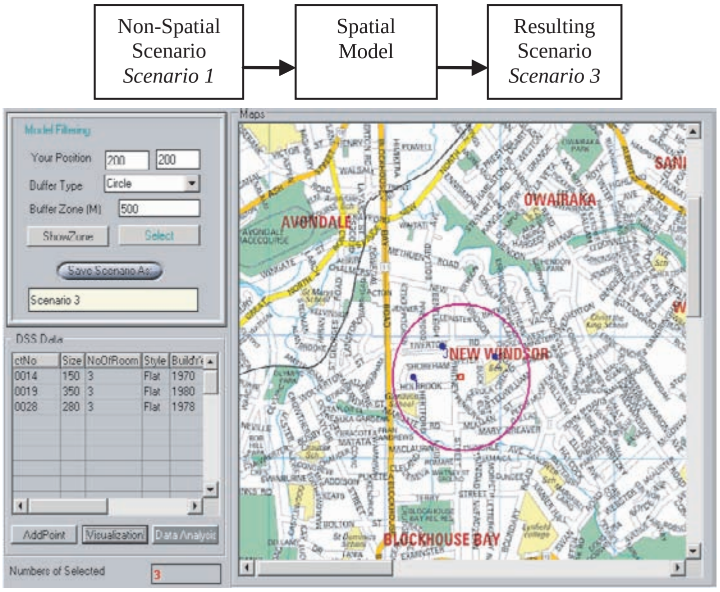
spatial solvers, for example, d*istance* or *point-in-polygon* solver (Figure 13).

During this integration process, the four non-spatial filtered scenario instances of *scenario1* as described earlier are supplied as input to the spatial filtering model. The resulting scenario instances are stored as *scenario 3* (3 instances).

The second way for integration of *scenario 1* and *scenario 2* is to supply the spatial *scenario 2* as input into the non-spatial filtering model and then apply the non-spatial Range solver for execution, as illustrated in Figure 14. The process develops three instances that are stored in the database as Scenario 3.

The scenario pipelining integration process can take place in many ways, either from non-spatial to spatial or from spatial to non-spatial or from spatial to spatial or from non-spatial to non-spatial. The flexible use and integration of spatial and non-spatial models, solvers, and scenarios is one of the most important features of the FSDSS. The above process helps the decision-maker to

Figure 13. Integration of non-spatial with spatial scenarios



Your Position: 200 200

Buffer Type: Circle

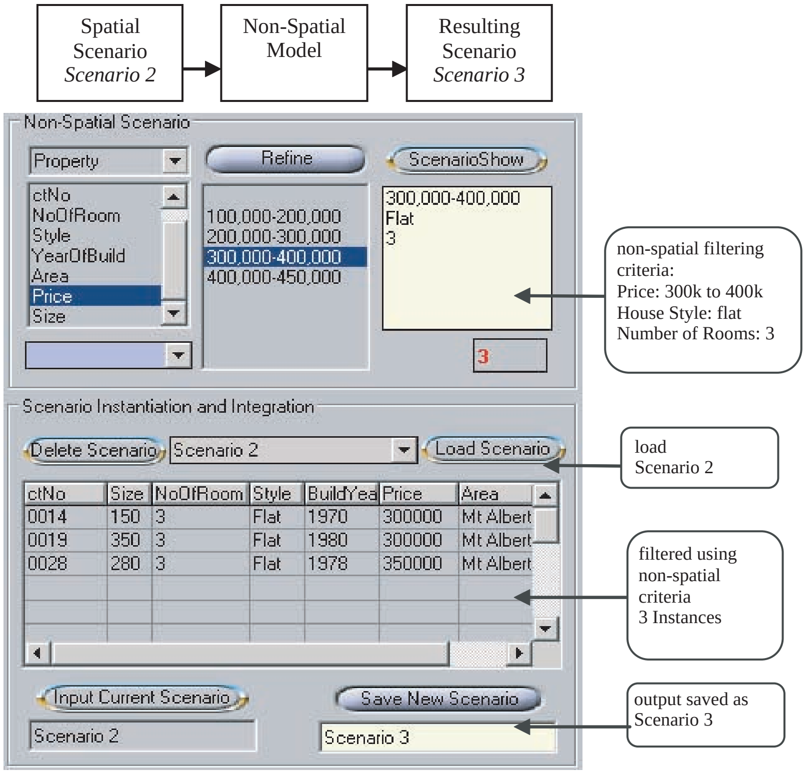
Buffer Zone (M): 500

Scenario 3

ctNo	Size	NoOfRoom	Style	Build
0014	150	3	Flat	1970
0019	350	3	Flat	1980
0028	280	3	Flat	1978

Numbers of Selected: 3

Figure 14. Integration of spatial with non-spatial scenarios



ctNo	Size	NoOfRoom	Style	BuildYea	Price	Area
0014	150	3	Flat	1970	300000	Mt Albert
0019	350	3	Flat	1980	300000	Mt Albert
0028	280	3	Flat	1978	350000	Mt Albert

choose the properties that satisfy the non-spatial criteria, for example, quality, cost, and the basic location requirements such as area. The following section illustrates another aspect of the location problem, namely, accessibility analysis.

Complex Spatial Scenario (Structural Integration)

The complex spatial scenario is generated using the *property* data, *distance* model, and *distance* solver as shown in Figure 15. The previously created s*cenario 3* and its three instances are loaded from the scenario pool. Now, the decision-maker focuses on distance to major facilities for accessibility analysis.

Distance has multiple dimensions. It includes the distance from a particular spatial object (e.g., *property 0014*) to another object (e.g., *hospital 2*). The distance from one object to a spatial layer (e.g., *school layer*) returns multiple values, in this case the system returns the shortest distance from the target object to a single object (e.g., *school 1*) in that layer.

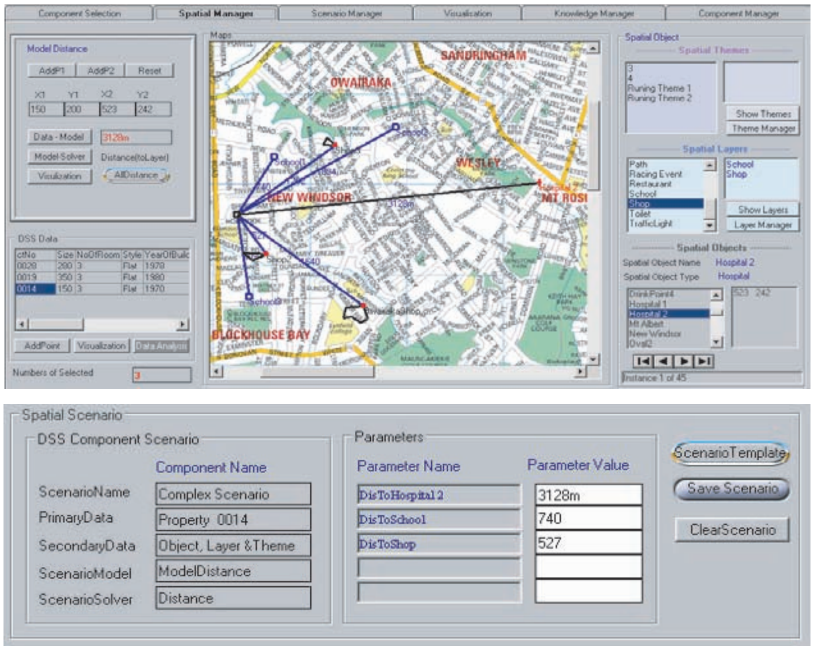
Step 5 and 6: Scenario Integration and Instantiation

The decision-maker integrates the simple combined scenario (*scenario 3*) structure with these newly- developed distance parameters to develop a more complex scenario that contains all the criteria for the problem.

The structural or permanent scenario integration takes place in two steps. First, a bare scenario template is created as shown in Figure 16. Then multiple scenario instances are created (Figure 17).

The scenario integration process is iterative in nature until all scenario instances have been

Figure 15. Multi-attribute spatial scenario creation



X1	Y1	X2	Y2
150	200	523	242

Data - Model: 3128m

Model-Solver: Distance(toLayer)

DSS Data

ctNo	Size	NoOfRoom	Style	YearOfBuild
0028	280	3	Flat	1970
0019	350	3	Flat	1980
0014	150	3	Flat	1970

Numbers of Selected: 3

Spatial Themes: 3, 4, Runing Theme 1, Runing Theme 2

Spatial Layers: Path, Racing Event, Restaurant, School, Shop, Toilet, TrafficLight — selected: School, Shop

Spatial Object Name: Hospital 2

Spatial Object Type: Hospital

DrinkPoint4, Hospital 1, Hospital 2, Mt Albert, New Windsor, Oval2 — 523 242

Instance 1 of 45

Spatial Scenario

DSS Component Scenario

	Component Name
ScenarioName	Complex Scenario
PrimaryData	Property 0014
SecondaryData	Object, Layer &Theme
ScenarioModel	ModelDistance
ScenarioSolver	Distance

Parameters

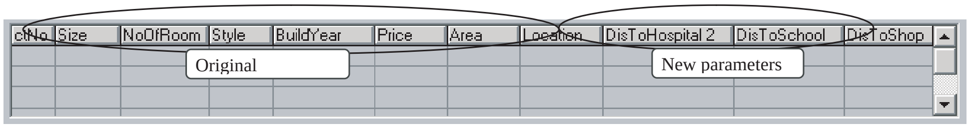
Parameter Name	Parameter Value
DisToHospital 2	3128m
DisToSchool	740
DisToShop	527

generated. The scenario template and its multiple instances are stored in the database as a complex scenario, and they can be retrieved for further analysis or evaluation. The distance to the schools and shops are calculated on a spatial layer, rather than a single spatial object. The system picks up the distance to the closest object in the layer for instantiation of the scenario parameter. The decision-maker can select any spatial object, layer, or theme for integration of scenarios using the spatial manager as shown in Figure 18.

Step 7: Scenario Execution

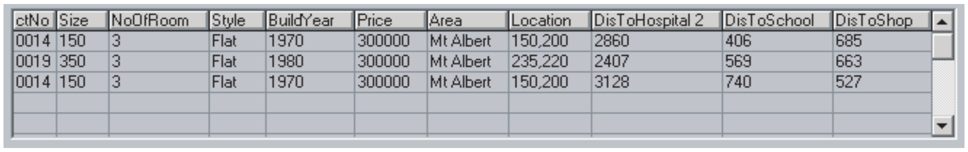
Scenarios can be instantiated with the relevant data, model, and a number of solvers can be applied for execution of the scenarios. The scenario can be executed in a simple process or using multiple steps. The integration of executed models (scenarios) is also the process of modelling the scenario. During the scenario execution process, one scenario is instantiated and executed using different solvers.

Figure 16. Scenario template for integration of spatial and non-spatial scenarios



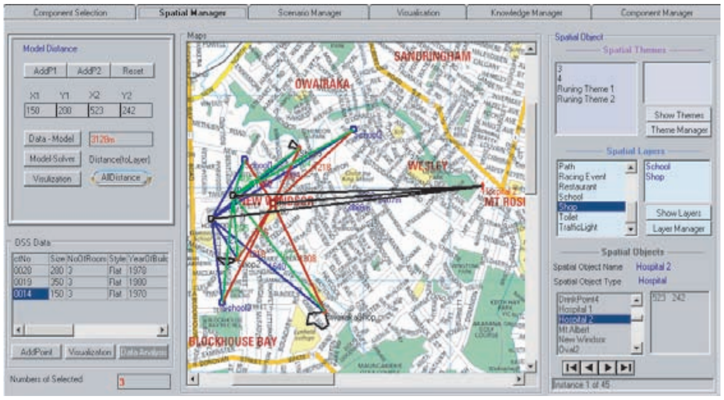
ctNo	Size	NoOfRoom	Style	BuildYear	Price	Area	Location	DisToHospital 2	DisToSchool	DisToShop

Figure 17. Multi-criteria spatial scenarios



ctNo	Size	NoOfRoom	Style	BuildYear	Price	Area	Location	DisToHospital 2	DisToSchool	DisToShop
0014	150	3	Flat	1970	300000	Mt Albert	150,200	2860	406	685
0019	350	3	Flat	1980	300000	Mt Albert	235,220	2407	569	663
0014	150	3	Flat	1970	300000	Mt Albert	150,200	3128	740	527

Figure 18. Multiple spatial scenario generation



X1	Y1	X2	Y2
150	200	523	242

Data - Model: 3128m

ctNo	Size	NoOfRoom	Style	YearOfBuil
0020	200	3	Flat	1970
0019	350	3	Flat	1980
0014	150	3	Flat	1970

Numbers of Selected: 3

Spatial Themes: 3, 4, Runing Theme 1, Runing Theme 2

Spatial Layers: Path, Racing Event, Restaurant, School, Shop, Toilet, TrafficLight — selected: School, Shop

Spatial Object Name: Hospital 2

Spatial Object Type: Hospital

DrinkPoint4, Hospital 1, Hospital 2, Mt Albert, New Windsor, Oval2 — 523 242

Instance 1 of 45

Step 8: Scenario Evaluation

The FSDSS supports the MCDM scenario evaluation process. The decision-maker needs to build a MCDM evaluation model by specifying parameters and assigning weights to each of these parameters. The evaluation model is instantiated with alternative scenario instances. These scenarios are executed using the solver that is tightly coupled within the evaluation model. The results are then ranked for selection. The sequence of the steps taken in this process is shown in Figure 19. The decision-maker selects the scenarios for evaluation to the scenario table as indicated in step 1. Then, an evaluation model is built by selecting the appropriate criteria from the input scenario. In step 3, the decision-maker assigns a weight to each of the criteria. Step 4 evaluates the scenarios using the model template created in step 2 and step 3. The built-in solver not only calculates values according to the formula but also ranks these values. The highest value is given as 100%, and other scenarios are calculated on a ratio basis by comparing the highest value.

Step 9: Decision-Making

As we can see from the results, *property 0014* (Figure 19) is ranked highest. Furthermore, the decision-maker can apply different evaluation models to explore alternative scenarios by considering the uncertainty involved in the decision-making process. Uncertainty may be caused by the error in available information to the decision-maker, or improper judgment regarding the relative importance of evaluation criteria.

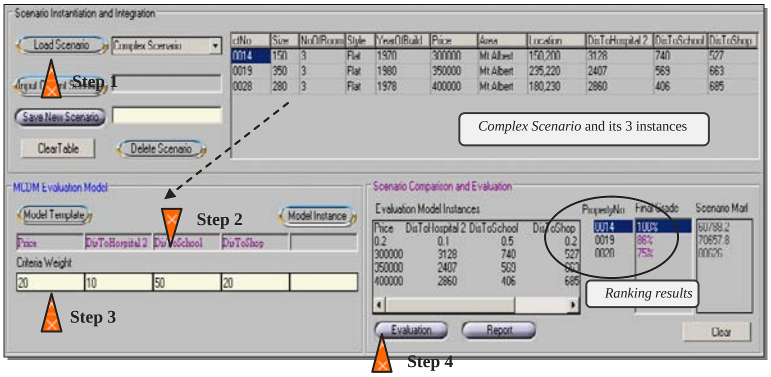
Sensitivity analysis is employed as a means for achieving a deeper understanding of the structure of the problem. Sensitivity analysis is done through changing data, model, solver, scenario, and evaluation models. The decision-maker can change any one of these aspects and then re-evaluate these scenarios. This process can be repeated until all the scenarios relevant to the decision-maker are explored.

TRACE THE SPREAD OF A DISEASE

The problem presented in this section is to identify the spread of the SARS epidemic in Hong Kong. We try to understand, analyse, and manage geographically distributed data using spatial functions. Overlaying quantitative graphics on a map enables the viewer to realise potential information in an extremely clear manner so that spatial patterns can be discovered.

We have aggregated a case database that includes the date, the number of cases confirmed,

Figure 19. Multi-criteria spatial scenarios



ctNo	Size	NoOfRoom	Style	YearOfBuild	Price	Area	Location	DisToHospital 2	DisToSchool	DisToShop
0014	150	3	Flat	1970	300000	Mt Albert	150,200	3128	740	527
0019	350	3	Flat	1980	350000	Mt Albert	235,220	2407	569	663
0028	280	3	Flat	1978	400000	Mt Albert	180,230	2860	406	685

Price	DisToHospital 2	DisToSchool	DisToShop
20	10	50	20

Price	DisToHospital 2	DisToSchool	DisToShop
0.2	0.1	0.5	0.2
300000	3128	740	527
350000	2407	569	663
400000	2860	406	685

PropertyNo	FinalGrade	Scenario Mark
0014	100%	60788.2
0019	86%	70657.8
0028	75%	[illegible]

and the places they were found. Through the geo-coding process, each case was mapped to a geographical object, for example, a building or a hospital. These spatial objects can then be referenced by the geo-coding locations on the map. Figure 20 presents an overall picture of the geographical distribution of SARS cases and the population density; this gives us information about the number of SARS cases among different population groups at any given time. The visual representation would be useful for developing hypotheses about relationship between the distribution of SARS and population density or groups (Chu, Gao, & Sundaram, 2005). It could provide useful pointers for further analysis and investigations.

We explore the above scenario one step further by applying a time frame, to give pictorial views of the rate of case increases in various hospitals over time. As we can see from Figure 21, on the 13th of March, 2003, 33 SARS patients were admitted by the Prince of Wales Hospital (PWH); among them, 18 were confirmed. There were also two confirmed patients in Pamela Youde Easter Hospital (PYEH). The total number of patients admitted in Hong Kong hospital was 35 (20 confirmed).

On the 20th of March, the total number of admissions increased to 99 (58 were confirmed). The number of suspected patients in PWH jumped to 77, and PYEH cases increased to ten. New suspected patients were also found in Princess Margaret Hospital and Queen Elizabeth Hospital (Figure 22).

Using the time series mapping, we were able to map the number of patients admitted with sus-

Figure 20. Case occurrences and population density (Source: Chu, Gao, & Sundaram, 2005)

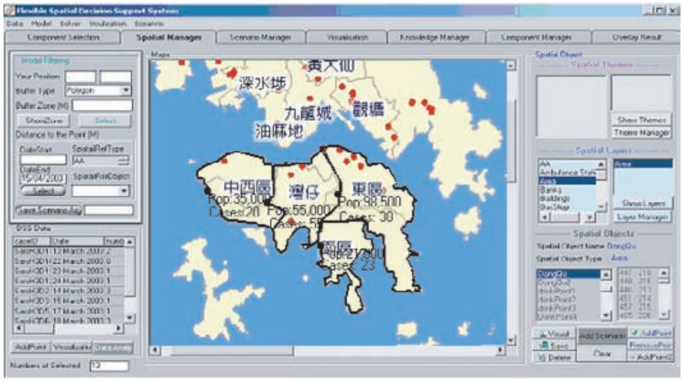
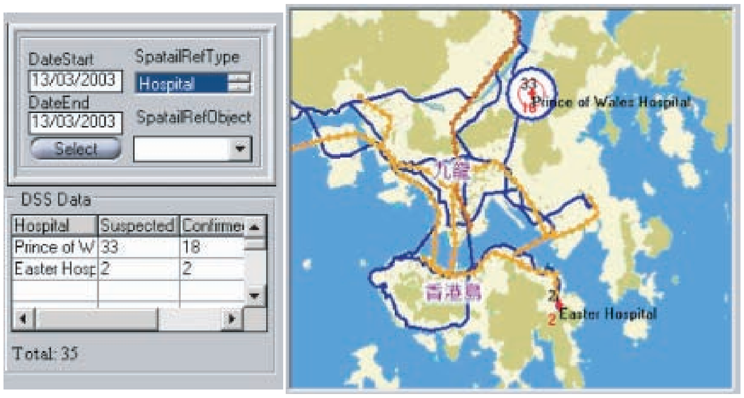


Figure 21. Time series presentation of SARS spread period 1


DateStart 13/03/2003

SpatailRefType Hospital

DateEnd 13/03/2003

SpatailRefObject

DSS Data

Hospital	Suspected	Confirme
Prince of W	33	18
Easter Hosp	2	2

Total: 35

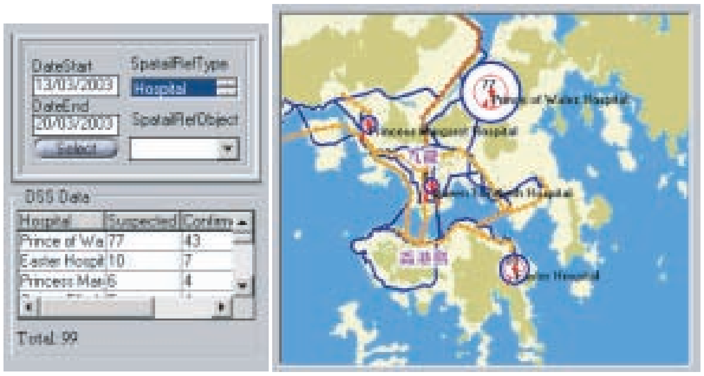
pected SARS symptoms and compare the number of these cases being confirmed as SARS patients subsequently at later times. Similarly, we can use the FSDSS to map the spread of SARS infections in the community. The system modules are interconnected, and new entry of data dynamically changes other modules. An example of this is the dynamic refresh of collection of spatial objects where there is an infection (as seen in the drop-down combo box that appeared in the left-hand side in Figure 23). These spatial objects could include residential buildings, schools, shops, and any other objects that have a spatial reference.

Visual overlay of spatial objects over time allows us to ask a question such as "why has one block (in Lower Ngau Tau Kok Estate, quite far away from the Amoy Gardens) a much higher rate of infection than any other building?" Demographic analysis later reviewed that residents in this block comprised mostly senior citizens and that they passed through the Amoy Garden shopping mall each day to do their shopping.

FUTURE TRENDS

Advances in MCDM, GIS, other relevant technologies, and their integration will have major impacts on the future development of SDSS. Multi-criteria spatial decision support is clearly the appropriate paradigm because it is such an adaptable and comprehensive concept. Multi-criteria spatial analysis is moving to a more exploratory, interactive emphasis with new decision analysis tools. There is also an increasing emphasis on the study of complex systems through simulation (Ascough II et al., 2002).

Figure 22. Time series presentation of SARS spread 2


DateStart 13/03/2003

SpatailRefType Hospital

DateEnd 20/03/2003

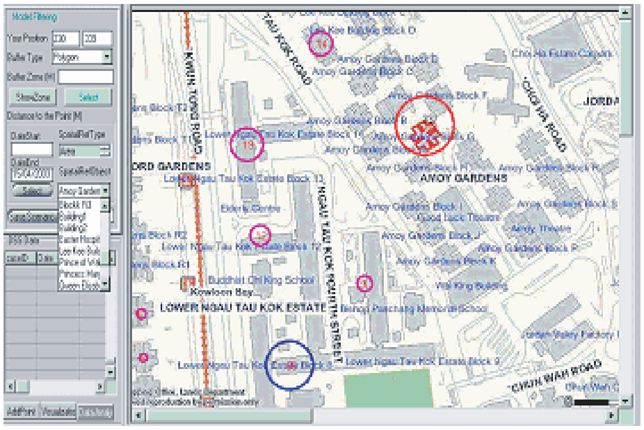
SpatailRefObject

DSS Data

Hospital	Suspected	Confirm
Prince of Wa	77	43
Easter Hospi	10	7
Princess Mar	6	4

Total: 99

Figure 23. Infected buildings, school, and others



GIS itself is moving to a greater level of integration with other types of software. Spatial data and tools will be ubiquitous, embedded in business systems, and transparent to most users as shown in Figure 24. GIS can be an interoperable part of most critical business information systems including ERP/enterprise systems (such as SAP and PeopleSoft), environmental, asset, financial, human resource, emergency, and customer relationship management systems, thus bringing the power of spatial analysis and data mining to bear to measure results (business intelligence) and future impacts (analytic intelligence). A major focus is the design and implementation of true strategic intelligence frameworks that integrates spatial and non-spatial data across different information systems and business units to create broader knowledge and understanding within organisations at all levels of decision-making (Holland, 2005).

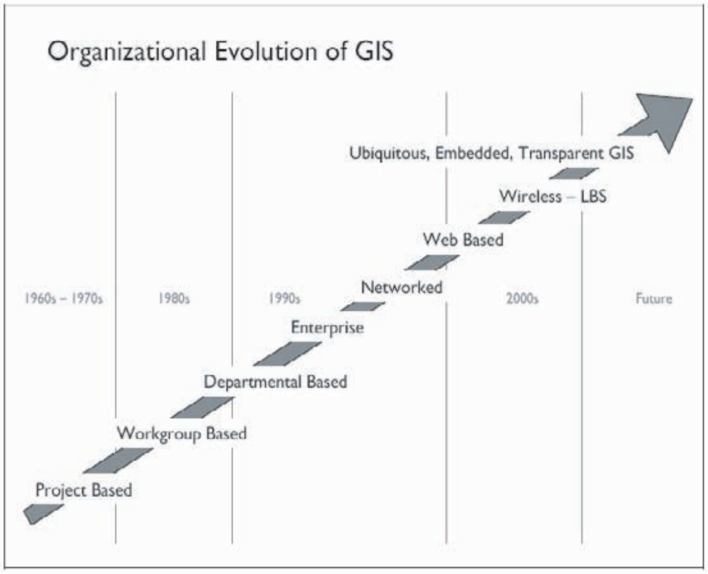
The design of an intelligent SDSS by coupling a GIS with an expert system is discussed by Zhu and Healey (1992). Spatial decision-making is based on two streams: the quantitative, which includes data analysis and modelling, and qualitative, which includes experience, intuition, judgment, and expertise. Current GIS systems focus on quantitative information and largely ignore the qualitative aspects of the process. The inclusion of expert systems, which perform decision-making tasks by reasoning, using rules defined by experts in the relevant domain, would greatly aid qualitative spatial decision-making within GIS, and thus SDSS.

CONCLUSION

Decision-makers perceive the decision-making processes for solving complex spatial problems as unsatisfactory and lacking in generality. Current SDSS fulfil their specific objectives, but fail to address many of the requirements for effective spatial problem-solving, as they are inflexible, complex to use, and often domain-specific. This research blends together several relevant disciplines in a unique way and attempts to overcome the problems identified in the fields of spatial decision-making and SDSS.

We proposed a spatial decision-making process. Within the context of the spatial decision-making process, we have proposed a modelling approach by addressing the need of differentiating the spatial and non-spatial elements for multi-dimensional complex problem modelling. We then developed a flexible spatial decision support system framework and architecture to support this process. We also implemented a prototypi-

Figure 24. Historical and future trends of GIS (Source: Holland, 2005)



cal FSDSS that acts as a proof-of-concept for the spatial decision-making process, FSDSS framework, and architecture. The proposed spatial decision-making process and the implementation of FSDSS have been evaluated through a number of scenarios across diverse domains. The evaluation results indicate that the proposed spatial decision-making process is generic, and it is effective in solving complex spatial problems in different domains. Furthermore, the flexible use across domains and different types of problems was due to the generic nature of the architecture and design that leveraged spatial modelling and object-oriented concepts.

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Chapter 2.14

Development of a Web-Based Intelligent Spatial Decision Support System (WEBISDSS):

A Case Study with Snow Removal Operations

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ABSTRACT

A SDSS combines database storage technologies, geographic information systems (GIS), and decision modeling into tools which can be used to address a wide variety of decision support areas (Eklund, Kirkby, & Pollitt, 1996). Recently, various emerging technologies in computer hardware and software such as speedy microprocessors, gigabit network connections, fast Internet mapping servers along with Web-based technologies like eXtensible Markup Language (XML), Web services, and so forth, provide promising opportunities to take the traditional spatial decision support systems one step further to provide easy-to-use, round-the-clock access to spatial data and decision support over the Web. Traditional DSS and Web-based spatial DSS can be further improved by integrating expert knowledge and utilizing intelligent software components (such as expert systems and intelligent agents) to emulate the human intelligence and decision-making. These kinds of decision support systems are classified as intelligent decision support systems. The objective of this chapter is to discuss the development of an intelligent Web-based spatial decision support system and demonstrate it with a case study for planning snow removal operations.

INTRODUCTION

Spatial Decision Support Systems

The past decade witnessed an explosive growth of spatial data and various applications that utilize spatial data. Geographic information systems (GIS) have been developed to facilitate storing, retrieving, editing, analyzing, and displaying spatial information. The increasing complexity of spatial data and a need for better modeling requires decision support systems that can handle spatial data. This led to the idea of spatial decision support systems (SDSS). Since the early 1980s, SDSS have been used in several applications that provide spatial functionalities such as routing, allocation modeling, and so forth.

Most of the existing SDSS do not employ any intelligent software components to enhance decision support. Only a very few researchers have explored the possibility of integrating intelligent software components with an SDSS for applications like multi-criteria decision analysis, routing, and weather-based decision-making. Most of the literature reviewed for Intelligent GIS systems deals with architectural as well as implementation issues of GIS-based decision support systems and integrating them with agents. The use of software agents for GIS-based systems is well documented (Odell, Parunak, Fleischer, & Brueckner, 2003; Sengupta, Bennett, & Armstrong, 2000; Shahriari & Tao, 2002; Tsou, 2002). Most of these systems are not Web-based, and they lack the advantages of Web-based systems like ease-of-use, cross platform functionality, low maintenance costs, centralized data storage, and so forth.

Also, recent advances in Web technologies like rich site summary (RSS), XML feeds, and asynchronous JavaScript and XML (AJAX) can help us device a seamless interface by providing real-time access to data over the World Wide Web. Therefore, integrating the process of decision-making with an intelligent component and Web-based technologies proves to be very beneficial. When integrated with encoded human intelligence, the spatial decision support systems can rival a human expert in a particular domain (e.g., snow removal, traffic management, logistics, etc.).

This chapter explores and discusses the development of a Web-based intelligent spatial decision support system for planning snow removal operations. Specifically, this chapter addresses the existing problems with snow removal decision-making in the USA. The SDSS discussed here integrates knowledge from snow removal experts and real-time weather information into a Web-based interface. The system is intended to provide advised decision support for officials at various departments of transportation across the country, and to serve as a guideline for development of a snow removal DSS for the decision-makers and stake-holders around the world.

Background on Snow Removal Operations

Snow removal operations during the winter are of prime importance in avoiding traffic accidents and providing safe travel conditions on the nation's highways and city streets. Quality snow and ice control service is critical for preserving traffic safety, maintaining city commerce, and allowing residents access to schools and medical facilities (Hintz, Kettlewell, Shambarger, & Sweeney, 2001). Department of Transportation (DOT) of each state is responsible for snow removal on all interstates, and primary highways like the U.S. Federal highways and state highways. The city streets are snowplowed by the Street Department of that city, or sometimes by the DOT itself (Iowa Department of Transportation (IDOT), 2005). Snowplowing is done according to a set priority assigned to each road depending upon the annual average daily traffic (AADT). Higher priority roads like the interstates are cleared before the lower priority routes like city streets.

Managing snow removal operations necessitates activities ranging from the preparation of roads before the snowfall by pre-wetting by salt (e.g., most roads and bridge decks are pre-wetted with salt before the snow to avoid bonding of ice to the pavement in order to prevent slippery road conditions) to the timely clearing of the snow off the roads after the snowfall. The personnel in charge of snow removal operations keep tabs on weather forecasts to verify conditions that require snowplowing. These conditions include snow, flurries, freezing rain, and sleet. Once the weather forecast predicts these conditions, routes that need snow removal or salt-treatment are determined, and the snowplowing vehicles are loaded with material. These vehicles are then sent out to the roads, both before and after the snowfall. Considering the number of managerial aspects like monitoring weather information, allocating resources like vehicles, drivers, and material, it is an overwhelming task for the personnel in charge of snow removal operations to administer timely deployment of snowplows and manage efficient resource allocation. Therefore, maintaining snow removal operations efficiently and optimally during the winter is a major challenge for many governmental as well as non-governmental agencies and prove to be a big budgetary burden (Hintz, Kettlewell, Shambarger, & Sweeney, 2001; Salim, Timmerman, Strauss, & Emch, 2002).

Existing Methods for Snow Removal Operations and Their Disadvantages

Most of the existing methods for snowplowing management such as resource allocation, inventory management, and routing are performed manually by a person or persons in charge of snow removal operations. These methods, in most cases, are based on a pre-determined set of static rules that are inefficient for snow plowing and resource allocation under constantly-changing weather conditions. They often result in inefficient and non-optimal results and tend to increase the cost of snow removal. Moreover, the reaction time and the margin of error during heavy storm conditions can prove deadly, and human-based methods are always prone to such errors.

In addition, our observations with various snowplowing stations showed that there is no substantial use of analytical methods before planning snowplowing operations to reduce cost and maximize overall effectiveness. For example, the methods used for most local government agencies (e.g., the DOT) do not use any special measures for efficient routing and resource allocation. Many of the existing methods do not choose the shortest or the quickest path from the snowplow station to reach the snowplow route. Neither do they optimize resource allocation by taking into consideration various important factors like the cost of operation of a vehicle, availability of drivers or vehicles, and so forth. Such methods have a severe limitation of being inefficient; even a very slight change in weather conditions would almost demand double the amount of resources and unplanned travel for a different, non-predetermined route, and thus result in waste of time and money. Moreover, the existing manual methods cannot deal efficiently with resource allocation for newly-added routes and changing weather conditions .

Also, existing methods do not use automated inventory management and control. Inventory management is very important, and analytical tools must be used to keep up with the demand of snow removal. Various factors like the lead time for order, reorder point, stock levels, and so forth, must always be monitored to keep the necessary materials (e.g., salt) in stock. Keeping in mind the importance of providing speedy response after a snowstorm, inventory management tools are indispensable for planning snow removal operations. In addition, the existing methods do not provide any visual feedback when it comes to routing and resource allocation. Visual feedback not only improves the perception of the current assignments, but also helps review the allocations for better planning in future allocations. Also, there is no integrated use of weather information that could alert the snow removal crews and provide a scenario-based decision support. Thus, snowplowing operations must be carefully planned to provide optimum resource allocation and efficient routing.

Further, a literature review reveals that there is lack of extensive research in the field of GIS-based winter maintenance decision support systems. One of the existing SDSS for snow removal planning is the "snow removal asset management system," SRAMS for short. Salim, Timmerman, Strauss, and Emch (2002) developed a SDSS called "snow removal asset management system"(SRAMS). SRAMS is a stand-alone, personal computer-based program that utilizes a rule-based expert system for decision support. The test runs of SRAMS concluded that snow removal can be planned efficiently, by reducing the deadhead times and optimizing resources for snow removal. While this system is useful to a certain extent, it ignores many aspects of resource allocation like the availability of drivers for a certain shift, the ability of a driver to drive a specific category of a vehicle, inability to read live weather data, providing scenario-based solutions, and so forth. Being a stand-alone program, SRAMS cannot be accessed from any other computer. Also, SRAMS was developed bearing a non-technical user in mind and therefore, there is a significant need to develop strong winter operations maintenance system that offers expert advice and decision support, while being easy-to-use for even a non-GIS professional.

Another decision support system for snow removal is the winter road maintenance decision support system (Mahoney & Myers, 2003). The maintenance decision support system (MDSS) focuses mainly on using weather data to design a decision support system for maintaining roads during winters. While MDSS uses advanced weather data, it lacks the ability to calculate the amounts of snow removal material which are needed. Also, MDSS lacks an asset management module that would have made the system much more efficient.

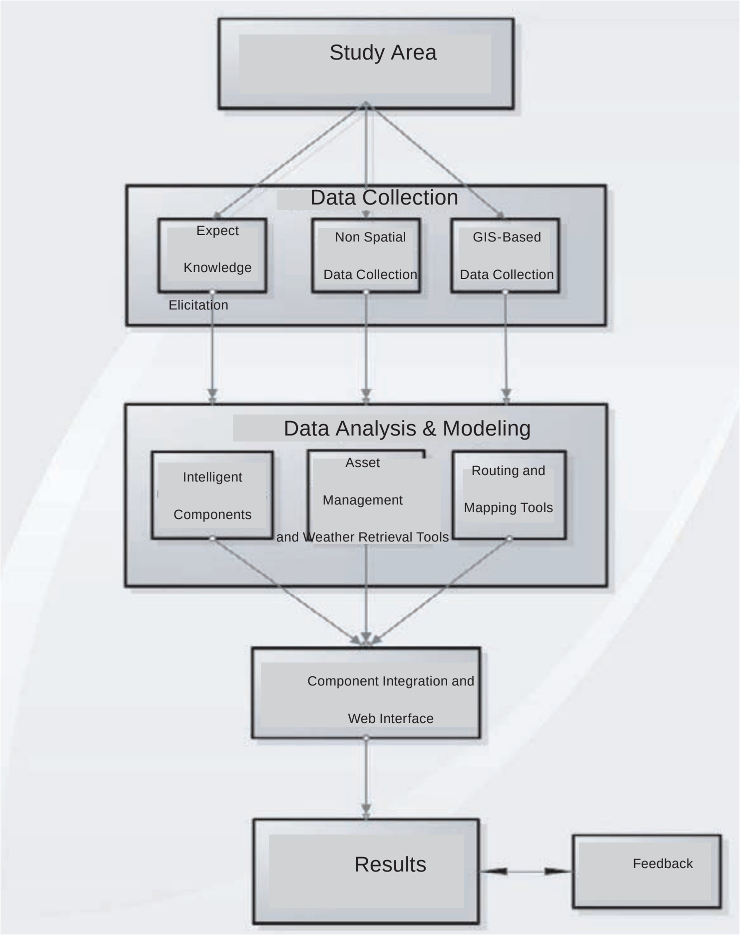
Similarly, a winter maintenance decision support system developed by the U.S. Department of Transportation (USDOT) allows viewing road-wise weather data, and various weather parameters like Visibility, Air Temperature, Snow Rate, Snow Accumulation, and so forth (U.S. Department of Transportation, 2004). Also, another system called "weather support to de-icing decision-making" (WSDDM) uses commercial weather data in the form of Next Generation Radar WSR-88D and METAR surface weather reports from automated surface observing system stations and observers. The system also uses snow gauges on the ground to measure the precipitation to provide decision support. The WSDDM essentially provides decision support for de-icing operations that take place at airports. The drawbacks of this system are the usage of commercial data and the lack of an intelligent component (e.g., expert system) for making crucial decisions.

In summary, there are no well established intelligent SDSS available for snow removal operations that integrate automatic routing, asset management, and real-time weather data. Further, the systems discussed in the literature do not leverage the potential of GIS using Web-based architectures and integrate expert system components for intelligent decision support. Therefore, there is a significant need for an intelligent system that provides analytical tools and decision support through visual feedback for managing snowplowing operations with optimal resource allocation and efficient routing.

METHODOLOGY

The methodology for developing WebISDSS encompassed the following four steps (shown in Figure 1): (a) data collection, (b) data analysis and modeling, (c) GIS and intelligent software component integration, and (d) providing results and obtaining feedback. Each of these steps is briefly described below.

Figure 1. Overall methodology adapted for developing WebISDSS (Source: Ilavajhala, 2005)



The first step in developing WebISDSS is data collection. During data collection, three categories of data were collected. These categories are expert knowledge, spatial data, and non-spatial data. The aim of expert knowledge elicitation is to gather knowledge of various snow removal operations like resource allocation, routing, and so forth, from the officials responsible for handling snowplowing operations. Officials from the Street Departments of Cedar Falls and Waterloo, IA, along with the county and Iowa DOT's highway maintenance supervisor in Waterloo were consulted to obtain the knowledge about snow removal in the study area of Black Hawk County. Through a series of direct interviews, a variety of information regarding the existing snow removal procedures was gathered.

The spatial data gathered is the county-wide roads and street dataset of Black Hawk County, IA. This data is available from the Iowa DOT's maps Web site (IDOT, 2005). The dataset essentially contains the centerlines for public roads including interstates, U.S. and state Highways, county roads, city streets, park roads, and institutional roads. For providing effective routing solutions like providing shortest or quickest path from the snowplow station to the snowplow route, the optimized road data set from GDT Inc., was purchased. This data set is commercially available in a format called spatial data engine (SDE). SDE is a format optimized to provide quick routing solutions. ArcIMS utilizes the SDE data through its RouteServer extension. The SDE data, in combination with ArcIMS, can be used to provide various kinds of routing and logistics options such as vehicle routing with multiple stops, interstate preference, and so forth.

The non-spatial data contains complementary data that could be used in combination with spatial data. There are two kinds of non-spatial information: (1) roads-related asset data, and (2) weather data. The road-based non-spatial data comes as a set of database files (DBF) that contain pertinent information like traffic volumes, number of lanes, lane length, and so forth. All the non-spatial data is available along with spatial road data from Iowa DOT's maps Web site in the form of DBF. These DBF are linked to the shapefile by the unique segment ID of each road.

The weather data is obtained from the Internet using the rich simple syndication or RSS feeds and XML technologies. RSS is an XML-based document format for syndicating news and other timely news-like information (NOAA, 2003). The reason for choosing weather feeds is that they provide a dynamic, seamless interface for obtaining live weather data without page reloads. Also, the weather feeds from most sources, including the ones from NOAA, are free of cost.

The data gathered through the various data collection procedures is analyzed and modeled in order to design the core components for WebISDSS, namely, the intelligence component (expert system) and the analytical tools (spatial and non-spatial tools). A major emphasis of this chapter is the use of an intelligent software component for decision support and integrating it with a Web-based GIS. The expert system component of WebISDSS provides decision support using the knowledge gathered from snow removal experts and real-time weather data. The functionality provided by the expert system includes providing advised decision-making for generating shortest paths and prioritized routes, allocating resources optimally for snow plowing, and generating suggestions based on real-time weather data.

The analytical tools available in WebISDSS provide functionality such as basic navigation, routing, resource management, and so forth. These tools utilize spatial and non-spatial data. The intelligent component and the analytical tools are integrated into a single interface that could be accessed through the World Wide Web. Therefore, a Web site is designed for publishing the road (street) map of Black Hawk County, IA. The Web site, in effect, will serve both as a user interface and a way to publish the resultant maps and show the results. Various routes are color coded for effectively presenting the route information visually for better understanding.

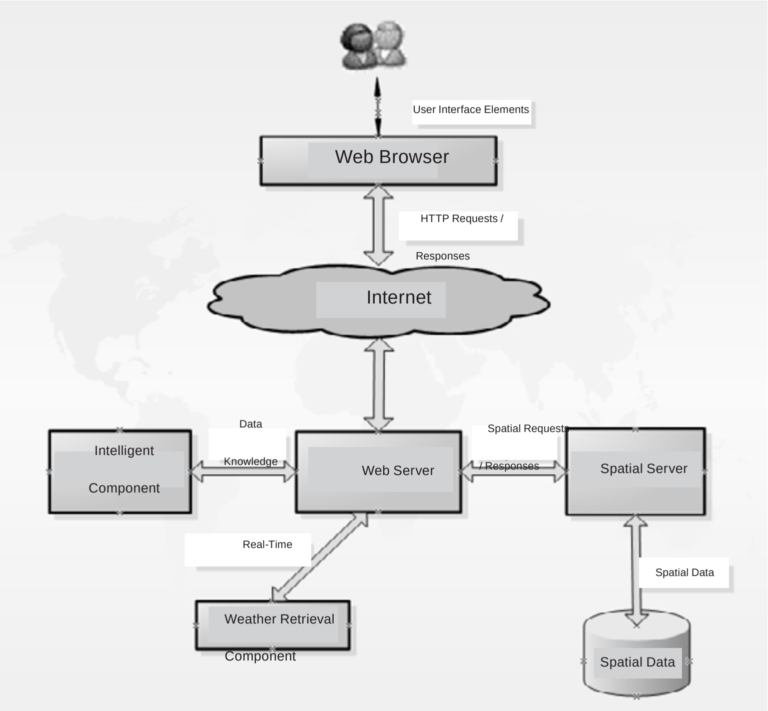
Architecture and Implementation

WebISDSS is designed using Web-based client/server architecture and rule-based artificial intelligence techniques. The implementation combines GIS and Web-based programming components from two leading technologies, Environmental Systems Research Institute (ESRI) and Microsoft. For developing the current prototype, ESRI ArcIMS ActiveX Connector is used in combination with Microsoft Internet information server and active server pages technology. The overall architecture of WebISDSS is shown in Figure 2. It contains the following two main components: (a) Web-based client interface, and (b) the server. These two components are briefly described as follows.

The Web-Based Client Interface

The primary functions of the Web-based client are providing the user interface and facilitating communication between the user and the server components. WebISDSS offers user interface by the means of a Web browser. The client corresponds with the server through requests; the server processes clients' requests and sends back a response.

Figure 2. The overall architecture of WebISDSS (Source: Ilavajhala, 2005)



The Server

The server is the "backbone" of the entire system and is composed of a set of components that work in tandem to process the user requests and provide a response. The server has the following components: (a) Web server, (b) spatial server, (c) non-spatial databases, (d) intelligent component, and (e) real-time weather retrieval component. A brief description of these components is given as follows.

The primary component on the server-side is the Web Server. It is the "central location" from where the user requests are received and processed or delegated further to other components like the spatial server or analytical tools, and so forth. The Web server for WebISDSS is the Microsoft Internet information server (IIS). The server is hosted on a Microsoft Windows XP Professional machine. All server side programming to create the analytical tools is accomplished using Microsoft active server pages (ASP) technology. The primary reason for choosing Microsoft technologies is their tight integration and ease-of-use.

The Spatial server is responsible for processing client requests that involve rendering and presenting maps and map-related information to the user. The spatial server is implemented using ESRI ArcIMS, the most popular Internet mapping software. The communication between the map display (client) and the spatial server components is performed via a standardized and proprietary XML format called ArcXML. WebISDSS utilizes ArcIMS ActiveX Object Connector v. 4.1. The ActiveX connector acts as an intermediary between the Web server and the spatial server by converting the user requests over HTTP into ArcXML statements, the language that the spatial server understands.

For providing routing solutions, the ArcIMS RouteServer extension is used. ArcIMS RouteServer comes as an additional component with ArcIMS and provides routing by using commercial data from TeleAtlas, Inc. This data is available in an optimized format called Spatial Data Engine (SDE) format. Advantages of using RouteServer are quick and efficient routing, complete integration with ArcIMS for use over the Web, and provision for obtaining fully-customized routes (e.g., percentage of interstates of travel, addition of multiple stops, etc.). All the routes are color-coded, according to a pre-determined priority, to take advantage of the visualization that GIS-based systems provide.

ESRI software was chosen over other vendors' products because we found ESRI products to be stable, scalable, and reliable. A detailed comparison of various Internet mapping software products from different vendors is beyond the scope of this chapter. Also, ESRI ArcIMS provides a programming model (object model) that is compatible with our server-side scripting language (ASP) and Web server (IIS), respectively.

The intelligent component developed for WebISDSS is a rule-based expert system. The knowledge gathered from the snow removal experts was carefully sifted and categorized into three knowledge categories, routing, resource allocation, and weather data. Categorizing the knowledge provided modularity and structure for storing the knowledge. The knowledge gathered was entirely conditions-based, in the form of a set of "actions" resulting from a set of "conditions." This sort of knowledge can be best represented as "if-then" structures. The intelligent component thus incorporates the expert knowledge and an inference engine. The expert knowledge is stored in a repository called the "knowledge base" and fed into the inference engine that provides a set of results or suggestions.

Rule Machine Corporation's Visual Rule Studio offers an easy and efficient way to code knowledge as "business rules", providing for encoding expert knowledge in the form of "if-then" rules. Each rule has a left-hand side (LHS) or conditions, and right-hand side (RHS) or results. The RHS is evaluated only when the LHS is true. These rules can be "fired" depending upon various data that is supplied and can help make a decision, rivaling a human expert. The knowledge-base is coded using Procedural Rule Language (PRL), a proprietary language of Rules Machines Corporation.

The asset databases contain information about various transportation assets that are utilized in snow removal activities such as characteristics of snowplows, capacity, mileage for equipment maintenance, odometer reading prior to assignment of the machine, details of the materials available at the central storage for snow removal, available quantity, unit cost of the material, reorder point, assignment of the operator to preferred machines, and so forth. All the asset databases are implemented in DBASE IV database file (DBF) format and are managed through the Web-based client.

As mentioned previously, the weather data for WebISDSS is obtained using the RSS and XML feeds technology. The weather data is embedded into the system by reading the free RSS and XML Weather feeds provided by www.weatherroom.com and NOAA's National Weather Service (http://www.nws.noaa.gov). These XML feeds essentially provide an XML document that encodes various weather parameters including the air temperature, wind speeds, wind direction, wind-chill, and visibility. Live as well as the forecast weather data can be obtained and presented to the user in this fashion by reading a particular weather feed from the Internet , and loading the information contained in the weather feed document. The current weather conditions help generate suggestions for material assignment and help determine the allocation of resources. The forecast data is used to generate alerts. The weather information can also be used for generating scenario-based solutions. Further, the live weather data, in combination with the encoded rules, help make intelligent decisions for snow removal and resource management and allocation.

RESULTS

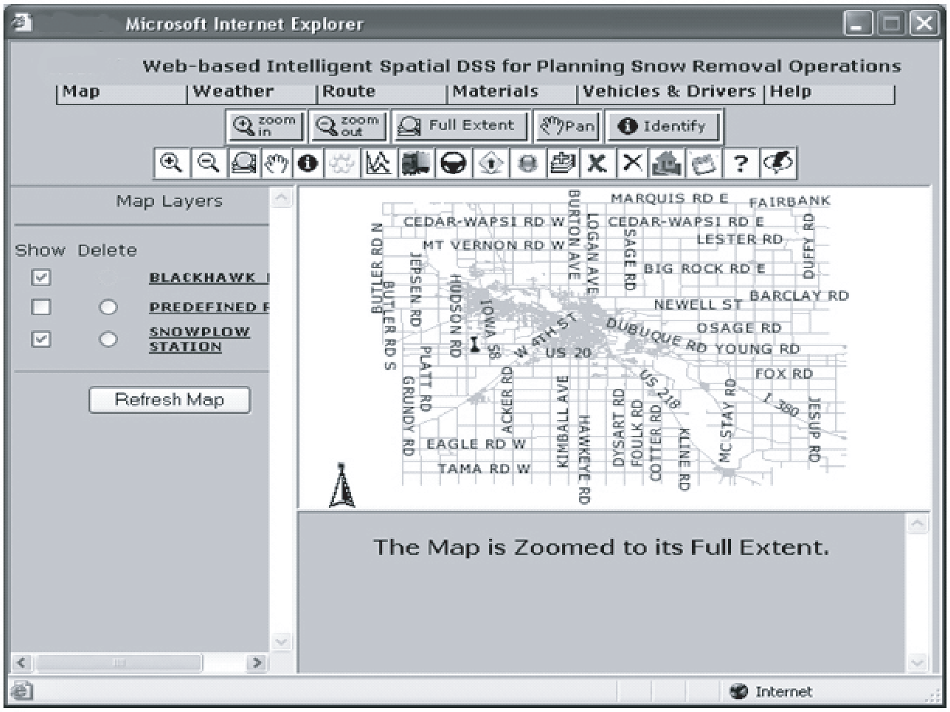
Application Example: Planning Snow Removal Using WebISDSS

One of the main objectives of WebISDSS is to provide easy-to-use Web-based interface and intelligent decision support for planning snow removal operations. To achieve this goal, the system uses the knowledge gathered from snow removal experts as well as real-time weather data. It provides an uncluttered interface, divided neatly into various "areas." For example, the menu and the tool bar appear on top, and the map and map layers area are beneath the menu, and a "message area" displays detailed messages to the users. The interface is mainly menu-driven, making it very easy to use. All the menu options are given appropriate, non-technical names so that a naïve computer user can also utilize the system. Figure 3 shows the main interface of WebISDSS and its organization into various "areas."

The system generates verbose and detailed alerts, warnings, tips, and other messages that help a non-technical user better understand the system. Most of the commonly-used menu options are provided as tools on a separate tool bar and can be used by clicking on the appropriate icon. When the user clicks on a particular tool, a message is displayed in the message area of the window. A detailed help system is available, which avoids technical jargon and provides the user with an easy guide to use the system. The salient features and functionalities of the menu interface of WebISDSS are briefly described as follows.

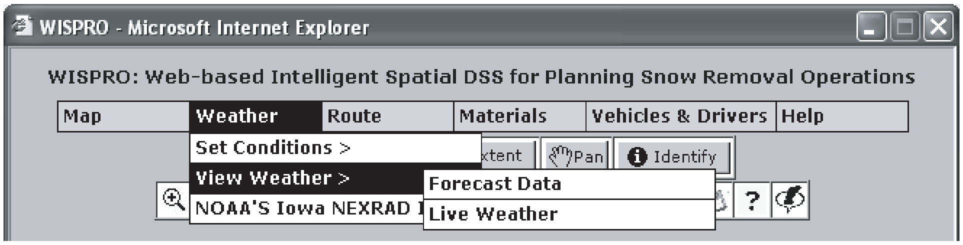
- **Weather menu:**The Weather menu lets the user set and view real-time weather information. The weather menu is shown in Figure 4. The user can choose to view live or forecast weather information and also store it. Weather conditions can be set either manually by entering a set of parameters or

Figure 3. The main interface of WebISDSS (Source: Ilavajhala, 2005)



The Map is Zoomed to its Full Extent.

Figure 4. The "Weather" menu interface of WebISDSS



by automatically obtaining them from the Web. The weather menu also provides an option to view live weather through NOAA NEXRAD radar image for the state of Iowa (Figure 5) or Forecast data. Figure 6 shows a screenshot of forecast weather retrieved by WebISDSS.

- **Route menu:** Route menu provides options for creating, deleting, and loading route information. The user can choose to create a route by clicking on the "start route" option, and then clicking on the road segments to snowplow. Clicking "end route" menu item will save the route, and generate driving directions from the station to the route by creating the shortest or quickest route, as chosen by the user. The user can also delete a route or a route segment. Deletion of route can either be temporary (deletion from the map) or permanent (deletion from the disk).
- **Vehicles and Drivers menu:** The Vehicles and Drivers menu provides options to assign drivers and vehicles. Also available from this menu is an option to manage drivers and vehicles by adding, deleting, or editing driver or vehicle information.
- **Materials menu:** Materials menu gives options related to materials management and control. Options include inventory analysis,

Figure 5. NEXRAD radar image obtained from NOAA

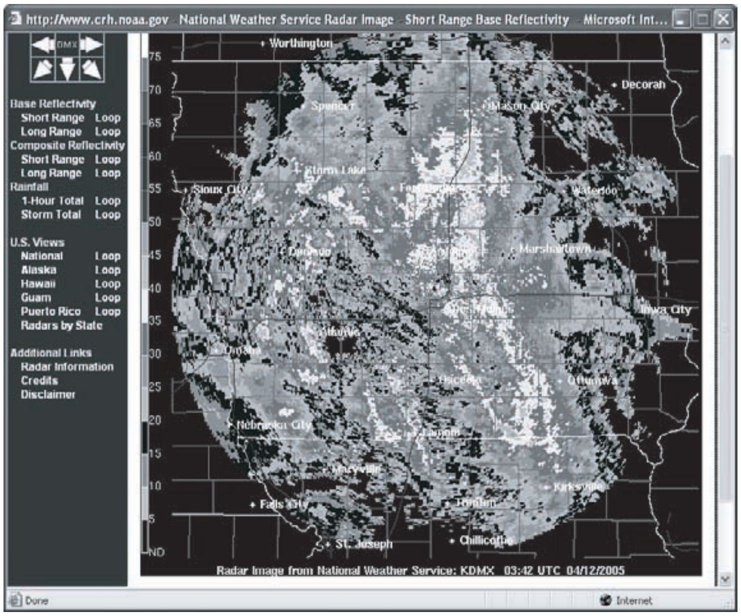
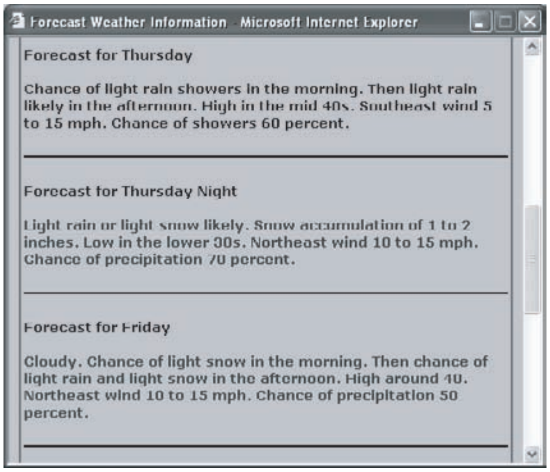


Figure 6. Screenshot of weather forecast information retrieved by WebISDSS



Forecast for Thursday

Chance of light rain showers in the morning. Then light rain likely in the afternoon. High in the mid 40s. Southeast wind 5 to 15 mph. Chance of showers 60 percent.

Forecast for Thursday Night

Light rain or light snow likely. Snow accumulation of 1 to 2 inches. Low in the lower 30s. Northeast wind 10 to 15 mph. Chance of precipitation 70 percent.

Forecast for Friday

Cloudy. Chance of light snow in the morning. Then chance of light rain and light snow in the afternoon. High around 40. Northeast wind 10 to 15 mph. Chance of precipitation 50 percent.

material assignment, addition/deletion/editing snowplowing materials such as salt, sand, and so forth.

- **Help menu:** The Help menu lets the user obtain information about how to use the system. The "Using WebISDSS" option shows the user the "Help central" screen with various options for getting help. Also, the help menu shows the product and copyright information.

SYSTEM WALKTHROUGH

The expert system provides suggestions based on user input. These suggestions include initiation of snow plowing operations, material to utilize for snowplowing, amount of material that must be used, number of lines to snowplow, and material assignment. To begin with, the user sets the weather conditions either by entering weather parameters like current conditions, temperature, dew point, wind speed, and so forth, or by using the system to read weather conditions from the Internet. The real-time weather retrieval component reads the encoded current and forecast weather data through the Web and provides a readable output to the user. Further, these suggestions are used for assisting and planning resource allocation, initiating snowplowing operations, and so forth. Thus, the real-time weather retrieval component works with the Web server and the intelligent component to provide suggested actions depending upon real-time weather information retrieved from the Web. These weather conditions are stored in a database file (DBF).

The expert system's inference engine examines the weather conditions stored in the database. The inference engine then produces a set of suggestions and stores these suggestions on the server's hard drive. These suggestions advise the user whether to initiate a snowplowing operation, which materials to use for snowplowing, and how much of each material should be used. Depending on the precipitation, the expert system also produces suggestions to either initiate anti-icing or de-icing operations. Other parameters that are used in producing suggestions are visibility and dew point. The system advises the exercise of caution if the visibility is less than a mile. The dew points are used to forecast precipitation and to caution the users to wet the bride decks to prevent icing.

Once the weather conditions are accessed and stored in the database, routes can be created. The WebISDSS calculates route parameters needed for snowplowing such as the number of lane miles, total route length, and so forth. These parameters are stored in a database along with other route parameters like route identification number, and so forth. These parameters are further used for making suggestions for material allocation.

After the routes are created, material can be assigned to these routes. Based on the weather conditions stored in the database, and various route parameters such as the route length, and so forth, the expert system provides suggestions on how much material should be used for snowplowing. Figure 7 shows part of the "rules" that the expert system uses to provide suggestions on material allocation and Figure 8 shows the material allocation interface of WebISDSS. Also, the expert system calculates the amount of material needed per route depending upon the precipitation levels. These calculations are based on a set of guidelines that the Iowa DOT uses to calculate material allocation.

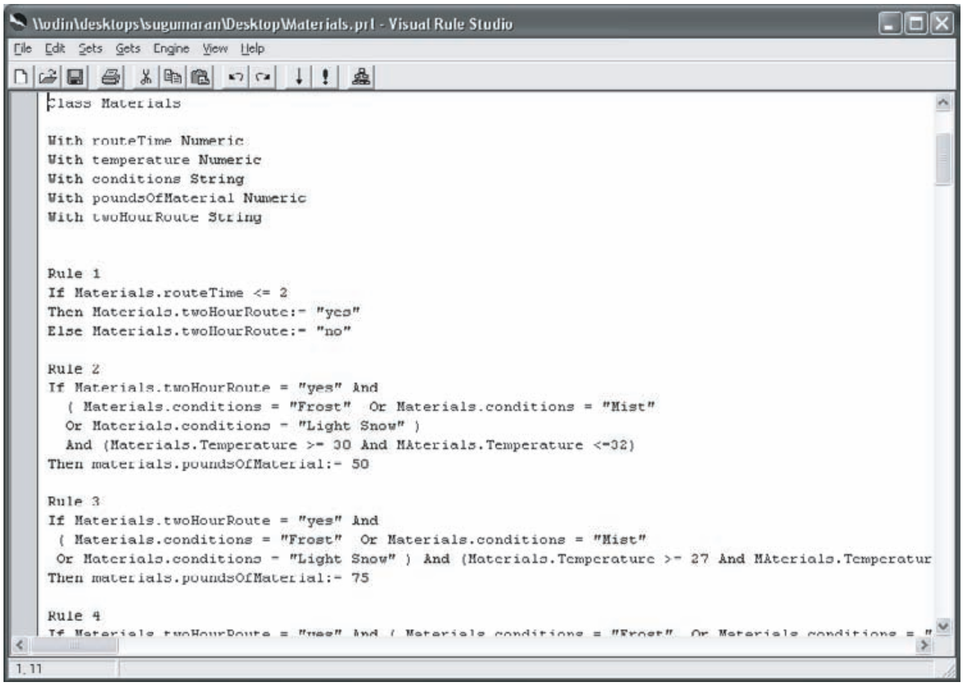
WebISDSS also provides a quick way to view all current assignments in one screen. The menu option "Map > Show Current Assignments" provides a screen with current vehicle assignments, driver assignments, weather conditions, and material estimations. Figure 9 shows one such screenshot.

SUMMARY AND FUTURE WORK

We have presented a Web-based intelligent spatial decision support system (WebISDSS) in this chapter that overcomes the disadvantages of existing systems by providing intelligent decision support for effectively planning snow removal operations. The system has been designed using ArcIMS ActiveX Connector with ArcIMS RouteServer extension and Web technologies such as ASP, XML, and RSS. The system also integrates an intelligent software component with geo-spatial and analytical techniques for providing real-time decision support.

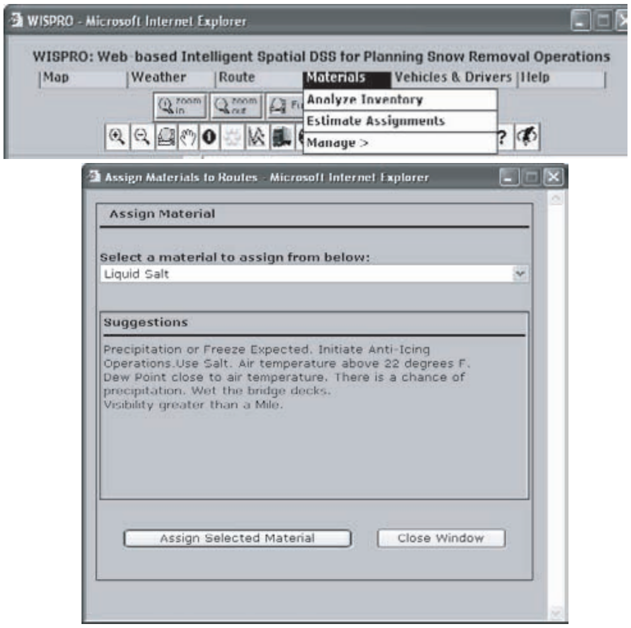
There is ample scope for further refining the WebISDSS system described in this chapter. Our future work is aimed at making WebISDSS more efficient and effective. For extending WebISDSS, ArcGIS Server 9.x can be used in conjunction with ArcObjects to provide advanced functionality like adding new features (e.g., new roads) and advanced geo-analytical tools. Additional solutions based on "intelligent technologies" such as intelligent software agents can be explored to extend the fundamental rule-based system to a full-scale "intelligent agent" based system. Also, the use of commercial weather data service that provides frequent updates and segment-wise conditions can improve the efficiency of the current prototype by generating very accurate snowplow routes and

Figure 7. Sample rules for material allocation



```
Class Materials

With routeTime Numeric
With temperature Numeric
With conditions String
With poundsOfMaterial Numeric
With twoHourRoute String


Rule 1
If Materials.routeTime <= 2
Then Materials.twoHourRoute:= "yes"
Else Materials.twoHourRoute:= "no"

Rule 2
If Materials.twoHourRoute = "yes" And
  ( Materials.conditions = "Frost"  Or Materials.conditions = "Mist"
  Or Materials.conditions = "Light Snow" )
  And (Materials.Temperature >= 30 And MAterials.Temperature <=32)
Then materials.poundsOfMaterial:= 50

Rule 3
If Materials.twoHourRoute = "yes" And
 ( Materials.conditions = "Frost"  Or Materials.conditions = "Mist"
 Or Materials.conditions = "Light Snow" ) And (Materials.Temperature >= 27 And MAterials.Temperatur
Then materials.poundsOfMaterial:= 75

Rule 4
If Materials.twoHourRoute = "yes" And ( Materials.conditions = "Frost"  Or Materials.conditions = "
```

Figure 8. Material assignment interface of WebISDSS

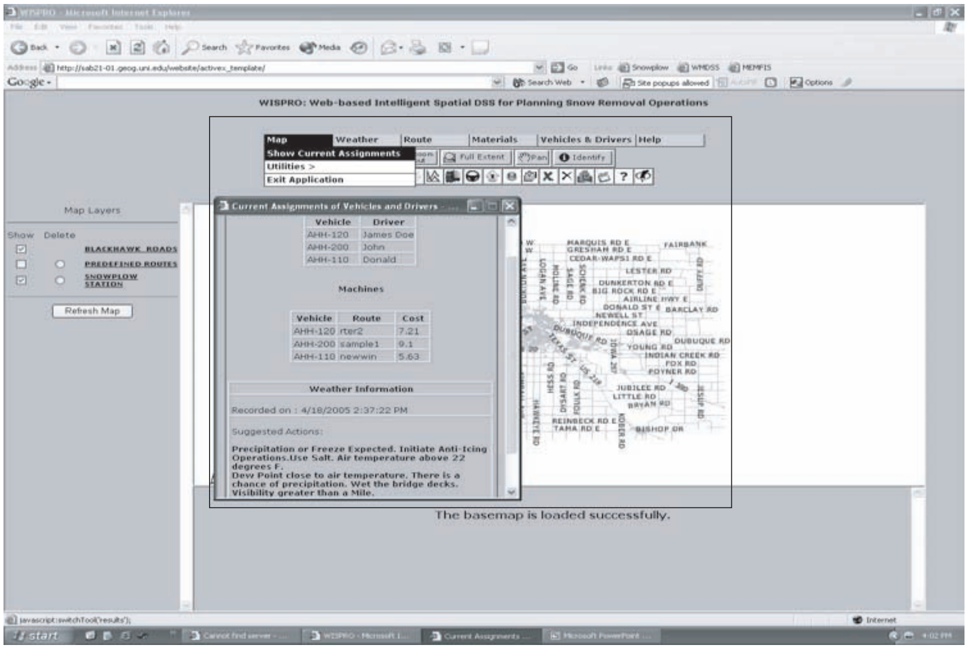


Select a material to assign from below: Liquid Salt

Suggestions

Precipitation or Freeze Expected. Initiate Anti-Icing Operations.Use Salt. Air temperature above 22 degrees F.
Dew Point close to air temperature. There is a chance of precipitation. Wet the bridge decks.
Visibility greater than a Mile.

Figure 9. Viewing all current assignments



Vehicle	Driver
AHH-120	James Doe
AHH-200	John
AHH-110	Donald

Machines

Vehicle	Route	Cost
AHH-120	rter2	7.21
AHH-200	sample1	9.1
AHH-110	newwin	5.63

Weather Information

Recorded on : 4/18/2005 2:37:22 PM

Suggested Actions:

Precipitation or Freeze Expected. Initiate Anti-Icing Operations.Use Salt. Air temperature above 22 degrees F.
Dew Point close to air temperature. There is a chance of precipitation. Wet the bridge decks.
Visibility greater than a Mile.

The basemap is loaded successfully.

by cutting costs further. The weather conditions can also be shown on the map to provide a visual display of various road weather conditions around the county. Furthermore, advanced algorithms can be implemented for sophisticated inventory analysis for better management of materials. Similarly, improved algorithms can be employed for driver and vehicle assignment purposes. Currently, the prototype is optimized to work with the Microsoft Internet Explorer browser. It can be expanded to work with other browsers such as Netscape, Mozilla, and Firefox by carefully considering the cross-browser functionality issues.

There is plenty of research and development yet to be done in the field of Web-based intelligent decision support systems. The prospect of employing intelligent autonomous agents for decision support is very promising. Advances in the fields of artificial intelligence and human computer interaction will have a big impact on how spatial decision support systems behave. Another emerging trend is the availability of decision support systems though a Web-based interface. This ensures cross-platform compatibility and ease-of-use. Further, these interfaces can be extended to work from portable devices like palmtops, cell phones, and so forth. In the coming years, the Web will change dramatically, reaching a wide population via a variety of handheld, smart devices. The future will also usher us into new ways of interaction with computing devices in a radically different way from today's interfaces.

The future for spatial decision support systems is promising considering the explosion of spatial data that we are experiencing. These spatial decision support systems provide many types of scenario-based decision support for governmental and non-governmental organizations (e.g., utility installation planning, right-of-way management, demographic research, etc.) and will be capable of providing advanced spatial analysis to further assist in decision-making. For example, the future spatial decision support systems will include active raster and vector data processing to provide instant results. This is a huge improvement from the various online mapping systems that use only raster data for providing driving directions, locations, and aerial photography.

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Chapter 2.15

Designing Clinical Decision Support Systems in Health Care:

A Systemic View

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ABSTRACT

Clinical decision support systems have historically focused on formal clinical reasoning. Most of the systems are rule-based and very few have become fully functional prototypes or commercially viable systems that can be deployed in real situations. The attempts to build large-scale systems without examining the intrinsic systemic nature of the clinical process have resulted in limited operational success and acceptance. The clinical function, another area of medical activity, has emerged rapidly offering potential for clinical decision support systems. This article discusses the systemic differences between clinical reasoning and clinical function and suggests that different design methodologies be used in the two domains. Clinical reasoning requires a holistic approach, such as an intelligent multiagent, incorporating the properties of softness, openness, complexity, flexibility, and generality of clinical decision support systems, while traditional rule-based approaches are sufficient for clinical function applications.

INTRODUCTION

Clinical decision support applications development in the field of medicine historically has been constrained by two factors. First, the design concept was limited to formal clinical reasoning based on expert physicians' rules of thumb. Second, design appears to have been technology driven, for nearly all of the current systems are rule-based, wherein rules in clinical reasoning (e.g., in diagnosis and treatment) are represented as rules in the clinical system. None of the clinical reasoning applications have yet to become fully functional prototypes or commercially viable (Bates, Kuperman, Wang, Gandhi, Kittler, Volk, & et al., 2003; Kaushal, Shojania, & Bates, 2003; Sim, Gorman, Greens, Haynes, Kaplan, Lehmann, & et al., 2001). The limited operational success of these large-scale systems (Kaplan, 2001) is due in large part to the failure to reflect more fully in the design the diverse systemic features of the clinical process. Newer sociotechnical approaches to design, for example, a multiagent approach, and more flexible representational methods are needed to produce viable clinical decision support systems (CDSSs).

A second area of medical activity, which we term here the clinical function, has emerged rapidly as health care participants (e.g., physicians, nurses, HMOs, hospitals, diagnostic labs) increasingly perform their clinical applications work using advanced information technology (IT), such as artificial intelligence-based (AI) systems (Wyatt & Spiegelhalter, 1991) and in-house medical staff. These new AI-based clinical function systems present design issues that differ from those of clinical reasoning systems. For example, these systems typically concern much smaller domains (e.g., alerting to drug interaction, monitoring patient vital signs, reminding to medicate patient) involving structured applications in medicine (Bates et al., 2003; Delaney, Fitzmaurice, Riaz, & Hobbs, 1999; Kaplan, 2001; Kawamoto, Houlihan, Balas, & Lobach, 2005; Ramnarayan & Britto, 2002).

The application of AI (e.g., expert systems) and other computational intelligence techniques (e.g., neural networks) to the field of medicine (Catley, Petriu, & Frize, 2004) has resulted in the attempts to develop CDSSs. Wyatt and Spiegelhalter (1991) have defined medical aids as “active knowledge systems which use two or more items of patient data to generate case-specific advice.” CDSSs have the potential to analyze, synthesize and integrate patient-related information to perform complex evaluations and provide that information to clinicians in real time. Over time, as they evolve in sophistication, they offer the prospect of improving the effectiveness and efficiency of patient care by preventing medical errors and enhancing quality (Johnston, Langton, Haynes, & Mathieu, 1994).

Further, the systems can improve preventive care services and help in adhering to recommended care standards (Kawamoto et al., 2005). The overall goal is to improve clinical decision making by focusing on individual patient characteristics and mapping them to a computerized knowledge base of characteristics of similar patients (Garg et al., 2005). They provide a range of levels of decision support, from simple alerts to complex diagnosis. For example, a CDSS can aid a physician in processing complex information to improve prescription writing practices in electronically delivered recommendations (Durieux, Nizard, Ravaud, Mounier, & Lepage, 2000). These types of systems are differentiated from operational decision support systems (DSSs), which are defined as enterprise repositories of clinical and financial information for utilization review, cost evaluation, and performance evaluation (Classen, 1998). In contrast, CDSSs focus on medical decisions (both on making decisions and assisting in making decisions). The key is to use patient specific information that transforms protocols into customized, real-time clinical advice (Kawamoto et al., 2005; Teich, Osheroff, Pifer, Sittig, & Jenders, 2005).

This paper discusses the clinical decision support applications design issues arising from the systemic differences (Churchman, 1971; Van Gigch, 1978, 1991) between clinical reasoning and clinical function systems, and it proposes that different design methodologies be used in the two domains. The paper is organized as follows. First, design issues in clinical reasoning and clinical function are discussed. Second, knowledge representation issues are highlighted. Third, the systemic properties of softness, openness, complexity, generality and purpose are discussed in the context of the two domains. Fourth, domain issues are identified. Next, operational examples of clinical reasoning and clinical function applications are described. Finally, conclusions are offered.

DESIGN ISSUES IN CLINICAL REASONING AND CLINICAL FUNCTION

Clinical reasoning is concerned with the decision processes of medical experts, such as physicians and surgeons, the interpretation of clinical information, and medical diagnostic rules. The outcome of clinical reasoning is some kind of clinical decision (diagnosis). On the other hand, the clinical function has emerged as a differentiated organizational entity. It is defined here as the set of activities that involves the routine and procedural application of medical rules and protocols to the operational needs of the medical care delivery organization. Differences between clinical reasoning and the clinical function are distinguished in terms of several system concepts. First, we discuss clinical knowledge representation and system design.

Clinical Knowledge Representation and System Design

Despite the domain complexity, most expert systems in clinical reasoning have involved the one-to-one mapping of rules of medicine onto rules in the system. This type of representational approach does not provide the flexible basis necessary to develop a sociotechnical clinical reasoning system that affords the openness, softness, complexity, and generality to deal with the dynamics of sociomedical aspects of clinical reasoning. Purely rule-based representation and problem solving are suitable for many clinical function applications that often involve narrow, structured well-designed domains. Knowledge representation for clinical reasoning, however, must include objects, frames, semantic nets, rules, and combinations of these to adequately represent different levels of knowledge, in combination with abstract medical concepts at higher levels and clinical rules at lower primitive levels. Combined with a multiagent systems model for complex problem solving, these representational modes enable interaction between multiple sources and levels of medical knowledge and different types of clinical reasoning, which comprise the problem-solving methodologies. The use of multiagent models will be a major departure from the current limited, rule-based approaches for implementation of AI clinical decision support systems.

Softness and Openness

Natural systems have been characterized as being somewhat hard, mechanistic, and rigid (Van Gigch, 1978). While clinical reasoning does involve some rigidity in terms of medical rules/procedures, the application of clinical reasoning reflects the relatively soft nature of the sociomedical aspects of medicine (e.g., consideration of gender, ethnicity, culture, religion, individual patient customized protocol). Softness considers subjectivity and value as important considerations in the design of clinical reasoning applications. Applications in the clinical function, on the other hand, usually involve specific routine procedures or repetitive tasks. Design models for the clinical function, therefore, should be more rigid and mechanistic in view of the procedural nature of this applied medical work.

Clinical reasoning involves open system properties (Hewitt, 1985), for, as an integral part of society and health care organizations, the medical system continually processes inputs and feedback from the environment, including changes in medical practice, new/modified protocols, new drugs, effect of clinical trials, societal values, replacement of medical experts, organizational perspectives (e.g., hospital mission), and others. The medical systems, as a model at the cusp of hard (pure science) and soft (social science) sciences, exhibits its negentropic nature as clinical reasoning adapts to changing goals (e.g., prevention vs. treatment), new research findings and advances in medicine, different sources of knowledge, and learning from experience. The clinical reasoning system must be capable of arriving at similar decisions equifinally by accepting inputs from multiple experts and applying alternate reasoning paths and different approaches to problem solving (Hewitt, 1985).

While the medical literature emphasizes the open-textured nature of medicine, openness is a feature of the entire medical system. Openness in the design of clinical reasoning systems provides for the flexibility to include several interacting domains in clinical reasoning, accepting inputs from multiple external sources of information and expertise, and accommodating the various reasoning mechanisms that are part of clinical decision processes.

In contrast, applications in the clinical function are essentially closed-system models requiring minimum feedback. Dynamic interaction and flexibility are limited because of the structured nature of clinical function tasks.

Complexity in DSSs

Complexity in CDSSs results from interaction internally between subsystems and externally with various systems in the environment, such as the economic (insurance) and primary care systems, as well as government entities, such as Medicare and Medicaid. Within an organizational health care delivery system (e.g., a hospital), there is also interaction and interdependence with the legislative bodies, the judiciary, the National Institutes of Health, the American Medical Association, medical experts, ethicists, managers, and the general public. The design of expert clinical reasoning systems must include provisions for the various modes of inquiry (Churchman, 1971) and complex interactions among various sources of clinical knowledge, such as medical facts, protocols, judgmental experience of medical experts and health care managers (e.g., nurse managers, discharge planners), customs, and medical precedents. Since societal values also impinge on outcomes, holism in design is essential to deal with the sociomedical complexity.

In the design of CDSSs for clinical reasoning, the trade off has historically been in formulating a computer model that is well structured and rigid in specification as opposed to one that provides for flexibility and adaptability. Strictly reductionaistic, rationalistic approaches to the design of clinical decision-making applications effectively eliminate these essential features. Mutiagent models hold considerable promise for assimilating the variety of inputs for complex clinical reasoning. The clinical function has emerged in health organizations because of increased organizational complexity and environmental uncertainty (e.g., hospitals). The growth of the clinical function was part of a general pattern of organizational elaboration and differentiation of specialized functions. While clinical reasoning is complex by nature, the clinical function is relatively simplistic, and interaction with the environment is minimal. Because of the procedural nature of most clinical function activities, rule-based (procedural) system approaches to application design are adequate and most often used.

Generality and Purpose in CDSSs

Research in AI frequently has emphasized the need for generality in the problem-solving methods. This is an important issue, for clinical reasoning applications should be capable of handling a wide range of medical problems.

Current design efforts for AI-based systems in clinical reasoning, however, tend to be limited to a single domain of medicine or reasoning. Generality in clinical reasoning suggests that the system cannot be limited to a single domain or a particular type of reasoning mechanism. For purposes of design, more general problem-solving models for the clinical reasoning domain have to be investigated. Again the multiagent model (e.g., the blackboard approach) possesses the characteristic of generality, and being conceptual, also can accommodate features that are unique to particular domains. In contrast, clinical function tasks are situation specific and do not require the generality needed by clinical reasoning systems.

Clinical reasoning applications are typically designed to arrive at a clinical decision. Examples of such systems include diagnosis of the cause of patient's chest pain (Hunt, Haynes, Hanna, & Smith, 1998); treatment of infertility (Garg et al., 2005); implementation of clinical guidelines on venous thromboembolism prophylaxis in an orthopedic surgery department (Durieux et al., 2000); analysis of outcome of patient cardiovascular risk (Montgomery, Hahey, Peters, MacIntosh, & Sharp, 2000); interpretation of blood work results (Classen, 1998); and others. Clinical reasoning culminates in decisions (e.g., outcomes—diagnosis of a disease, treatment selection) as the result of the interaction among various sources of knowledge and types of reasoning. The goals for clinical reasoning applications are relatively vague and ill defined. Clearly, a holistic and integrative view of design is needed, rather than the current focus on segmentized, disparate approaches that compartmentalize types of clinical reasoning, including analysis, critiquing, diagnosis, pattern recognition, and treatment recommendation, to name a few (Ramnarayan & Britto, 2002).

Clinical function applications are designed to execute programmed decisions involving narrowly defined medical tasks to achieve specific goals in the health care delivery organization. Some generic examples of such clinical function applications include detection of drug overdose (Hunt et al., 1998); selection of appropriate drug dosage, providing immunization reminders (Garg et al., 2005); alerting to drug interaction and monitoring patient vital signs (Classen, 1998); and others. Typically, the clinical function activities include alerting, recognition, alerting, and monitoring (Kawamoto et al., 2005; Ramnarayan & Britto, 2002).

Domain Issues

The variety of issues faced by clinical decision processes poses significant problems for domain definition in design. Historically, the boundary identification problem in design has been addressed by limiting the system domain to a particular specialty of medicine (e.g., disease), type of reasoning (e.g., rule-based, case-based), or problem-solving approach. Such design limitations have led to the problems with clinical reasoning systems discussed previously. The design of clinical function applications, while not trivial, is less challenging, for the boundaries of individual systems are limited to specific tasks. It is becoming more common for these tasks to be performed by nurse practitioners, nurses, and clinical technicians, who have gained expertise in routine and repetitious tasks in narrow medical domains and who are being increasingly supported by clinical function systems. Examples of clinical function applications include nurse practitioner functions. By and large these are the most readily developed for rule-based applications. Nurse practitioners carry out routine repetitive tasks and develop expertise in such domains as alerting, monitoring, and reminding and, therefore, provide input for clinical decision processes at higher levels. A number of generic applications are currently available to support nurse practitioner tasks. Most of the applications are fairly simple and implemented as rule-based systems. However, they lack the sophistication necessary to support clinical reasoning tasks.

Examples of clinical reasoning tasks include diagnosis, interpretation, and planning. All these high-level clinical decisions are characterized by complexity, ill-structuredness, and uncertainty. Typically, such decisions are collectively made by a group of medical experts. Table 1 summarizes the example of clinical reasoning and clinical function tasks in health organizations. As seen in Table 1, most programmed tasks are performed at lower and middle levels. Rule-based approaches are suitable for (expert system) applications development for these tasks. The higher-level tasks are typically nonprogrammed, ill-structured, and complex. Multiagent models are more appropriate for applications supporting these activities.

Table 1. CDSSs

Health Organization Level	Problem Type	Tasks
Top		
Physicians Surgeons Medical directors Residents Specialists	**Ill-structured, complex Nonprogrammed (multiagent model)**	**Diagnosis Causal analysis Clinical reasoning Recommendation Interpretation Prediction**
Middle		
Physician assistants Nurse practitioners Nurses	**Semistructured, somewhat Comples, nonprogrammed (single to multiagent)**	**Alerting Monitoring Clinical reasoning Clinical function Reminding**
Lower		
Nurses Clinical assistants Discharge planners	**Structured, routine, Programmed (single angent)**	**Alerting Reminder**

Other Issues

The identification of users and experts in the clinical function is straightforward, while deciding whether the physician is the only user or the expert in clinical reasoning is not always so clear. Clinical reasoning involves deeper epistemological and ontological considerations; the development time for a clinical reasoning application is lengthy; the cost is very high; the design and implementation effort is extensive; risks are considerable (e.g., misdiagnosis); and the payoffs are uncertain. In contrast, clinical function applications involve shorter development time, low costs, and considerably less effort. A clinical function application can be built using available technology, such as shells (rule-based expert system). Unlike clinical reasoning applications, these systems do not require extensive medical knowledge on the part of the knowledge engineer. Knowledge acquisition is easier and application validation is more readily achieved. User acceptance of clinical function applications is higher, especially for systems that act as “intelligent clinical assistants” for medical task performance (e.g., drug dosage tracking, monitoring patient vital signs), leading to increased potential for use and commercial viability. Table 2 summarizes the systemic differences between clinical function and clinical reasoning.

Operational Examples of Clinical Reasoning and Clinical Function Systems

With regard to clinical reasoning systems, St. Mary’s Medical Center in West Palm Beach, FL, maintains statistics about infants (e.g., vital signs) in an electronic documentation system. This data is analyzed and mined, for example, to identify potential risks and side effects from commonly used medications (Landro, 2006). At Partners Health in Boston, expert systems provide information on medication dosing for specific types of patients, taking into account several factors. Also, iLog, a decision support software, enables the sharing of clinical best practices to gather and analyze

Table 2. Clinical reasoning versus clinical function

Concept	Clinical reasoning	Clinical function
Nature of model	Open Soft Flexible Dynamic Holistic	Closed Hard Inflexible Axiomatic Sequential
Solution	Satisficing	Optimal
Reasoning	Opportunistic Mulitagent	Rule-based
Knoweledge Representation	Accommodates rules Frames, objects, and others Modular	If-then rules Chain of rules
Control	Mostly explicit	Mostly implicit
Domain Characteristics	Ill-structured Multiple sources of knowledge Multiple reasoning mechanisms Nonprogrammed	Structured Single source Single line of reasoning (typically rule-based) Programmed
Decision tasks	Planning Diagnosis Interpretation	Alerting Monitoring Reminder
Knowledge Acquisition	Modular, Multiple	Data intensive Integrated

new or yet untapped data (Mcgee, 2006). IBM and Sloan-Kettering Cancer Center are working with systems to extract lab-result details from text intensive pathology reports to discover correlations by analyzing patterns, for example, of how specific kinds of tumors respond to various therapies (Mcgee, 2006). At West Mead Hospital, Sydney, Australia, Brain Resource in collaboration with IBM is building DSS software that can help analyze data from millions of sources of brain data (Mcgee, 2006). Mayo Clinic and IBM are applying pattern recognition and data-mining techniques to the electronic records of millions of patients to customize medical treatments to individual patients, such as selecting the best chemotherapy for a cancer patient with a particular genetic marker (Mcgee, 2004). In surgery, New York-Presbyterian Hospital is testing Penelope, a robot arm, that uses voice and visual recognition techniques to provide nursing assistance in the operating room (Santora, 2005). A system to analyze lab, pharmacy, patient, and other data, using inference engine software (infection control system), is being used at New York-Presbyterian Hospital. The purpose of this is to study data patterns to alert infectious disease nurses when a situation within the hospital could lead to an outbreak (Havenstein, 2005; Mcgee, 2005). Additionally, AI software is used to create treatment plans for patients in the cardiac intensive care units (using case-based approaches). Furthermore, the Cleveland Clinic and IBM are developing a translational medical platform and infrastructure to apply data-mining techniques to support clinical decision making. In another example, Kaiser Permanente's comprehensive medical database was used (via analysis and pattern recognition) to demonstrate that the arthritis drug Vioxx could cause heart problems (Eweek, 2006). In terms of clinical function applications, Aurora St. Luke's Medical Center, Milwaukee, uses the eICU system, which monitors patients electronically, helping a team of doctors and nurses to keep constant watch on more than 10 ICUs in four different hospitals across eastern Wisconsin (Fischman, 2005). A prototype wristwatch that monitors recovering cardiac patients' vital signs and sends them to their doctors via the cell phone network is being scheduled to be launched in 2006. The system called MDKeeper is being developed by Tadiran Spectralink of Israel (New Scientist, 2005). In Canada, the Global Public Health Intelligence Network (GPHIN) functions as a secure Internet-based early warning system assessing and cross referencing patients to track the length of time spent in a hospital or in quarantine. This type of information assists in providing a big-picture view of the operations of pandemics over large regions (Songini, 2006). Kranhold (2005) reports about a physician-alert system that alerts physicians if they are prescribing a medication that may react with another medication that the patient is taking—the system tracks patients' allergies and warns physicians if a medication might interact badly with the allergy. At University of Pittsburgh Medical Center (UPMC) in western Pennsylvania, a clinical information system delivers treatment information to doctors and nurses at the bedside, providing fast access to lab tests and X-rays, so they do not have to be repeated. The data also can be analyzed for possible outbreaks (Landro, 2005a). Also, another computer-order entry system at the UPMC Children's Hospital automatically calculates appropriate drug doses, based on a child's age and weight, and flags possible allergies or drug interactions (Landro, 2005b). Another application allows doctors to type in a patient's symptoms, and, in response, the system outputs a list of possible causes is reported in Leonhardt (2006). At St. Joseph's Hospital Health Center, Syracuse, NY, a picture archiving and communications system enables physicians and lab technicians to search and access patient information, data, and X-Rays via a Web portal (Mearian, 2005). Children's Memorial Hospital of Chicago is using a new system that confirms that the right medication is being administered at the right time to the right patient by scanning bar codes on the medication bags and sending it to a central computer that performs the matching (Pettis, 2006). The New York City is using a system for early warning of disease patterns called the Syndronic Surveillance System. It uses statistical analysis to calculate risk probabilities for possible disease outbreaks (Perez-Pena, 2003).

CONCLUSIONS

Distinguishing the systemic differences between clinical reasoning and the clinical function can enhance the design of CDSSs by assisting in the selection of the appropriate problem-solving architecture. The automation of clinical reasoning required a holistic approach that incorporates the properties of softness, openness, complexity, flexibility, and generality of medical systems.

The trend toward distributed systems, multiagent models, parallel open-system architectures, and general models of intelligence for complex problem solving indicates that these alternatives must be explored in the design of automated clinical reasoning systems. Decision support applications development in medicine is in a primitive stage compared to other domains, but the use of system constructs in design can accelerate its maturing process.

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Chapter 2.16

A Framework for a Scenario Driven Decision Support Systems Generator

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ABSTRACT

Traditional Decision Support Systems (DSS) provide strong data management, modelling and visualisation capabilities for the decision maker but they do not explicitly support scenario management appropriately. Systems that purport to support scenario planning are complex and difficult to use and do not fully support all phases of scenario management. We introduce scenario as a core component of decision making systems and present a life cycle approach for scenario management, which helps the decision maker with idea generation, scenario planning, development, organisation, analysis, execution, evaluation, and decision support. This research designs and develops a domain independent framework and architecture for Scenario-driven Decision Support Systems Generator that aligns the DSS with the scenario management process. We then propose a generalised evaluation process that allows homogeneous and heterogeneous scenario comparisons among multiple instances of similar and dissimilar scenarios respectively. The framework and architecture is implemented and validated through a concrete prototype.

INTRODUCTION

Herman Kahn, a military strategist at Rand Corporation, first applied the term scenario to planning in the 1950s (Schoemaker, 1993). Scenario analysis was initially an extension of traditional planning for forecasting or predicting future events. Currently, scenarios are constructed for discovering possibilities, leading to a projection of the most likely alternative. Scenario has been defined as a management tool for identifying a plausible future (Alter, 1980; Porter, 1985; Schwartz, 1991; Tucker, 1999) and a process for forward-looking analysis. Scenario has also been defined in many other ways, for example. a kind of story that is a focused description of a fundamentally different future (Schoemaker, 1993); that is plausibly based on analysis of the interaction of a number of environmental variables (Kloss, 1999); that improves organization learning by putting many bits of information in order (De Geus, 1997; Desmarais, 2000; Van der Heijden, 1996; Wack, 1985); that is analogous to a "what if" story (Tucker, 1999); that is more dynamic and interactive than the what-if analysis (McGillivray & McGillivray, 1995). It is a description of the current situation and a series of events that could lead the current situation to a possible or desirable future state (Schoute, Finke, Veeneklaas, & Wolfert, 1995). Scenarios are not forecasts (Schwartz, 1991), future plans (Epstein, 1998), trend analyses or analyses of the past. It is for strategy identification rather than strategy development (Schoemaker, 1993) and to anticipate and understand risk and to discover new options for action. Ritson (1997) agrees with Schoemaker (1995) and explains that scenario planning scenarios are situations planned against known facts and trends but deliberately structured to enable a range of options and to track the key triggers which would precede a given situation within the scenario.

Scenarios explore the joint impact of various uncertainties, which stand side by side as equals. Usually sensitivity analysis examines the effect of a change in one variable, keeping all other variables constant. Moving one variable at a time makes sense for small changes. However, if the change is much larger, other variables do not stay constant. Schoemaker (1995) argues that scenario, on the other hand, changes several variables at a time, without keeping others constant. Decision makers have been using the concepts of scenarios for a long time, but due to its complexity, its use is still limited to strategic decision making tasks. Scenario planning varies widely from one decision maker to another mainly because of lack of generally accepted principles for scenario management. Albert (1983) proposes three approaches for scenario planning, namely, expert scenario approach, morphological approach and cross-impact approach. Ringland (1998) identifies three-step scenario planning—namely brainstorming, building scenarios, and decisions and action planning. Schoemaker (1995) outlines a ten-step scenario analysis process. Huss and Honton (1987) describe three categories of scenario planning. The literature still lacks a suitable approach for planning, developing, analyzing, organizing and evaluating the scenario using model-driven decision support systems. Currently, available scenario management processes are cumbersome and not properly supported by the available tools and technologies. Therefore, we introduce a life cycle approach based scenario management guideline.

Generation of multiple scenarios and sensitivity analysis exacerbate the decision maker's problem. The available scenario planning tools are not suitable for assessing the quality of the scenarios and do not support the evaluation of scenarios properly through comparison processes. We introduce an evaluation process for comparison of instances of homogeneous and heterogeneous scenarios that will enable the user to identify the most suitable and plausible scenario for the organization. Considering the significance of scenarios in the decision-making process, this research includes scenario as a decision-support component of the DSS and defines Scenario-driven DSS as an interactive computer-based system, which integrates diverse data, models, and solvers to explore decision scenarios for supporting the decision makers in solving problems.

Traditional DSS have been for the most part data-driven, model-driven and/or knowledge-driven but have not given due importance to scenario planning and analysis. Some of the DSS have partial support for sensitivity analysis and goal-seek analysis but this does not fulfill the needs of the decision maker. In most cases, the available scenario analysis tools deal with a single scenario at a time and are not suitable for development of multiple scenarios simultaneously. A scenario impacts on related scenarios but currently available tools are not suitable for developing a scenario based on another scenario.

To address the problems and issues raised above we followed an iterative process of observation/evaluation, theory building, and systems development (Nunamaker, Chen, & Purdin, 1991), wherein we proposed and implemented a flexible framework and architecture for a scenario driven decision support systems generator (SDSSG). It includes scenario as a DSS component, extends the model-driven DSS, and incorporates knowledge and document-driven DSS (Power, 2001). A prototype was developed, tested and evaluated using the evaluation criteria for quality and appropriateness of scenarios (Schoemaker, 1995) and principles of DSSG frameworks and architectures (Collier, Carey, Sautter, & Marjaniemi, 1999; Geoffrion, 1987; Ramirez, Ching, & Louis, 1990). The details of these validation criteria are mentioned in the implementation section. The conceptual framework as well as the prototype was modified on the basis of the findings and the process was continued until a satisfactory result was achieved.

In the rest of this article, we first introduce a life cycle approach for management of scenarios including a detailed discussion of handling homogeneous and heterogeneous scenarios. We then propose a scenario-driven flexible decision support framework and follow this up with a discussion on how it realizes the scenario management process. We then present an n-tiered architecture that details the SDSSG framework. Finally we discuss the implementation platform and domain within which the proposed process, framework, and architecture were validated.

SCENARIOS: A DEFINITION AND AN EXAMPLE

Definition of a Scenario

The definitions given in the previous section do not give a complete picture of scenario modeling as they do not entail the exact scenario structure. Chen (1999) provided an implementation level definition of scenario—*a combination of the instance of data, model, solver, and visualization*. This definition is very narrow and specific for a generic scenario management process. To overcome this shortcoming, an implementation level scenario definition is provided that addresses the structure of the problem situation and its dynamic behavior. A scenario is a situation that is comprised of one or more problem instances. A change in one scenario might have chain effects on any related scenarios. The basic structure and behavior of the scenario is similar to the decision support system components model and solver respectively. Hence, we define scenario as a complex situation analogous to a model that is instantiated by data and tied to solver(s). A scenario can be presented dynamically using different visualizations. A scenario may contain other scenarios. Hence, a scenario structure is an object that establishes a complex relationship among various models, solvers, visualizations, contained scenarios (if there be any), and related data for integrating them.

An Example Scenario

Before we discuss scenario management, we discuss an example that will be used during the discussion of implementation. For example, mortgage management includes a series of external environment sensitive inter-related scenarios. AMP (2001) describes a mortgage scenario wherein the median wage and the home price increase and the interest rate drops. What is the impact of this change or any other changes on the individual buyer as well as on the mortgage market? The change in interest rate, average income of the people, demand and supply of houses, and so forth, highly influence the mortgage markets.

This scenario broadly depends on several other scenarios, for example, affordability scenario, loan scenario, and payment scenario. The affordability scenario helps in understanding the borrower's eligibility to get a loan and capacity to repay the loan. The loan scenario analyses the cost of financing, loan amount, and installments. Depending on the loan type, this analysis process can differ widely. The payment scenario analyzes installments, interest payments, principal repayment, and loan balance. The payment scenario addresses the entire life cycle of the loan repayment. Affordability scenario is a constraint to the loan analysis scenario. Each of these scenarios can again be decomposed into several smaller scenarios, for example, the affordability scenario depends on the the income scenario and expense scenario while the income scenario may be sub-divided into the personal income scenario and family income scenario. All these scenarios are inter-related and the higher level scenarios are dependent on the lower level scenarios. Sensitivity analysis and goal-seek analysis of these scenarios would greatly enhance the decision making process.

SCENARIO MANAGEMENT: A LIFE CYCLE APPROACH

The scenario can be different for different problems and domains but a single management approach should support the model-driven scenario analysis process. Therefore, this research introduces a scenario management process using life cycle approach that synthesizes and extends ideas from Ringland (1998, 2002), Schoemaker (1995), Albert (1983), Huss and Honton (1987), Van der Heijden, (1996), and Wright, (2000). The proposed life cycle approach for scenario management process addresses a variety of problem scenarios. The life cycle process starts with scenario idea generation and finishes with the usage of scenario for decision support as illustrated in Figure 1. The following sections present all the phases of the life cycle approach for scenario management.

Idea Generation

The scenario planner foresees the key issues that exist within the scenario and analyses the concerns for identifying the influential driving forces and parameters for the scenarios. In addition the planner may also use the existing scenarios from the scenario pool. The leading factors, which could be either internal and/or external, could lead to various changes to the system. The decision maker as a domain expert predicts the possible changes to the indicators that would guide to the development of ideas for scenario planning.

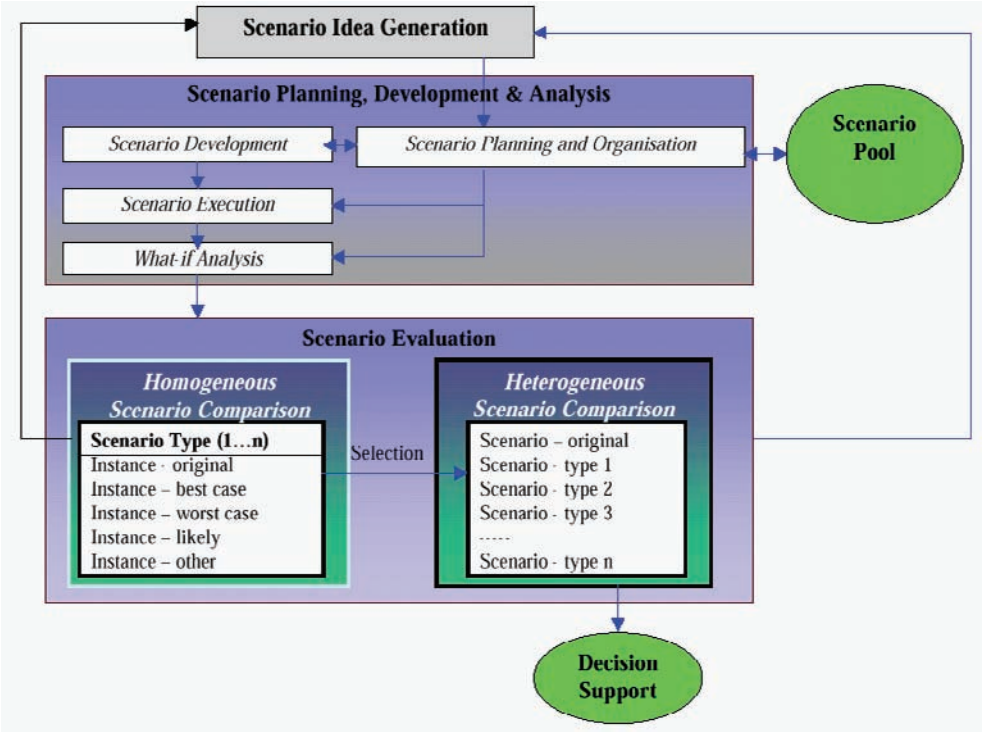
Scenario Planning, Development and Analysis

In this phase, the decision maker will carry out the tasks of scenario planning and organization, scenario development, scenario execution, and what-if analysis. Existing scenarios could also act as inputs to this phase apart from the ideas generated from the previous phase.

Scenario Planning and Organization

The scenario planning step mainly focuses on decomposing the whole big scenario into multiple inter-related scenarios that are suitable for development, execution, analysis and evaluation. It also includes scenario structuring and identification of the scenario components.

Figure 1. Scenario Management: A Life Cycle Approach



Scenario Structure

The components of the scenario can be either pre-customized or loosely coupled. For a pre-customized scenario, the relationships between data, model, and solver as well as with other dependent scenarios are inflexible. The relationships between data-model, model-solver, and data-model-solver-scenario are defined during scenario planning. For example, a scenario is a collection of data, models, solvers, and scenario(s) in which the relationships among the constituent components are fixed and the model instantiation and model evaluation processes by data and solver are distinct. So, the scenario components are tightly integrated and the relationships are not exposed for the decision maker as shown in Figure 2.

For a loosely coupled scenario, the scenario components namely, the data, model, solver, and dependent scenarios remain independent within the scenario. The relationships among these components are established at runtime using a mapping component as shown in Figure 3.

The visualization component is omitted as it can be flexible for both the pre-customized and loosely coupled scenarios.

A Mechanism for Structuring Scenarios

Scenarios are complex and dynamically related to other scenarios. In view of addressing the complexity and inter-relatedness of scenarios, we propose to divide larger scenarios into multiple simple scenarios having independent meaning and existence. In this context we identify three types of scenarios, namely:

- Simple Scenarios—The simple scenario is not dependent on other scenarios but completely meaningful and usable.

Figure 2. Pre-customised Scenario Structure

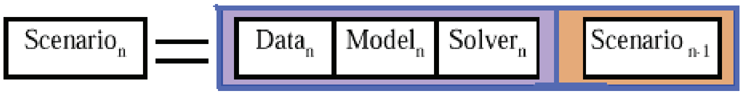
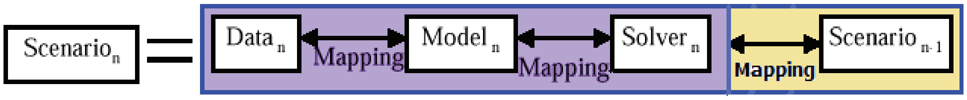


Figure 3. Loosely coupled scenario structure



- Aggregate Scenarios—This scenario is comprised of several other scenarios. The top level scenario can be broken down to low level scenarios or several low level scenarios can be added together to develop a top level scenario. The structures of different scenarios or results from multiple scenarios are combined together to develop an aggregate scenario.
- Pipelining Scenarios—One scenario is an input to another scenario in a hierarchical scenario structure. In this type of scenario, each constituent scenario will have independent existence but the lower-level scenarios may be tightly or loosely integrated with the higher-level scenario.

The decision maker may combine simple as well as complex scenarios together using pipelining and aggregation to develop more complex scenarios.

Scenario Organization

Scenario organization activities include making available already developed scenarios, storing, retrieving, deleting, and updating scenarios to and from a scenario pool. This scenario pool should support both temporary and permanent storage systems. The temporary storage, termed as a runtime pool, is used for managing scenarios during development, analysis and evaluation. The newly developed and retrieved scenarios are cached in the runtime pool for developing aggregate and/or pipelined scenarios. The scenario pool also permanently stores scenarios for future use or reference. Both the temporary and permanent storage systems are capable of storing the scenario structure, scenario instance and executed scenarios.

Scenario Development

Scenario planning and scenario development stages are inter-dependent and iterative. Scenario development is the process of conversion and representation of planned scenarios into fully computer based scenarios. Chermack (2003) argues that scenarios have rarely been applied to develop alternative processes. The proposed life cycle approach supports development of alternative process models and scenarios. In this stage, the decision maker organizes the related data, model, solver, and dependent scenarios for constituting the relationships among them to develop scenario(s). The decision maker could potentially use pre-customized and/or loosely coupled scenarios and may skip this step if they use previously developed scenarios. The scenarios are developed in mainly two steps. In step 1, the basic scenarios of the domain are developed, and in step 2, scenarios related to what-if (goal seek and sensitivity) analysis are developed.

Scenario Execution

The proposed scenario development process ensures that the scenario can be executed and analyzed for determining quality and plausibility. In this step, the models are instantiated with the data, and then the model instance is executed using the appropriate solver(s). Model selection is completely independent while one or more solvers may be used for a model execution. A flexible mapping process bridges the state attributes of the model and solver to engage in a relationship and to participate in the execution process. For a complex scenario, the decision maker may need to apply several models and solvers to analyze various aspects of the scenario. If a scenario contains other scenario instances, execution of the containing scenario will depend on the execution of the contained scenarios. But if the containing scenario contains the structure of the contained scenarios, the execution of the containing scenario depends on a series of model instantiation and model execution. This process may be pre-customized during the scenario development step or customized during the execution step. The decision makers can skip this step if they use only the previously stored scenario instances and executed scenarios from the scenario pool.

What-if Analysis

What-if analysis can be divided into two categories, namely sensitivity analysis and goal-seek analysis. Sensitivity analysis allows changing one or more parametric value(s) at a time and analyses the outcome of the change. It reveals the impact itself as well as the impact on other related scenarios. Because one scenario contains other scenarios, each and every change dynamically propagates to all the related scenarios. Goal-seek analysis accomplishes a particular task rather than analyzing the changing future. This goal seek analysis is just a reverse or feedback evaluation where the decision maker supplies the target output and gets the required input.

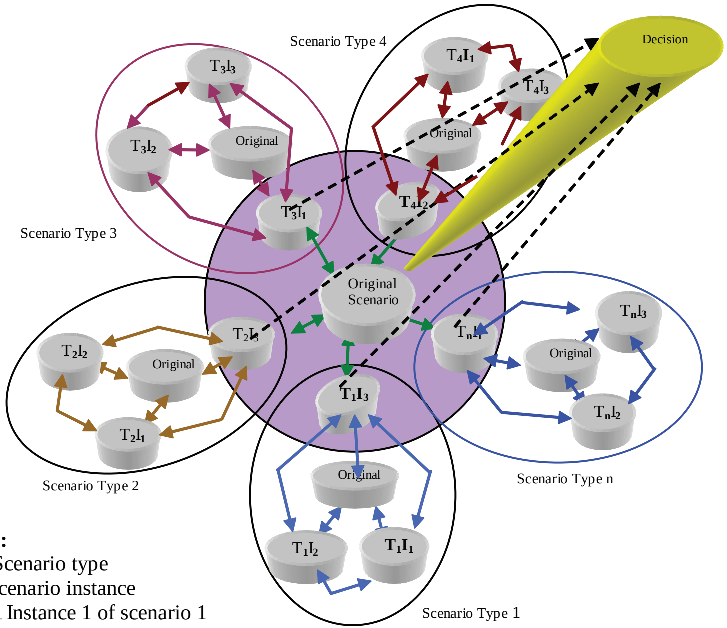
Scenario Evaluation Process

Scenario evaluation is a challenging task (Chermack, 2002) but some end-states are predetermined dependent upon the presence of an interaction of identified events (Wright, 2000), which can be used to devise an evaluation process. The decision maker could potentially develop many scenarios. The question is do all these scenarios represent a unique situation? Each scenario might appropriately draw the strategic question; represent fundamentally different issues; present a plausible future; and challenge conventional wisdom. Schwartz (1991) and Tucker (1999) discourage too many scenarios and advocate the use of best-case scenario, worst-case scenario and most-likely scenario. The evaluation is done through scenario execution and comparison of the executed results. A visualization object displays results of all the executed scenario instances either as a table or as a graph. This presentation helps comparing the computed inputs and outputs including other attributes. The comparison may take place among homogeneous scenarios or heterogeneous scenarios as shown in Figure 4. This two-phase comparison process is detailed in the following sections.

Homogeneous Comparison

Homogeneous scenarios are a similar type of scenario but the instances are quite distinct from one another. The decision maker selects a scenario instance on completion of each homogeneous scenario comparison. For example, in Figure 4, five outer ellipses represent five different scenarios while small ellipses, for example, $\mathbf{T_1I_1}$, $\mathbf{T_1I_2}$ and $\mathbf{T_1I_3}$ represent three instances of type 1 scenario

Figure 4. Scenario evaluation process



Note:
T – Scenario type
I – Scenario instance
T_1I_1 – Instance 1 of scenario 1
T_1I_2 – Instance 2 of scenario 1
T_2I_1 – Instance 1 of scenario 2
T_2I_2 – Instance 2 of scenario 2

and the ellipse containing **Original** represents the current instance of the type 1 scenario**.** The $\mathbf{T_1I_1}$, $\mathbf{T_1I_2}$, $\mathbf{T_1I_3}$ instances and the original instances are compared and the decision maker selects the most plausible scenario instance, which happens to be $\mathbf{T_1I_3}$ as shown in the Figure 4. If none of the instances are plausible, or do not have an optimal result, then the decision maker can go back to the idea generation step and repeat the whole process. From this homogeneous scenario comparison, the decision maker can select at least one scenario instance for each type of scenario. In Figure 4, the selected scenario instances are $\mathbf{T_2I_3}$, $\mathbf{T_3I_1}$, $\mathbf{T_4I_2}$, and $\mathbf{T_nI_1}$ for scenario type 2, 3, 4, and n respectively.

Heterogeneous Comparison

Heterogeneous scenarios are different types but inter-related scenarios as shown in the big middle circle in Figure 4. It is almost impractical to compare heterogeneous scenarios as the attributes of these scenarios could vary widely from one another. The decision maker can only compare them by presenting the executed scenario outputs using some common attributes. If the decision maker finds that a specific instance of the scenario is not suitable for heterogeneous comparison, then the decision maker can go back to the idea generation and repeat the whole process to identify a new instance for that scenario. This gives the decision maker an excellent picture of the entire decision problem and the probable solutions. For example, as shown in the Figure 4, instances of five scenarios i.e. T_1I_3, T_2I_3, T_3I_1, T_4I_2, and T_nI_1 have been compared with the instance of the current situation during heterogeneous comparison.

Decision Support

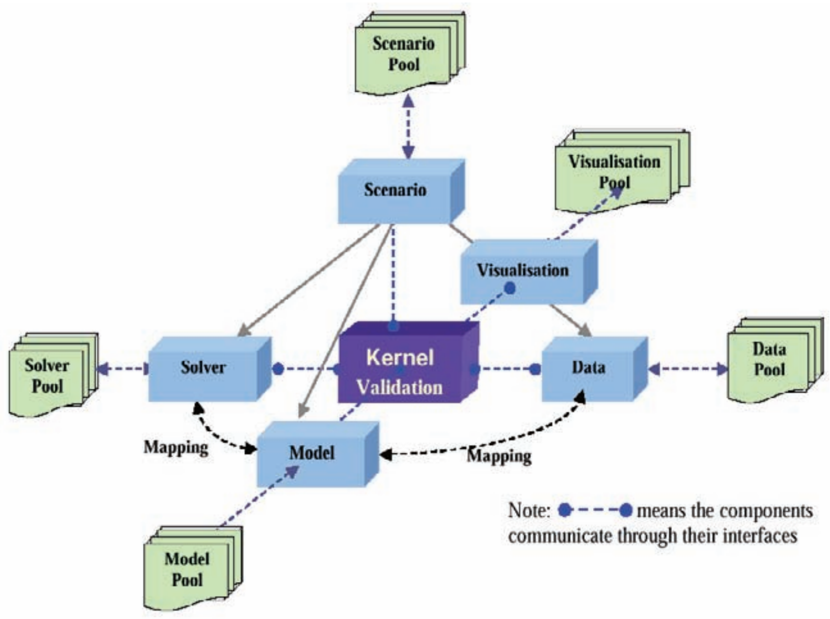
The previously described scenario planning, development, and evaluation through comparative analysis results in improved participant learning (De Geus, 1988; Godet, 2001; Shoemaker, 1995) and helps decision makers re-perceive reality from several points of view (Der Heijden et al., 2002) and thereby provides better support for decision making. The following section proposes a framework that realizes the proposed scenario management process.

SCENARIO DRIVEN FLEXIBLE DECISION SUPPORT SYSTEMS FRAMEWORK

Few of the DSS frameworks emphasize fully featured scenario planning, development, analysis, execution, evaluation and their usage for decision support. DSS components such as data, model, solver, and visualization have been extensively used in many DSS framework designs but they do not consider scenarios as a component of DSS. Scenario plays such an important role in the decision-making process that it is almost impractical to develop a good decision modeling environment while leaving out this component. While scenarios resemble model-driven DSS they are more complex than models and need to be considered as independent entities in an explicit fashion. Therefore, we propose that scenario-driven DSS should add the *scenario* as an independent component in addition to existing decision-support components. The scenario does not have a separate existence without its base components. Every scenario is built up from a unique problem (model) that can have a number of alternative unique instances (data) and each instance can be interpreted, executed or implemented using one or more alternative methods (solvers).

To overcome the problems and address the issues mentioned above we propose a scenario-driven decision support systems generator (SDSSG) framework as illustrated in Figure 5. The SDSSG components are separated into the following three categories:

Figure 5. Scenario-Driven Decision Support Systems Generator (SDSSG) Framework



Note: ●- - -● means the components communicate through their interfaces

- Decision-support components (DSC) that include the data, model, solver, scenario and visualization.
- Integration components (IC) that include kernel, component set, mapping, and validation component.
- Component pools that include data pool, model pool, solver pool, scenario pool, and visualization pool. Each component of the DSC has a direct relationship with a component pool.

In this framework, the DSCs, ICs and component pools are independent of each other. The DSCs communicate via the kernel component. The mapping component develops the correct path of communication between data and model, and model and solver, while the validation component tests the correct matching of the component interface and the proper communication between the components.

The data, model, solver, scenario, and visualization can be stored in different component pools as shown in Figure 5 and the framework allows retrieving these components from the component pools. The related model, data and solver can be combined together to develop a scenario. This scenario can be saved to the scenario pool for future use. This also allows using the scenario(s) as an input for developing a number of simple, aggregate, and pipelined scenarios. Every instance of the scenario can be termed as a specific decision support system. Therefore, the framework is a generator of scenarios as well as decision support systems.

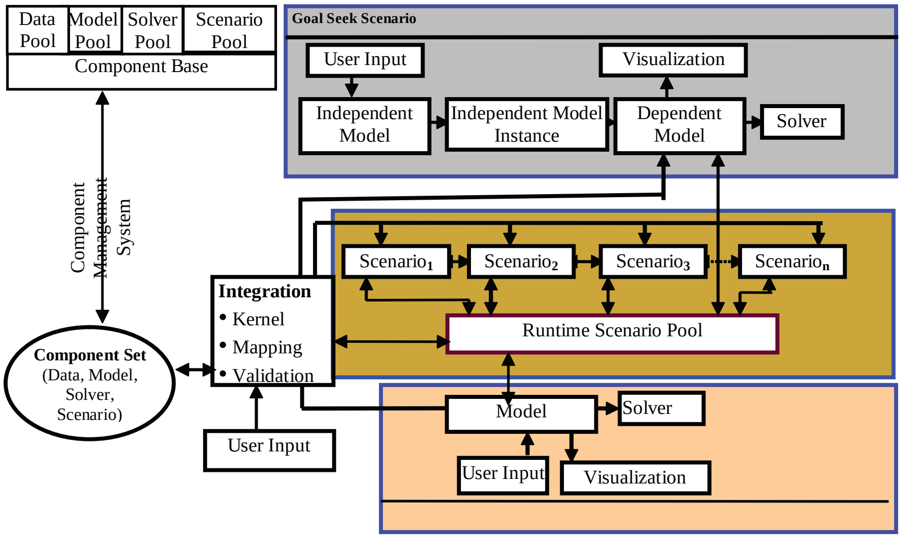
Scenario information can be saved and retrieved to and from the scenario pool and the same can again be customized using models and solvers. The scenario instances can be used as complex data for input to the next level model for further analysis. Different scenarios can be computed simultaneously and sensitivity and goal-seek analysis can be done. The framework is suitable for analyzing internally coherent scenarios or scenario bundles, and examining the joint consequences of changes in the environment for supporting the decision maker's strategy.

REALISATION OF THE SCENARIO MANAGEMENT PROCESS USING THE SDSSG FRAMEWORK

In this section we discuss and illustrate (Figure 6) the mechanisms through which the scenario management process is realized using the SDSSG framework. Specifically we discuss the means by which the framework supports all the life cycle phases of the proposed scenario management process. The key features of this framework are as follows:

- **Supporting idea generation:** Allows retrieving the required data, model, solver, and scenario from the respective pools. The decision maker develops a scenario that uniquely represents an instance of a scenario type through establishing the relationships among these retrieved scenario components. A problem can be represented by different models and various solvers may be used for their execution. Therefore it supports generation of multiple instances of a scenario through various combinations of constituent components.
- **Scenario planning*:*** Supports the planning of modeling-based scenario structure, pre-customized and loosely coupled scenarios.
- **Runtime scenario organization:** Incorporates a runtime only temporary storage system named runtime scenario pool (RSP) to store the completed scenarios. The completed scenario(s) can be pulled from the RSP to develop complex scenarios and this completed scenario can again be stored in the RSP.
- **Scenario storing and retrieving:** Allows saving, retrieving, updating or deleting the

Figure 6: Realisation of the Scenario Management Process using the SDSSG Framework



scenarios from the scenario pool using the data access component. The RSP is linked with the component set through the kernel and data components. This allows scenarios to be saved to the scenario pool.

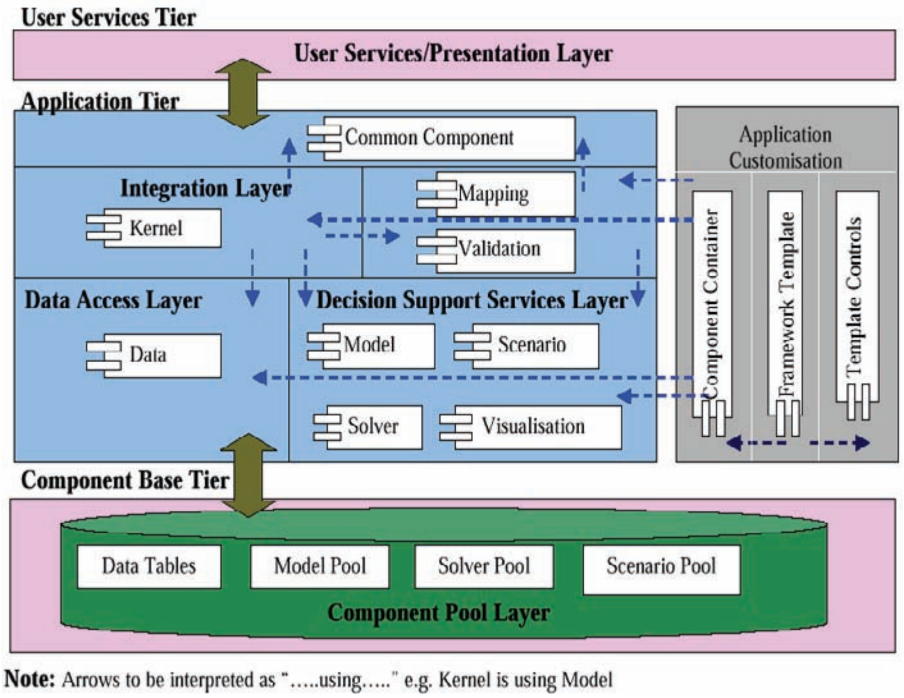
- **Scenario development:** The basic scenario is developed using building blocks such as data, model, solver, and previously executed scenarios. The sensitivity and goal-seek scenario analysis processes use original data sources, user input data regarding the changes of scenario parameter, dependent scenario values from the runtime scenario pool along with related sensitivity model(s) and solver(s) to represent and solve problems.
- **Development of aggregate and/or pipelined scenarios:** In a pre-customized pipelining system, scenarios are pre-defined as a chain from lower level to upper-level scenarios. The upper-level scenarios directly receive the executed value of the lower-level scenarios. But, in loosely coupled scenarios, a top-level scenario uses the values of the lower-level scenario from the runtime scenario pool.
- **Scenario selection:** The framework allows the user to select any scenario depending on the suitability and appropriateness of the scenario.
- **Scenario execution:** The framework facilitates instantiation of model with the data and execution of the instantiated model with appropriate solvers.
- **Scenario evaluation:** The framework supports evaluation of scenarios through visualizing the output of basic, sensitivity, and goal-seek scenarios in a comparison table or graphs.
- **Decision support:** The framework supports Simon's (1960) decision-making phases. These phases are comparable to scenario generation, analysis, comparison, and selection of plausible scenarios. Scenario analysis and evaluation using the comparison process increases the cognitive knowledge of users which in turn supports and leads them towards the final decision.

SDSSG ARCHITECTURE

In order to implement the SDSSG framework we develop a component-based layered architecture as shown in Figure 7 that is suitable for implementation as an n-tiered system. The proposed architecture is comprised of the user services tier, application tier, and component base tier; and the layers are user services, integration, data access, decision support services, application customization, and component pool. The component pool layer stores data, models, solvers, and scenarios. A relational database management system or XML documents can be used as a component layer. The data access layer provides components' management services such as addition, retrieval, update, and deletion of component information. The decision support services layer provides the services of DSS components namely, model, solver, scenario, and visualization. The integration layer provides integration, mapping and validation services through kernel, mapping, and validation components. The kernel arranges communication between data-model, model-solver and scenario-visualization using the mapping component for model instantiation, model execution, and scenario presentation respectively. It also uses the validation component to validate the proper communication and execution of the components. The common component facilitates creation of dynamic graphical user interfaces (GUI) and presentation layer depending on the decision maker's selection of data, model, solver, scenario, and visualization components at runtime. This GUI supports decision maker interactivity with the system for input, mapping, scenario development, execution, analysis, evaluation, and presentation activities.

The architecture also contains an application customization module, which contains component container, framework template, and template controls. This module facilitates customization of the SDSSG system with newer components. The Application Customization module works

Figure 7. SDSSG architecture



Note: Arrows to be interpreted as "…..using….." e.g. Kernel is using Model on top of the other architectural components for their customization. This framework template component is the medium of user interaction for customization of the system. Framework control component creates controls on the framework template for user interaction with the customization process of the system. The component container contains abstract components and interfaces of all the architectural components.

The architecture separates the decision-support components from the integration components. It supports independent development and use of the components, flexible scenario modeling, scenario manipulation and integration, flexible mapping between different DSS components, flexible integration of DSS components, and finally scenario analysis. Pre-customized and customizable modeling systems can be achieved through predefined relationships and the mapping components respectively. The mapping component facilitates dynamic communication between model-data, model-solver, and model-visualization pairs.

IMPLEMENTATION

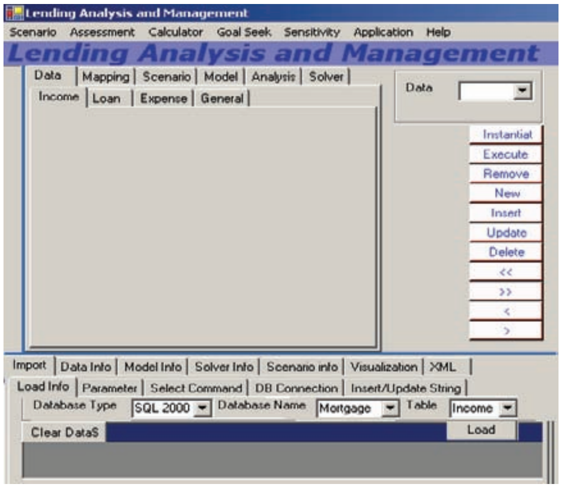
The SDSSG framework and architecture can be implemented using any platform that supports component-based development. Since object-orientation and componentization concepts are the central focus of the SDSSG framework and architecture, C# was used for implementing the SDSSG architecture that leverages Microsoft's .NET Framework. Relational database management systems (e.g., SQL 2000 Server, Microsoft Access) and extensible markup language (XML) were also used in building the system for managing data, model, solver, and scenario components.

Ringland (2002) explains that business case should be at the centre of the scenario planning. Therefore the SDSSG framework and architecture have been implemented within the context of the mortgage domain introduced in section 2.2. We implemented base scenarios e.g. affordability scenario, lending scenario (equal installment, reducing installment, interest only lending scenarios), payment scenario, and so forth. A user interface of the system is shown in Figure 8.

We explored a number of alternative scenarios including the best-case and worst-case scenarios through sensitivity analysis and evaluated the executed instances of homogeneous and heterogeneous scenarios through comparison. Within each of these scenarios we explored sensitivity and goal-seek analyses. The system compares multiple scenarios of similar type (homogeneous comparison as shown in figure 9) or different types (heterogeneous comparison as shown in figure 10) or both homogeneous and heterogeneous at a time in a single visualization.

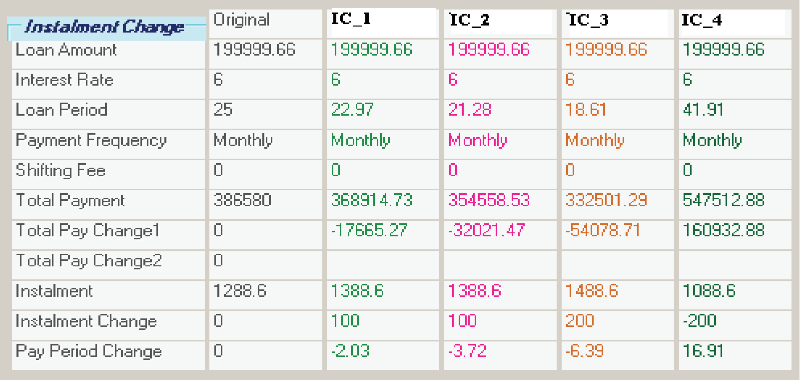
The system was tested and evaluated for sensitivity analysis for strategic management of the loan in future for scenarios of interest rate change (IRC), loan amount change (LAC), an on-off payment (IPC) at any time, installment change (IC), and loan period change (PPC). The loan payment scenario sensitivity for different instances of IC scenario is shown in Figure 9 for a $200,000 loan at the rate of 6 percent per annum. Figure 10 shows another example of the sensitivity analysis of the same loan for IRC, PPC, IC and IPC scenarios. Both the analyses

Figure 8. The SDSSG implementation in the mortgage domain



Database Type: SQL 2000
Database Name: Mortgage
Table: Income

Figure 9. Homogenous scenario comparison



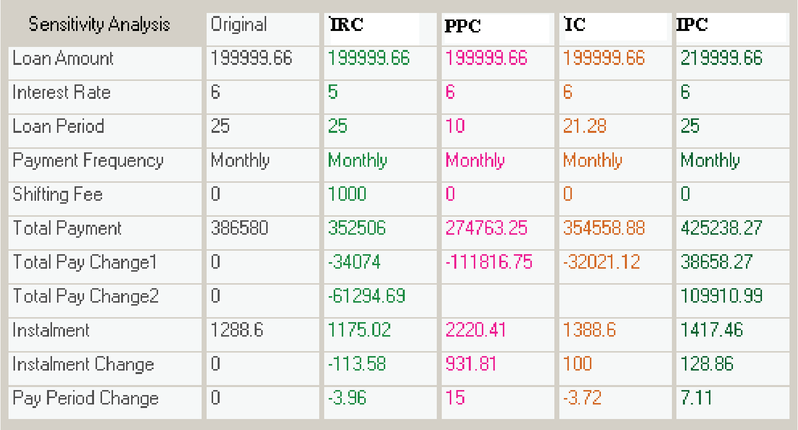
Instalment Change	Original	IC_1	IC_2	IC_3	IC_4
Loan Amount	199999.66	199999.66	199999.66	199999.66	199999.66
Interest Rate	6	6	6	6	6
Loan Period	25	22.97	21.28	18.61	41.91
Payment Frequency	Monthly	Monthly	Monthly	Monthly	Monthly
Shifting Fee	0	0	0	0	0
Total Payment	386580	368914.73	354558.53	332501.29	547512.88
Total Pay Change1	0	-17665.27	-32021.47	-54078.71	160932.88
Total Pay Change2	0				
Instalment	1288.6	1388.6	1388.6	1488.6	1088.6
Instalment Change	0	100	100	200	-200
Pay Period Change	0	-2.03	-3.72	-6.39	16.91

present the impact on the payment period, net savings/loss, and installment. PPC, IC, and IPC scenarios do not have any impact on IRC scenario as this is an external factor. Apart from this we also explored sensitivity analysis on complex interlinked scenarios which in turn were made up of sub-scenarios.

The system supports complex analyzes from very lower-level/simple scenarios to higher-level/aggregate scenarios. Scenarios analyzed bottom-up may or may not satisfy the prime objective. In this circumstance, a top-down scenario analysis (goal-seek analysis) could bring the optimum acceptable scenarios that would satisfy the objective. The prototype supports different level of users (Sprague, 1980) and various levels of customization and abstraction. In order to minimize the trade-off between versatility and usability (Matheus, Chan, & Piatesky-Shapiro, 1993), SDSSG enables the decision maker to use both customizable generic systems and pre-customized and packaged scenarios for a particular use. A DSS builder configures the SDSSG system to develop purpose-built very specific and effective DSS and stores them for use by decision makers. Due to the nature of dynamic user interface and visualization, this specific DSS is easy to use for the intended purpose.

We used eight different categories of evaluation criteria namely: scenario management, scenario analysis and development, scenario evaluation, appropriateness of scenarios, com-

Figure 10. Heterogeneous scenario comparison



Sensitivity Analysis	Original	IRC	PPC	IC	IPC
Loan Amount	199999.66	199999.66	199999.66	199999.66	219999.66
Interest Rate	6	5	6	6	6
Loan Period	25	25	10	21.28	25
Payment Frequency	Monthly	Monthly	Monthly	Monthly	Monthly
Shifting Fee	0	1000	0	0	0
Total Payment	386580	352506	274763.25	354558.88	425238.27
Total Pay Change1	0	-34074	-111816.75	-32021.12	38658.27
Total Pay Change2	0	-61294.69			109910.99
Instalment	1288.6	1175.02	2220.41	1388.6	1417.46
Instalment Change	0	-113.58	931.81	100	128.86
Pay Period Change	0	-3.96	15	-3.72	7.11

putational performance, functionality, usability, and ancillary task support for evaluation of the SDSSG framework and architecture, and various processes. The principles proposed by Geoffrion (1987), Ramirez, Ching, and St. Louis (1990), and Collier et al. (1999) namely, ease of model selection, algorithmic variety, flexible visualization, management of components, data-model independence, model-solver independence, data-visualization independence, mapping, reusability, domain independence, extensibility, model abstraction levels, purpose independence, model instantiation, model termination, model execution, and model version support were applied for critical evaluation and validation of the SDSSG framework and architecture. The quality and appropriateness of the scenarios were evaluated based on the appropriateness, usability, uniqueness, variety, and quality as prescribed by Schoemaker (1995). The evaluation criteria were extended to assess various processes such as scenario management, scenario planning, scenario development, scenario analysis, scenario evaluation, and mapping between components. The scenario management process was evaluated using the life cycle stages of scenarios namely idea generation, scenario analysis and management, scenario development, scenario storage and retrieval, runtime scenario management, scenario execution, and scenario evaluation. Scenario planning, development and analysis processes were evaluated using principles of scenario structuring (simple scenario, simple pipelining scenario, complex scenario, complex pipelining scenario), provision of runtime scenario pools, ability to conduct sensitivity and goal-seek analysis, ease of scenario generation, and the tightness and flexibility of coupling of components. Scenario evaluation sub-processes were evaluated based on the ability to compare multiple instances of a scenario and instances of multiple scenarios, ease of scenario comparison and use, support for decision making, and organizational learning. In addition to the above mentioned processes, the observations of various conference review groups (e.g., Ahmed & Sundaram, 2005) have also been incorporated during finalization of the framework and architecture, and scenario life cycle processes.

The structure of many of the models and solvers that we used are domain independent and they can be used in any applicable domain. Specialized scenarios are more oriented towards the domain to represent the problem domain. These types of models and their relevant solvers are sometimes domain dependent. We have extensively explored the use of the system in the context of the mortgage domain but due to its generic nature the concept, models, and solvers explored are equally applicable to other domains where ‘what-if’ analysis, goal-seek and iterative problem solving/search is of importance. The current SDSSG system allows minor versioning of the components without any impact on the kernel; however a major change in the paradigm could necessitate a change to the public interface of the components which in turn may require modification of the kernel component.

CONCLUSION

Current scenario planning and analysis systems are very complex, not user friendly, and do not support modeling and evaluation of multiple scenarios simultaneously. To overcome these problems we propose a scenario management life cycle, and a framework and architecture that support the lifecycle. The lifecycle as well as the framework and architecture are validated through a concrete implementation of a prototype.

This research introduces the concepts of scenario structure and their development strategy. It decomposes large complex scenarios into multiple small and executable scenarios and uses the decomposition and re-composition methodology for defining the scenario structure. The research also proposes a life cycle approach for scenario management that supports a range of activities from conceptualizing and understanding the scenario to final use of the scenario for decision making. Key phases of the life cycle are idea generation, scenario planning, organization, development, execution, analysis, evaluation, and finally decision support. The process hides external factors and complexities of the scenario and allows the seamless combination of decision parameters for appropriate scenario generation. We also propose a generalized scenario evaluation process to enable the decision maker in finding appropriate and plausible scenarios through homogeneous and heterogeneous scenario comparisons among the multiple instances of similar and dissimilar scenarios respectively.

The research further realizes the scenario-driven decision-making processes through extending model-driven decision support systems. We develop a generic scenario driven flexible decision support systems generator framework and architecture that supports the above-mentioned scenario management processes as well as sensitivity and goal-seek analysis. Scenarios are introduced as a new DSS component alongside the traditional data, model, solver, and visualization components.

The proposed framework and architecture are domain independent, platform independent, component-based and modular. The architecture is comprised of multiple layers, namely component pool layer, data access layer, decision support services layer, integration layer, and user services layer. Each layer performs specific functions, which are suitable for implementation of the architecture as an n-tiered system. The implemented system supports customization for developing semi-automated, pre-customized, and specific DSS.

FURTHER RESEARCH AND IMPLEMENTATION

The generalizability of these concepts, frameworks, and architectures has been proved in other domains and other paradigms. For instance, Ahmed and Sundaram (2007) have applied these principles for developing a generic DSS framework and architecture for sustainability modeling and reporting. The concept of this framework, architecture and scenario management processes can be applied to the decision making components of existing enterprise systems such as SAP and Oracle. Future research could explore the applicability of our concepts, frameworks, and architectures to other domains and paradigms as well as their use in conjunction with existing transaction processing, analytical, and strategic information systems.

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Chapter 2.17

An Approach of Decision-Making Support Based on Collaborative Agents for Unexpected Rush Orders Management

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ABSTRACT

Decisions at different levels of the supply chain can no longer be considered independently, since they may influence profitability throughout the supply chain. This paper focuses on the interest of multi-agent paradigm for the collaborative coordination in global distribution supply chain. Multi-agent computational environments are suitable for a broad class of coordination and negotiation issues involving multiple autonomous or semiautonomous problem solving contexts. An agent-based distributed architecture is proposed for better management of rush unexpected orders. This paper proposes a first architecture validated by a real and industrial case. [Article copies are available for purchase from InfoSci-on-Demand.com]

INTRODUCTION

The Supply Chain (SC) is increasingly interest for many business enterprises and a challenge for logistics management in the 21st century. Supply chain is defined as the chain linking each entity of the manufacturing and supply process from raw materials through to the end user (New and Payne, 1995). A supply chain comprises many systems, including various manufacturing, storage, transportation, and retail systems (Han et al., 2002). Supply Chain Management (SCM) has commanded attention and support from the industrial community. It consists in the coordination of production, inventory, location, and transportation among the participants in a supply chain to achieve the best mix of responsiveness and efficiency for the market being served (Hugos, 2003). The optimal deployment of inventory is one of the principal goals of SCM. Indeed, Many collaborative processes (e.g. CPFR: Collaborative Planning, Forecasting and Replenishment (VICS Association, 2007), VMI: Vendor Managed Inventory (John Taras CPIM, 2007), CRP: Continuous Replenishment Program and ECR: Efficient Consumer Response (ECR, 2006) and software systems (e.g. APS: Advanced Planning Systems (Simchi-Levi et al., 2000), ERP: Enterprise Resource Planning (Baglin et al., 2001) are used for management and control of inventory in order to reduce the total system cost of inventory as much as possible while still maintaining the service levels that customers require. Literature shows that the common objectives of these practices is to avoid the surplus inventory, reduce the inventory shortage, minimize the safety stock, produce and deliver products in the right quantities and at the right time. However for the distributor centers, it is difficult to achieve this goal, because the rush unexpected orders placed by the wholesalers always present a challenge. This challenge will vary from one company to another and from one supply chain to another. In fact, the distributor can not predict the date and the ordered quantity of this type of orders since it is a random one whose causes are multiple and depend closely on the branch of industry. In addition, this type of orders has a very short delivery date. In this emergency case, the distributor is not able to wait for the next planned delivery of products from the supplier. Therefore, generally the order can be cancelled or can cause an inventory shortage if the ordered quantity is large. This will have a bad impact on the quality of the offered service within the satisfaction of the final customer policy.

Some suppliers allocate an additional human resources and logistics for delivering the rush unexpected orders of their distributors. The disadvantage of this solution is that the costs suggested are generally very high.

In multi-echelon networks, which is a common distribution model for many distributors and manufacturers, the distributors can deliver the rush unexpected orders. The echelon inventory includes the sum of local stock and the stock of all the forward distribution centers (Siala et al., 2006). However, multi-echelon inventory management is more coherent to the centralized decisions and it requires that all locations must be submitted to the relevant control of a single enterprise. In addition, it requires a high degree of information sharing between the various actors of the SC, but if the supply chain consists in independent enterprises, information sharing becomes a critical obstacle, since each independent actor is typically not willing to share with the other nodes its own strategic data (as inventory levels). Also, it monitors his inventory levels (by using autonomous action and policies) and places the orders to its suppliers in order to optimize its own objective (Siala et al., 2006).

This paper focuses on unexpected swings in demand and on unexpected exceptions (problem of production, problem of transportation, etc.), which are important coordination and communication issues in SC management (Giannoccaro et al., 2003) (Zhao et al., 2002). Both events can engender the presence of a rush unexpected orders in a node of supply chain; in particular, at the wholesalers and the distribution centers levels. In this context, we propose a collaborative process which presents an effective solution (to the distributors) for better management of the rush unexpected orders for which the quantity of product cannot be delivered partially or completely from the available inventory. This process includes the distributors of the same or equivalent products and their wholesalers. The participants in the process can be competitors. To implement the process, we apply an agent-based distributed architecture in order to guarantee the autonomy and the strategic data confidentiality of all participants. Agent technology provides to the distributed environment a great promise of effective communication (Swaminathan et al., 1998). An agent is a program that performs a specific task intelligently without any human supervision and can communicate with other agents cooperatively. Therefore, agent technology is suitable to solve communication concerns for a distributed environment. Recent researches also show that the multi-agent approach plays a significant role in supply chain management, for example (Kimbrough et al., 2002), (Wu, 2001) and (Swaminathan et al., 1998).

This paper is organized as follows; in Section 2, the literature on supply chain coordination and agent technology is reviewed; in Section 3, the rush unexpected order is presented. The collaborative process and system architecture are proposed in Section 4. In Section 5, a set of negotiation protocols are presented and modeled within UML sequence diagrams. A case study is presented in Section 6 to validate the proposed architecture. Section 7 concludes the paper.

BACKGROUND REVIEW

To improve the supply chain's performance under demand uncertainty and exceptions, various levels of collaboration techniques based on information sharing were set up in real supply chains. These techniques are essentially, VMI, CRP and CPFR. VMI and CRP are very similar, but are used in different industries. The idea is that retailers do not need to place orders because wholesalers use information centralization to decide when to replenish them. Although these techniques could be extended to a whole supply chain, current implementations only work between two business partners. In fact, many customers are attracted to these techniques, because they mitigate uncertainty of demand. Moreover, the frequency of replenishment is usually increased every month or every week (or even daily), and from which both partners benefit. CPFR is a standard that enhances VMI and CRP by incorporating joint forecasting. Like VMI and CRP, current implementations of CPFR include only two levels of a supply chain, i.e., retailers and their wholesalers. With CPFR, companies electronically exchange a series of written comments and supporting data, which includes past sales trends, scheduled promotions, and forecasts. This allows participants to coordinate joint forecasting by focusing on differences in forecasts. Companies try to find the cause of such differences and agree on joint in order to improve forecasts.

In the literature, various researches to compensate for the uncertainty that exists in a supply chain have been reported. Cohen and Lee (Cohen and Lee, 1988) have developed a planning model to optimize material supply, production and distribution processes. Arntzen et al. (1995) have proposed a resource allocation and planning model for global production and distribution networks. Kimbrough et al. (2002), McBurney et al. (2002), Chen et al. (2000) focused on demand forecasting. Most of these researches suppose that companies in the supply chain share the information and coordinate the orders. But if the supply chain consists of autonomous enterprises, sharing information becomes a critical obstacle, since each independent actor typically is not willing to share with the other nodes its own strategic data (as inventory levels) (Terzi and Cavalieri, 2004); An example is the case of several competitor wholesalers (located in the same or different geographical areas) which source of the same distributor.

Various projects applied the multi-agent system paradigm to solve different problems in Supply Chain (as inventory planning, demand and sales planning, distribution and transportation planning, etc). DragonChain was implemented by Kimbrough et al. (2002) at the University of Pennsylvania (Philadelphia, PA, USA) to simulate supply chain management, and more particularly to reduce bullwhip effect. For that, they base their simulation on two versions of the Beer Game, the MIT beer game (i.e. the original game) and the Columbia Beer Game, and they use agents that look for the best ordering scheme with genetic algorithms. Maturana et al. (1999) have developed a hybrid agent-based mediator-centric architecture, called MetaMorph, to integrate partners, suppliers and customers dynamically with the main enterprise through their respective mediators within a supply chain network via the Internet and Intranets. In MetaMorph, agents can be used to represent manufacturing resources (machines, tools, etc.) and parts, to encapsulate existing software systems and to function as system or subsystem coordinators/mediators. Swaminathan et al. (1998) have proposed a multi-agent approach to model supply chain dynamics. In their approach, a supply chain library of software components, such as retailers, manufacturers, inventory policy, and so on, has been developed to build customized supply chain models from the library. Sadeh et al. (2001) have developed an agent-based architecture for a dynamic supply chain called MASCOT. The MASCOT is a reconfigurable, multilevel, agent-based architecture for a coordinated supply chain. Agents in MASCOT serve as wrappers for planning and scheduling modules. Petersen et al. (2001) have proposed a multi-agent architecture, called AGORA, for modeling and supporting cooperative work among distributed entities in virtual enterprises. We have already proposed (Nfaoui et al., 2006) an agent-based distributed architecture of simulation in decision-making process within the supply chain context. Agents in this architecture use a set of negotiation protocols (such as Firm Heuristic Negotiation, Recursive Heuristic Negotiation, CPFR Negotiation Protocol) to make decisions collectively in a short time. Chehbi et al. (2003) have proposed multi-agent supply chain architecture to optimize distributed decision making.

THE RUSH UNEXPECTED ORDER AND SAFETY INVENTORY

Safety inventory is necessary to compensate for the uncertainty that exists in a supply chain. Retailers and distributors do not want to run out of inventory in the face of unexpected customer demand or unexpected delay in receiving replenishment orders so they keep safety stock on hand. As a rule, the higher the level of uncertainty is, the higher the level of safety stock is required.

Safety inventory for an item can be defined as the amount of inventory on hand for an item when the next replenishment EOQ (the Economic Order Quantity) lot arrives. This means that the safety stock is inventory that does not turn over. In effect, it becomes a fixed asset and it drives up the cost of carrying inventory. Companies need to find a balance between their desire to carry a wide range of products and offer high availability on all of them and their conflicting desire to keep the cost of inventory as low as possible. That balance is reflected quite literally in the amount of safety stock that a company carries.

In practice, the safety stock is not enough to cover all types of unexpected swings in demand and the unexpected exceptions. As an example, the case of a customer (retailer, wholesalers, etc) who contacts his supplier (distributor) and asks for a product quantity as an immediate request, and the supplier discovers that his safety stock is lower than the ordered quantity at that moment. If this happens after the item has been logged in as a confirmed order, will the supplier be able to respond within a suitable timeframe to the customer?

We propose hereafter an agent-based distributed architecture to solve this problem of rush unexpected orders. The rush unexpected order is an object which is characterized by two attributes, the ordered quantity and the short delivery time. Multiple causes of rush unexpected order exist, they closely depend on the branch of supply chain sector. For distributors, the main interest got from such rush unexpected order delivery depends on the customer's profile and other additional criteria such as:

- It allows interesting benefit;
- The distributor does not look for benefit, but he only interests to attract and retain the customer. It is the case for a wholesaler strategic customer for example.
- It helps increasing the number of customers. It is the case of a wholesaler who is a customer of another distributor or a regular customer who is in hurry, which will appreciate the offered service and may become a new customer.

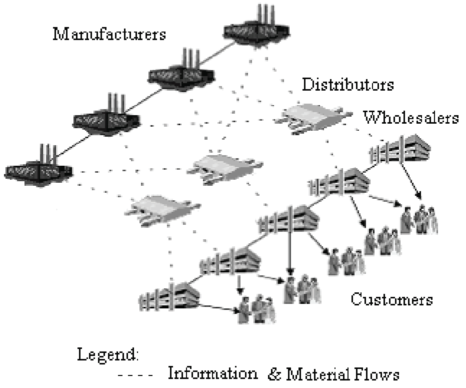
AGENT BASED APPROACH

In this section, the agent-based approach is presented, the multi-agent system architecture is described and different agents, as well as their specific roles, are defined.

Main Idea

Figure 1 shows the typical structure of a global distribution supply chain. Systems that are defined as distribution systems can be of important varying structure. Nonetheless, such systems need to contain a number of common properties. A distribution system needs to include one or more customers who are defined by having a demand on a given product. In addition, the system needs to include one or more sources, which are defined by producing or containing the product demanded by the customer(s). Finally, the system needs a connection between the source(s) and customer(s), which can accommodate a flow of the product from the source(s) to the customer(s) in order to obtain fulfilment of the demand.

Figure 1. Overview of a global distribution supply chain



Let us suppose that a wholesaler or a particular customer had placed a rush unexpected order which is characterized by two attributes:

- The ordered quantity OQ which cannot be delivered partially or completely from the distributor's available inventory;
- The delivery time DT.

Two cases are then possible:

a. The distributor does not have any part of the ordered quantity OQ;
b. It has a part of the ordered quantity and must complete the rest.

In both situations:

$$OQ = DisQ + RQ$$

Where DisQ: available quantity which can be delivered by the distributor. Two situations are possible: DisQ = 0 (a) or DisQ < OQ (b).

RQ: required quantity which must be looked for.The problem can be then summarized as follows:

Find the required quantity RQ in order to deliver the rush unexpected order while respecting the delivery time DT.

One of the practices of the distributors (see other solutions in introduction) consists of seeking the required quantity from another wholesaler or distributor. In general, the distributor will be limited to some close and faithful wholesalers or to distributors of the same company. This shows that the chosen solution (if it is found) can not be the best. Moreover, it takes enough time since the negotiation is carried out generally by phone. Within the context of SCM, we propose to extend this practice by involving (into collaboration) several wholesalers, same products distributors and equivalent products distributors. So, the distributor will be supplied from three different actors:

- 1st type (distributor and its wholesalers)
    - Wholesalers belonging to the same area as the customer;
    - Wholesalers belonging to different areas from the customer;
    - Both cases above.
- 2nd type (distributor/same products distributors)
    - The same products distributors and/or their wholesalers.
- 3rd type (distributor/equivalent products distributors)
    - The equivalent product distributors and/or their wholesalers.
- 4th type
    - Hybrid Solution: two or three types at the same time.

In practice, to implement this process in the industrial cases, and in order to satisfy the distributors' needs, three conditions must be checked:

- Quick and automatic solution. The manager contacts the collaborative participants only to confirm the solution.
- Autonomy and data confidentiality of each participant must be guaranteed since they can be independent.
- Transportation costs should be minimized, which will be added to the basic high purchase price since the products will not be delivered directly by the distributor.

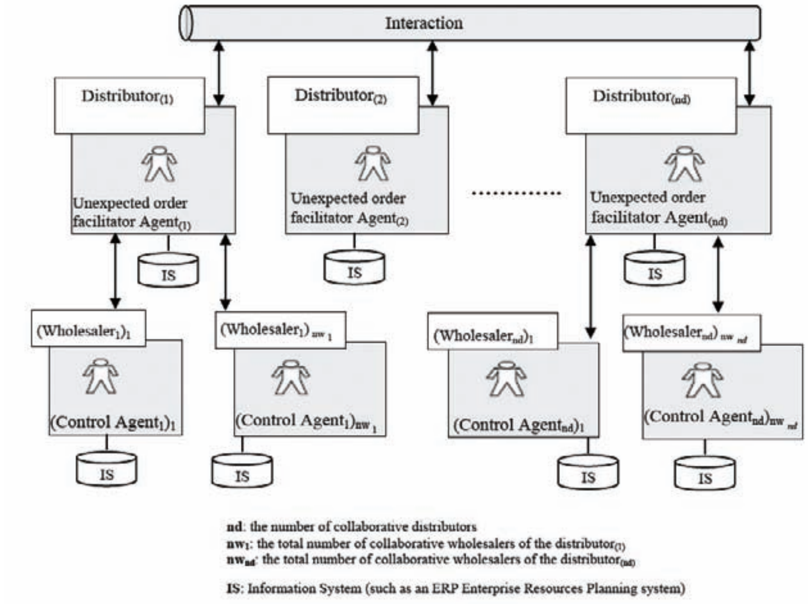
As shown in the background review (section 2), the agent technology is more suitable for this type of problem. In this respect, we propose in the section below an agent-based distributed architecture which implements this process.

Agent-Based Solution Approach

The proposed system does not substitute the existing tools and the SCM strategies and practices, but it can be used as a complement which improves them in the case of the presence of a rush unexpected order. The system architecture is shown in Figure 2.

The main purpose of this system is to coordinate all collaborative participants in order to find the OQ quantity and minimize total cost of transportation when a rush unexpected order is presented. The complete architecture includes two types of agents: control agents "*WhoAgent*" for wholesalers and the unexpected order facilitator agents "*DisAgent*" for distributors. Each distributor is modeled by a $DisAgent_i$ (where i ∈ [1, nd] and *nd* is the number of collaborative distributors) and each wholesaler is modeled by a $(WhoAgent_i)_j$ (where j ∈ [1, nw_i] and nw_i is the total number of collaborative wholesalers of the distributor$_{(i)}$). These coordinated agents have the ability to specify both static and dynamic characteristics of various supply chain entities (Lee, 1997);

Figure 2. System architecture



in particular, the level of distributors and their wholesalers.

The control agent plays a liaison role between a supply chain manager and the system. It collects strategies from managers, seeks the accurate data and aims at building a rule-base for better coordination and better decision-making process. When an unexpected order facilitator agent $DisAgent_i$ asks a control agent $(WhoAgent_i)_j$ (where $j \in [1, nw_i]$ and nw_i is the total number of collaborative wholesalers of the distributor$_{(i)}$) for possible quantity of product that it can deliver, control agent $(WhoAgent_i)_j$ sends information about possible quantity and costs, and transportation costs. The agent system is autonomous because it allows any manager to change strategies of that node. Also, it allows overcoming the hurdle which consists of need for sharing sensitive information of participants in the SC, because the agents do not exchange information about inventory levels and strategies. In real world coordination, sharing information truthfully is problematic since intra-organizational trust cannot be easily developed. Next, if the collaborative participants (wholesalers and their distributors) are independent and operate within the same sector (same or equivalent products); information sharing becomes a critical obstacle, since each independent wholesaler/distributor is typically not willing to share with the other nodes its own strategic data (as inventory level for example). On the real global distribution cases, and especially in the same distribution sector, it is easy to implement the interaction between a distributor and its wholesalers. However, it is difficult, even impossible, to implement it between a distributor and the wholesalers of another distributor. Indeed, the participants are confronted to the increasing impact of competitive pressures. Also, each distributor tries to increase the number of its customers. To represent the real global distribution cases, each agent $DisAgent_i$ can interact with other agents $\{DisAgent_k / k \in [1, nd], k \neq i\}$ and control agents $\{(WhoAgent_i)_j / j \in [1, nw_i]\}$, but a control agent can interact only with its distributor agents.

The unexpected order facilitator agent $DisAgent_i$, which communicates with control agents and other unexpected order facilitator agents, plays the same role of control agent. In addition, it provides the best solution of solving the rush unexpected order, which tries to minimize the total transportation costs. When a rush unexpected order (which characterized by: OQ and DT) is presented at the distributor$_{(i)}$, the manager asks the unexpected order facilitator agent $DisAgent_i$ to search the best solutions. At this moment, the agent carries out the algorithm "search_OQ" for solving the problem which can be summarized as follows:

- Search the RQ: it can be delivered completely by only one wholesaler or gathered from several wholesalers (1st type).
- Find and classify a series of possible paths in an ascending order depending on transportation cost (which depends closely on the distance) to transport OQ while respecting the delivery time DT.
- Propose quantity Q_j to be supplied by each participant belonging to a path.

Algorithm Search_OQ Constants'

- ($d_{k,j}$) distances (D matrix) and ($t_{k,j}$) times (T matrix) between wholesalers (where $1 \leq k,j \leq nw_i$ and nw_i is the total number of collaborative wholesalers of the distributor$_{(i)}$). (See Boxes 1 and 2.)

- (dd_j) distances (DD matrix) and (td_j) times (TD matrix) between distributor$_{(i)}$ and its wholesalers.

$$\mathrm{DD} \ = \ (\mathrm{ddj}) \ = (dd_1 \quad dd_2 \quad \ldots \quad dd_{nw_i})$$

$$TD(tdj) = td_1 \quad td_2 \quad \ldots \quad td_{nw_i}$$

- The Minimal quantities ($qm_{k,j}$) (QM matrix) of product which can be transported in the segments connecting the wholesalers (see Box 3).
- The Minimal quantities (qmd_j) (QMD matrix) of product which can be transported in the segments connecting the distributor$_{(i)}$ and its wholesalers.

Box 1.

$$\mathrm{D} \ = \ (\mathrm{dk,j}) \ = \begin{bmatrix} 0 & d_{1,2} & d_{1,3} & .... & d_{1,\mathrm{nw_i}} \\ d_{2,1} & 0 & & & \\ . & & 0 & & \\ . & & & 0 & \\ d_{\mathrm{nw_i},1} & & & & 0 \end{bmatrix}$$

Box 2.

$$\mathrm{T} \ = \ (\mathrm{tk,j}) \ = \begin{bmatrix} 0 & t_{1,2} & t_{1,3} & .... & t_{1,\mathrm{nw_i}} \\ t_{2,1} & 0 & & & \\ . & & 0 & & \\ . & & & 0 & \\ t_{\mathrm{nw_i},1} & & & & 0 \end{bmatrix}$$

Box 3.

$$QM = (qmk,j) = \begin{bmatrix} 0 & qm_{1,2} & qm_{1,3} & .... & qm_{1,nw_i} \\ qm_{2,1} & 0 & & & \\ . & & 0 & & \\ . & & & 0 & \\ qm_{nw_i,1} & & & & 0 \end{bmatrix}$$

$$QMD = (qmd_j) = (qmd_1 \text{ and } qmd_2 ... qmd_{nw_i})$$

- (ccp_j) coefficients of collaborative proximity (trust, levels of seniority,…) of each $(\text{wholesaler}_i)_j$ towards the $\text{distributor}_{(i)}$:

$$CCP = (ccp_j) = (ccp_1 \quad ccp_2 \quad ... \quad ccp_{nw_i})$$

```
Begin
// determine the customer's place
If (the customer is a collaborative wholesaler) Then
Its distances are defined (D, DD, T and TD matrices)
Else
Use the distances of the wholesaler nearest to the customer
End If
Read DT // the Delivery Time
Read OQ // the Ordered Quantity
Read DisQ // the available quantity which can be delivered by the distributor$_{(i)}$
RQ = OQ – DisQ // Deduce the Required Quantity
```

Send a message of performative *QUERY-REF* to control agents $\{(WhoAgent_i)_j \,/\, j \in [1, nw_i]\}$ (nw_i is the total number of collaborative wholesalers of the $\text{distributor}_{(i)}$) to ask them for its maximum quantities of product which they can deliver. The agents use the FIPA-ACL language (FIPA, 2002) for communication. QUERY-REF is the act of asking another agent to inform the requester of the object identified by a descriptor. Each control agent $(WhoAgent_i)_j$ replies by a message of performative *INFORM* indicating the maximum quantity $Qmax_j$ which can deliver (or a message of performative *REFUSE* in case of rejection).

```
Construct an empty list LWC // the list of wholesalers candidates
Do //loop 1
Do //loop 2
Read N // N is the maximum number of wholesalers including in a path. $N \in [1, nw_i]$.
Determine the list LWC of wholesalers candidates: $\{(WhoAgent_i)_j \,/\, j \in [1,t] \text{ and } t \le nw_i\}$.

/* If (N=1) then: $(WhoAgent_i)_j$ is candidate if it satisfies the constraint below :
    $Qmax_j \ge RQ$
If (N≥2): $(WhoAgent_i)_j$ is candidate if there exists at least N-1 $(WhoAgent_i)_{k \neq j}$ which belong to LWC and satisfy the constraints below :
-   (The sum of the quantity $Qmax_j$ and quantities $Qmax_k$) $\ge RQ$
-   $Qmax_j < RQ$
-   Each $Qmax_k$ is less than $RQ$
*/
While ((LWC is empty) AND ($N < Nu$)) // Nu is the unacceptable value of N. Nu depends on RQ.
//End loop 2
If ($N \ge Nu$) // the unacceptable value of N is reached
Then
```

```
Break and start a new research in same products
      distributors or equivalent products distributors (2nd type, 3rd type or 4th type).
End If
   Construct an empty list LPP // the list of possible paths
```

At this step, the agent must found a list *LPP* of possible paths and order it by transportation costs (in case of close solutions, the manager will use the coefficients of collaborative proximity (CCP_j)). It must also propose the quantity Q_j ($Q_j \in [Qmin_j, Qmax_j]$) for each wholesaler belonging to a path. A possible path is characterized by:

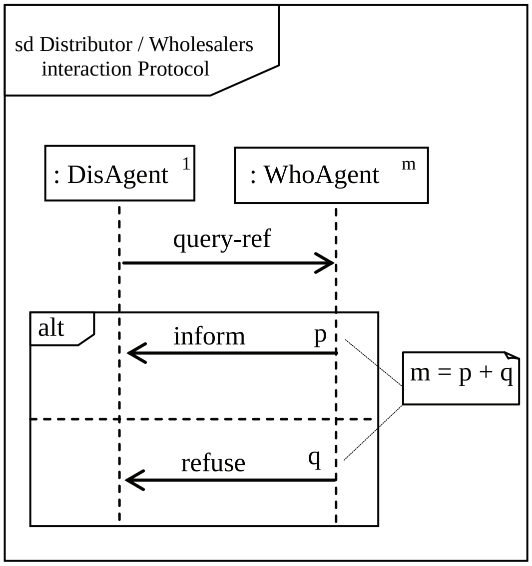
- Starting point ;
- Destination point (customer) ;
- It includes *N* wholesalers. Each wholesaler belongs to the list *LWC* and can deliver Q_j.
- It must satisfy the constraints below :

```
  If (the distributor$_{(i)}$ is included in the path)
      Then
    -   The sum of the quantity DisQ and quantities $Q_j$ must be equal to OQ.
    -   The time of path (TP) must be less or equal to the delivery time (DT).
  Else
    -   The sum of the quantities $Q_j$ must be equal to OQ.
    -   The time of path (TP) must be less or equal to the delivery time (DT).
  End If
  While ((the list LPP is empty) AND ($N < Nu$))
  // End loop 1
  If ($N \geq Nu$) // the unacceptable value of N is reached
  Then
  Break and start a new research in same products distributors or equivalent products distributors (2nd type, 3rd type or 4th type).
  End If
End //algorithm Search_OQ
```

Figure 3 shows the UML (Unified Modeling Language) sequence diagram (Bauer and Odell, 2005) that expresses the exchange of messages through the interaction protocol between the unexpected order facilitator agent $DisAgent_i$ and the control agents $\{(WhoAgent_i)_j \ / \ j \in [1, nw_i] \}$. These agents use other negotiation protocols (cf. section 5).

If no solutions are found (whenever an unacceptable value of *N* is reached) or the manager is not satisfied by the proposed solutions, the agent can interact with the unexpected order facilitator agents $\{DisAgent_k \ / \ k \in [1, nd], k \neq i\}$ of other distributors in order to find the best solution. In this case, the agent $DisAgent_i$ sends a message of performative *QUERY-REF* to all the collaborative unexpected order facilitator agents to find the *RQ*. Each agent applies his decision-making process in order to deliver the *RQ*. They can interact if necessary with the control agents to get the best solution. At the end, the unexpected order facilitator agent $DisAgent_i$ sorts all the received solutions. Figure 4

Figure 3. Distributor/wholesalers interaction protocol

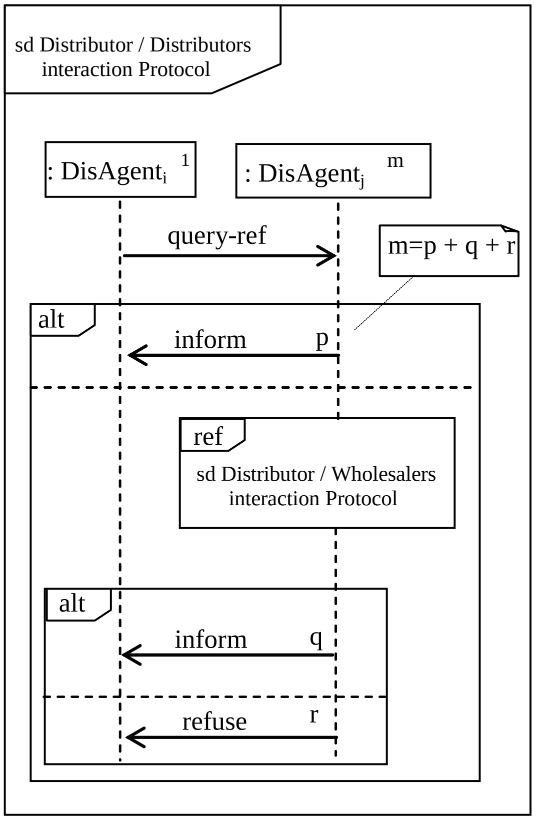


shows the UML sequence diagram that expresses the exchange of messages through the interaction protocol between the unexpected order facilitator agents of several distributors. These agents use other negotiation protocols (cf. section 5).

NEGOTIATION PROTOCOLS

In our distributed architecture, the agents use several negotiation protocols. The negotiation is the mechanism by which the agents can establish a common agreement. In the case of intelligent agents and of the MAS (Multi-Agent Systems), the negotiation is a basic component of the interaction because the agents are autonomous (Jennings, 2001); there is no solution imposed in advance and the agents must find solutions dynamically, while solving the problems.

Figure 4. Distributor/distributors interaction protocol



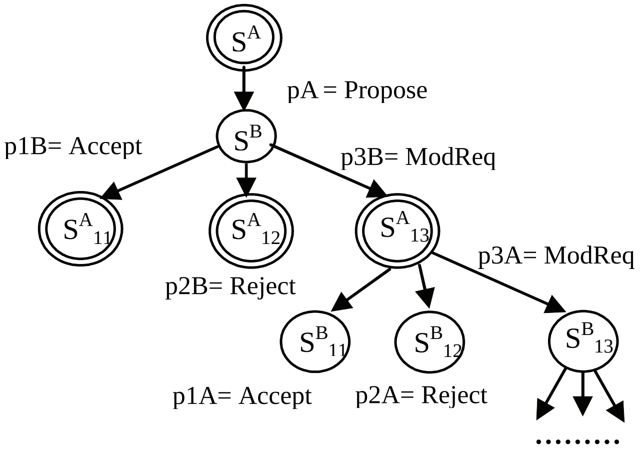
In the SCM process, the agents are co-operative, having the same goal (aggregation of the local objectives). They share and solve problems together. For this reason, the agents must provide useful reactions to the proposals that they receive. These reactions can take the form of a counterproposal (modified proposal). A counterproposal of an agent for a proposal is defined as the solution which is constructed by modifying the communicated proposal (Yoshida, 2007). From such reactions, the agent must be able to generate a proposal which is probably ready to lead to an agreement. Consequently, the agents of our system must use protocols respecting the criteria which have been stated above and that mainly depend on three parameters:

- The branch of supply chain sector (textile and clothing sector, consuming goods sector, etc.);
- SCM strategies and practices used for the companies' co-operation and coordination;
- Objects to be negotiated: rush order, ordinary order, sales forecasts, orders forecasts; modification of delivery plans in case of trouble, etc.

Heuristic Negotiation

The heuristic negotiation is shown in figure 5 (Florea, 2002). In this protocol several proposals and counterproposals can be exchanged in various steps. Agent "A", with proposal "pA", is the initiator of the negotiation, whereas the agent "B" (participant) can reply with the answers "p1B", "p2B" and "p3B" (to modify the request). The number of the counterproposals is limited. Once this limit is reached, the agents arrive to a rejection. We propose to recapitulate the heuristic negotiation protocol using an UML sequence diagram (Figure 6).

Figure 5. Heuristic negotiation



Proposal for a Firm Heuristic Negotiation

In some situations of negotiation, the collaborative agents must find an agreement. For this reason, the heuristic negotiation (cf. Figure 6) should include only ACCEPT-PROPOSAL or PROPOSE performatives (without the REFUSE performative). Thus, we propose the "firm heuristic negotiation protocol" which is a particular case of the heuristic negotiation. The word "firm" stands for this protocol since it always leads to an agreement. Figure 7 shows the sequence diagram that describes this protocol.

Proposal for a Recursive Heuristic Negotiation

The recursive negotiation protocol that we propose takes place at least between three agents, the initiator of the negotiation (sender), and the receiver who could become the initiator of a new heuristic negotiation with the third agent; hence the word "recursive" qualifying this heuristic protocol. Figure 8 shows the corresponding sequence diagram.

In our system, the recursive heuristic negotiation either belongs to a protocol corresponding to a SCM practice and strategy or corresponds to the negotiation of a rush order or scenario to be adopted in the case of disturbance (such as a disturbance of transport). In the general case, the negotiation takes place in the following way:

- The initiator of the negotiation sends messages (not necessarily identical) of type PROPOSE to all the direct agents (upstream and/or downstream) whom he thinks could be candidates in a negotiation. So, the initia-

Figure 6. Heuristic negotiation

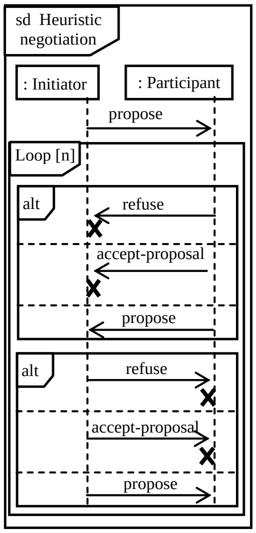


Figure 7. Firm heuristic negotiation

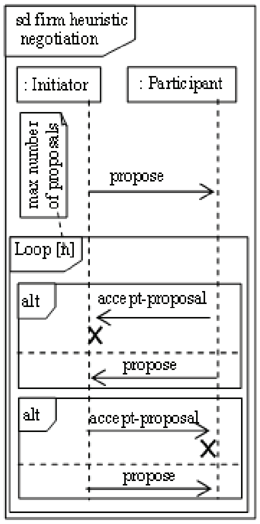
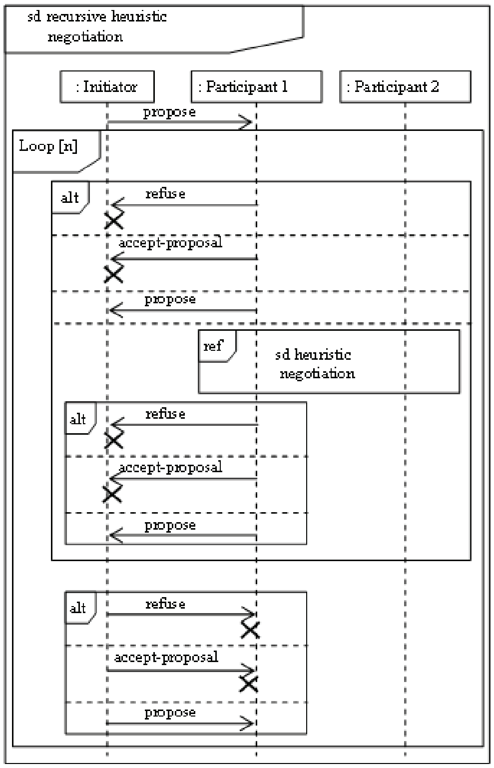


Figure 8. Recursive heuristic negotiation



tor launches several independent negotiations. It does not wait for all the answers to make a decision. Moreover, according to the situation and the time interval, it can come up with the best solution by creating new proposals deduced from the received answers;

- Since the agents of our architecture are cooperative, each one of them - receiver of a message - can start a negotiation if necessary between other agents in order to find the best solution.

CASE STUDY: VALIDATION OF SOLUTION APPROACH

Description

A case study of the proposed agent-based distributed architecture is conducted at a leading distribution company in North Africa. The aforementioned company operates in the sectors of toilets and showers (washbasin, baths, etc.), taps, tiling, plumbing and pieces of furniture. It offers about 800 low-end and high-end items at both its wholesale and retail market locations which are geographically distributed throughout the region. The products are sourced from two national suppliers (Morocco) and two main foreign suppliers (Spain and Turkey). The distributor mainly manages three types of independent-demand inventory systems: Periodic Review system (sometimes called a fixed interval reorder system or periodic reorder system) (Baglin et al., 2001) which is used to manage the inventory of the high-end products sourced from the foreign suppliers; a new order is always placed at the end of each review; the Time Between Orders (TBO) is fixed at 6 months for high-end items of plumbing, and 1 month for high-end items of tiling. The reorder point system (or fixed ordering quantity system), which tracks the remaining inventory of an item (sourced from national suppliers) each time a withdrawal, is made to determine whether it is time to reorder. Demands are estimated from forecasts and/or customer orders. A sourcing-to-order is used for some items depending closely on taste and last fashion (like products of tiling, etc).

The distributor has noticed that, in the whole, there are 6 to 10 rush unexpected orders that could take place each month. Actually, it is a big challenge because the aforementioned orders do not concern the same product. At the average level, 60% of such orders are cancelled, 20% are made at other distributors, and the delivery time of the other 20% can be modified after a tough negotiation with the customer.

Example of an Emergency Situation

At the beginning of the month of January 2007 (the beginning of the low sales season), a real-estate operator (who already promised the delivery of the apartments to the customers at a precise time) must have closed the building site (located in Fez city) during one week in order to have the housing license agreement as soon as a high-end item required in the construction had been in shortage. This latter is due to the inventory shortage of this item at the distributor. Because of a problem in the supplying process mainly due to one of the foreign suppliers, the next planned delivery of this item has been backlogged. In addition, the required high-end item cannot be supplied from other distributor because the aforementioned distributor is the only exclusive actor of such product. This order placed during the first week of the month was regarded as an unexpected firm rush order (delivery time: 9 hours; and it can neither delayed nor cancelled).

Adopted Solution

In this emergency case, the distributor was compelled to place an order of an equivalent item (brand, color…) at another competitor distributor located in Casablanca city (289Km from Fez city). Even if the costs were high, the distributor was interested to attract and retain the real-estate operator.

Solutions Provided by the Proposed System

In order to show the effectiveness and usefulness of the suggested architecture, we have made use (as a tangible demonstration) of the aforementioned item inventory level history of 37 wholesalers distributed throughout the country (Table 1). They are identified by scm1, scm2… scm37.

Figure 9 shows three of 13 existing solutions (paths and quantities) proposed by the unexpected order facilitator agent, according to the value of the number of wholesalers involved in each path. This number is chosen by the manager (Figure 10). Figure 11 shows only the first three paths. In the Figure 9, Qmin is the minimal quantity of product which can be transported in a segment connecting a wholesaler and the next wholesaler in the same path.

Results and Discussions

We notice that even if the required quantity cannot be delivered completely by only one wholesaler, it can gathered from both wholesalers scm26 (Ourzazate) and scm23 (Marrakech). This solution is not appropriate since the distance of the path is 687km. Indeed, the costs of transportation will be high.

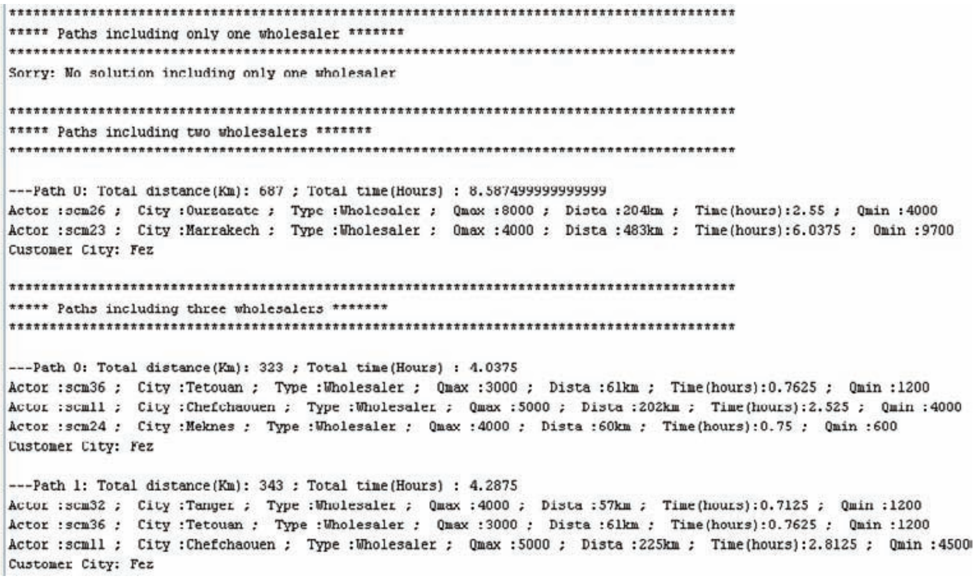
The distributor has 12 choices concerning the paths including 3 wholesalers. The time of the first three paths are almost equal to half of the required delivery time. The distances (323km, 343km) of the first two paths (Tetouan, Chefchaouen, Meknes, Fez; Tanger, Tetouan, Chefchaouen, Fez) are about 289km (distance between the competitor distributor and the customer). Certainly, these two solutions are better than the adopted solution, at least for two reasons:

1. The costs of transportation will be almost the same;
2. The purchase prices offered by the collaborative wholesalers (involved in the same

Table 1. Cities of the wholesalers

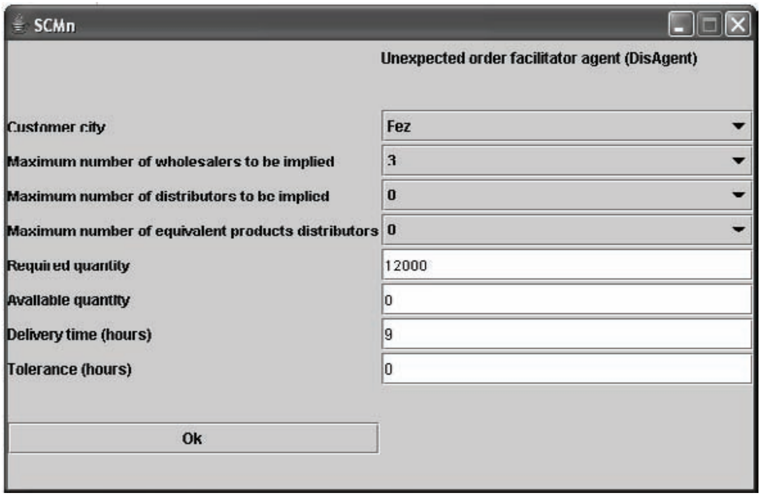
scmName	City
scm1	Agadir
scm2	Al Hoceima
scm3	Azilal
scm4	Beni Mellal
scm5	Boulemane
scm6	Casa Blanca
scm7	Casa Blanca
scm8	Casa Blanca
scm9	Casa Blanca
scm10	Casa Blanca
scm11	Chefchaouen
scm12	El Jadida
scm17	El Kelaa
scm13	Errachidia
scm14	Essaouira
scm15	Fez
scm16	Figuig
scm18	Kenitra
scm19	Khemisset
scm20	Khenifra
scm21	Khouribga
scm22	Laayoun
scm23	Marrakech
scm24	Meknes
scm25	Nador
scm27	Oujda
scm26	Ourzazate
scm28	Rabat
scm29	Safi
scm30	Settat
scm31	Smara
scm32	Tanger
scm33	Tan-Tan
scm34	Tarfaya
scm35	Taza
scm36	Tetouan
scm37	Tiznit

Figure 9. Proposed solution



```
******************************************************************************************
***** Paths including only one wholesaler *******
******************************************************************************************
Sorry: No solution including only one wholesaler

******************************************************************************************
***** Paths including two wholesalers *******
******************************************************************************************

---Path 0: Total distance(Km): 687 ; Total time(Hours) : 8.587499999999999
Actor :scm26 ;  City :Ourzazate ;  Type :Wholesaler ;  Qmax :8000 ;  Dista :204km ;  Time(hours):2.55 ;  Qmin :4000
Actor :scm23 ;  City :Marrakech ;  Type :Wholesaler ;  Qmax :4000 ;  Dista :483km ;  Time(hours):6.0375 ;  Qmin :9700
Customer City: Fez

******************************************************************************************
***** Paths including three wholesalers *******
******************************************************************************************

---Path 0: Total distance(Km): 323 ; Total time(Hours) : 4.0375
Actor :scm36 ;  City :Tetouan ;  Type :Wholesaler ;  Qmax :3000 ;  Dista :61km ;  Time(hours):0.7625 ;  Qmin :1200
Actor :scm11 ;  City :Chefchaouen ;  Type :Wholesaler ;  Qmax :5000 ;  Dista :202km ;  Time(hours):2.525 ;  Qmin :4000
Actor :scm24 ;  City :Meknes ;  Type :Wholesaler ;  Qmax :4000 ;  Dista :60km ;  Time(hours):0.75 ;  Qmin :600
Customer City: Fez

---Path 1: Total distance(Km): 343 ; Total time(Hours) : 4.2875
Actor :scm32 ;  City :Tanger ;  Type :Wholesaler ;  Qmax :4000 ;  Dista :57km ;  Time(hours):0.7125 ;  Qmin :1200
Actor :scm36 ;  City :Tetouan ;  Type :Wholesaler ;  Qmax :3000 ;  Dista :61km ;  Time(hours):0.7625 ;  Qmin :1200
Actor :scm11 ;  City :Chefchaouen ;  Type :Wholesaler ;  Qmax :5000 ;  Dista :225km ;  Time(hours):2.8125 ;  Qmin :4500
Customer City: Fez
```

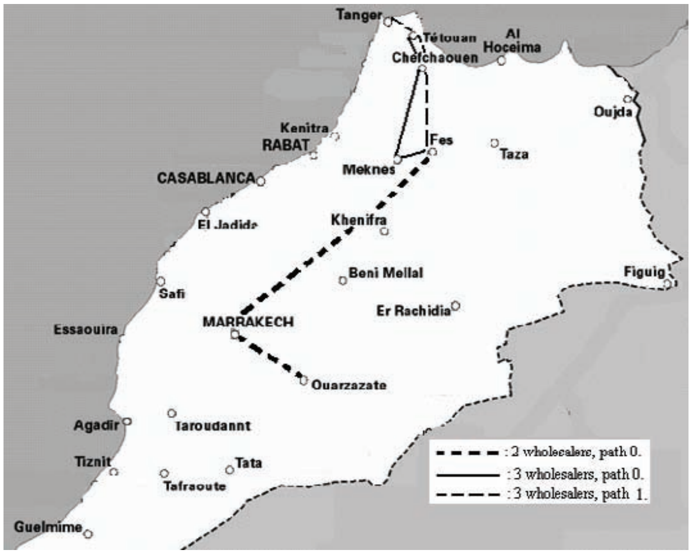
Figure 10. Unexpected order facilitator agent



Unexpected order facilitator agent (DisAgent)

Customer city	Fez
Maximum number of wholesalers to be implied	3
Maximum number of distributors to be implied	0
Maximum number of equivalent products distributors	0
Required quantity	12000
Available quantity	0
Delivery time (hours)	9
Tolerance (hours)	0

Figure 11. The first three paths



supply chain) are lower than the offered prices from the competitor distributor.

We deduce that the distributor had three solutions better than the adopted solution. We can conclude that more the number of actors constituting a path and the required quantity are large, more the number of choices is important.

In practice, several emergency situations exist and depend closely on the branch of supply chain sector.

Implementation

The prototype has been implemented using JADE (Java Agent DEvelopment Framework) from CSELT, Turin, Italy. JADE is a middle-ware that

Table 2. Implementation environments for the prototype

Implementation environment	JADE 3.4
Implementing language	Java
DBMS	SQL Server 2000
Agent communication language	FIPA ACL Standards
Operating system	Windows XP

could be used to develop agent-based applications in compliance with the FIPA specifications for inter-operable intelligent multi-agent systems (Bellifemine et al., 1999). JADE is java-based and provides the infrastructure for agent communication in distributed environments, based on FIPA standards. Table 2 shows our implementation environments for the prototype.

CONCLUSION AND FUTURE WORK

In this paper, we presented an agent-based distributed architecture for collaborative decision-making processes within the global distribution supply chain. We proposed a process (thanks to the multi-agent properties) for a best management of the rush unexpected order. At this stage, the architecture is validated and tested on a leading distribution company. The results are very promising and show that our proposed system could be connected to the existing SC tools. In this case, enterprise application integration assumes a great importance. Enterprise Application Integration (EAI) enables an enterprise to integrate its existing applications and systems and to add new technologies and applications to the mix.

In the next stage of this work, we will take into account the size of the transported batches, i.e. to represent the price of transportation per unit of product as being lower when the transported quantity is large. In this case, it will be necessary to seek the quantities which optimize the costs of transportation (we intend to use a genetic algorithm). Then, we will extend our architecture in order to use it in the global manufacturing supply chain (including manufacturers, suppliers…).

ACKNOWLEDGMENT

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Chapter 2.18

Effective DMSS Guidance for Financial Investing

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ABSTRACT

Investment decisions have a significant impact on individuals, groups, organizations, the economy, and society. As a result, many formal methodologies and information systems have been designed, developed, and implemented to assist with financial investing. While these tools can improve decision making, none offer complete and integrated support for financial investing. This article seeks to close the support gap by offering a theoretical decision making support system for financial investing and illustrating the system's use in practice. The demonstration indicates that the theoretical system can improve the process of, and outcome from, investing.

INTRODUCTION

Financial decisions are some of the most challenging and important decisions made daily by individuals, groups, organizations, and other entities. These decisions are complex and, at best, semi-structured, and the selected actions will have a substantial impact on the well-being of these entities, in particular, and the economy, in general.

A large amount of available quantitative data support financial decision making, and many rigorous models capture financial phenomenon (R C Merton, 1995). Various information systems are available to deliver the model's embedded expertise to the investor (C. Zopounidis & M. Doumpos, 2000). Vellido et al (1999) reviewed neural network applications in finance, concluded that the literature is rich with neural network applications, and suggested that future work should explore the combining of knowledge-based techniques with neural network techniques. A review of articles on the subject of finance in the journal *Expert Systems with Applications* highlighted a pattern of knowledge-based work in the 1980s and early 1990s and machine learning work from the mid-1990s till now (Roy Rada, 2008).

Yet, most of the models, and thereby the information system delivery, focus on an aspect of the financial situation and typically are tailored to specific categories of investors. Such a fragmented and incomplete approach to financial analysis may not provide the investor with the specific and precise guidance needed for effective decision making in practice (Bob Berry, 2004).

This article examines the issue of effective guidance for financial investing. First, the relevant literature is reviewed. Next, the financial investing approaches inspired by this literature and the pertinent decision support gaps in the approaches are identified. Then, the article offers a decision making support system that can close the support gaps and provide specific and precise guidance for financial investing in a complete and integrated manner. The article concludes with an examination of the implications for financial decision making, in particular, and for financial engineering, in general.

FINANCIAL ENGINEERING

Financial investing may be seen as a three step process of collecting data about assets, evaluating assets, and buying and selling assets into and from a portfolio. Usually, investors will seek professional advice to assist in the investment process. Typically, the professional's organization employs technical experts, or financial engineers, to develop tools that help financial professionals in the advisement process.

Financial engineers, broadly speaking, design new financial instruments and create solutions to financial problems. In particular, financial engineering includes these four areas (J M Mulvey *et al*., 1997):

1. Corporate Finance (new instruments to secure funds, engineering takeovers and buyouts)
2. Trading (develop dynamic trading strategies)
3. Investment Management (repackaging and collaterization)
4. Risk Management (insurance, hedging, and asset management)

Risk management may in turn be decomposed into (J M Mulvey et al., 1997):

- strategic asset management (via multi-stage stochastic optimization) and
- operational asset management (via immunization models).

Often, financial engineering is accomplished with the assistance of optimization, statistical, and econometric approaches. Sometimes, these approaches assume the problem is well-posed and has a single objective. Financial decisions, however, could involve:

- the existence of multiple criteria,
- conflicts among criteria,
- ill-structured evaluation, and
- political and social factors involved with human decision-making.

Management scientists, economists, and others have developed additional models to deal with these financial complexities.

Investors and the investment professionals typically do not have the knowledge about, or interest in, the financial models to effectively utilize these tools in practice. Consequently, financial engineers, and information systems professionals, have developed information systems designed to deliver the available financial models to the investors and investment professionals (C. Zopounidis & M. Doumpos, 2000). The most efficient and effective delivery vehicle for such a purpose is the decision making support system (DMSS).

FINANCIAL DECISION MAKING SUPPORT

Decision-making Support Systems (DMSS) are computer-based information systems that support individual, group, or organizational decision-making processes in an interactive manner. Depending on the supported decision making phases or steps supported, a DMSS may take the form of a Decision Support System (DSS), Executive Information System (EIS), Expert System (ES), or some integrated combination of the functions delivered by a DSS, EIS, and/or ES (G Forgionne *et al*., 2005)

For example, recent advances in information technology and artificial intelligence could be used to enhance DSS or EIS processing, giving rise to Intelligent-DMSS (IDMSS) (Jatinder Gupta *et al*., 2006). The support rendered in an IDMSS can occur at four levels (B Roy, 1996):

1. Determine object of the decision
2. Analyze criteria
3. Model preferences
4. Develop recommendations

This support often is achieved through the delivery of operations research methods such as:

1. multi-objective mathematical programming
2. multi-attribute utility theory
3. outranking relations, and
4. preference disaggregation analysis.

Each of these methods has been applied to a rich variety of financial problems. For instance, multi-objective mathematical programming was applied to the investment problem of fund allocation among shopping malls (R Khorramshahgol & A A Okoruwa, 1994), and multi-attribute utility theory was used to assess sovereign risk (J C S Tang & C G Espinal, 1989).

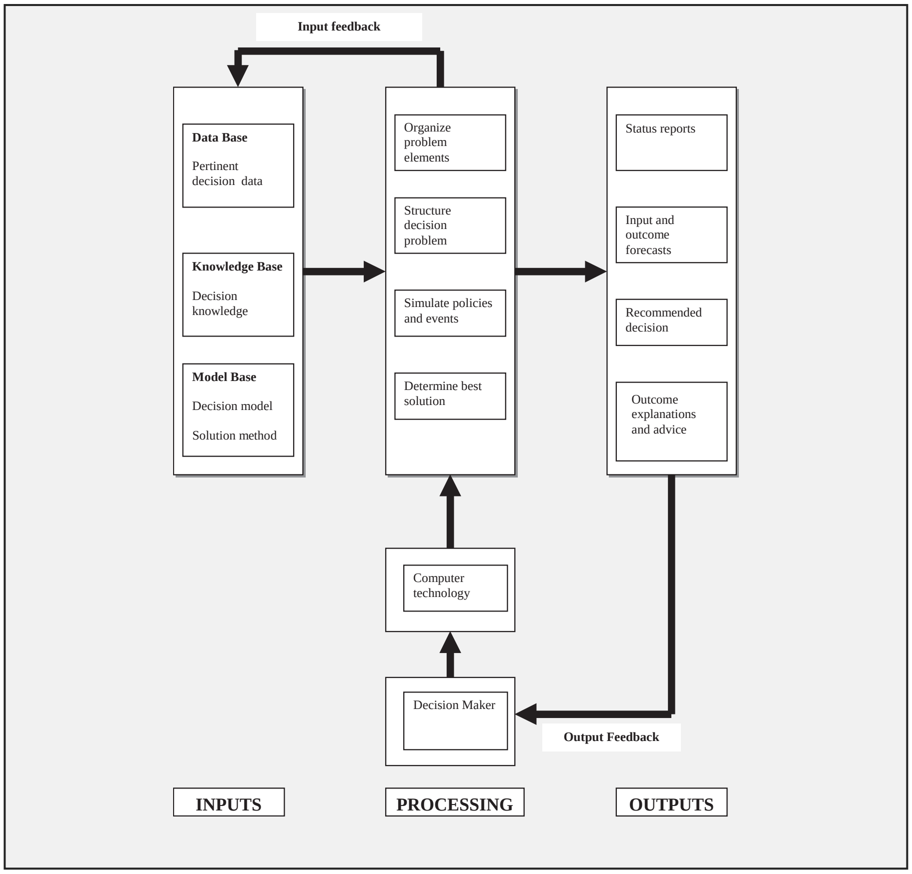
Decision Making Support System Architecture

Decision making support systems (DMSS), regardless of their specific form, generally will have the architecture shown in Figure 1. As this figure shows, DMSS inputs include a database of pertinent decision data, a knowledge base of decision knowledge, and a model base that contains a model of the problem and an appropriate solution method. Knowledge may be represented as production rules, semantic networks, frames, or in some other way.

The decision maker utilizes computer technology to access the various input bases and execute the processing tasks of organizing problem elements, structuring the problem, simulating policies and events, and finding the best problem solution. This decision maker controlled processing usually is called the dialog management system and is the mechanism that makes a DMSS interactive. Processing generates status reports on the problem elements, forecasts of inputs and outputs, recommended decision actions and strategies, and explanations for the recommendations.

Processing may be assisted through artificial intelligence methodologies. For example, expert system and case-based reasoning functionality can help decision makers access data and models, infer relationships, and interpret outputs (G I Doukidis, 1988). Machine learning can be used to generate forecasts of problem elements, and natural language and vision processing can facilitate dialog management.

Figure 1. General decision making support system architecture



Feedback loops from outputs to the decision maker and from processing to inputs indicate that DMSS processing is dynamic and continuous in nature. Outputs may suggest further decision maker processing, and processing may create new or additional data, knowledge, models, or solution methods relevant for future processing.

A specific DMSS may have all or parts of this general architecture. For example, an IDMSS would have a knowledge base, but a DSS would not. Moreover, the content of the data, knowledge, and model bases and the processing tasks may differ from one DMSS to another. For instance, an EIS model base may contain data mining and statistical models, while a DSS model base may require an economic, accounting, or management science model. Similarly, an EIS may not find a best problem solution, while optimization may be the dominant task in a DSS.

DMSS in Finance

A number of Decision Making Support Systems have been applied to finance. An example of an expert system for finance is the FINEVA system (N.F. Matsatsinis *et al*., 1997**.** FINEVA has a knowledge base about assessing companies for financial viability. It has hundreds of rules which operate on input of financial ratios from financial statements. The system also interacts with the user to collect qualitative data about the management of the companies that are being assessed. The financial ratios that are considered are those which experts have said they typically use (and correspond generally to what the textbooks say are relevant ratios), such as the Quick ratio. The rules (as the ratios) are grouped into categories of profitability, solvency, managerial performance, and qualitative criteria. The rules connect with each other in a hierarchy. For instance, some rules look at debt ratios and some other rules look at liquidity ratios. The rules for debt and liquidity ratios are combined at a higher level into rules about solvency.

If one takes the area of machine learning and looks at recent examples of applications to finance, one can find a host of integrated techniques, and model them in various ways. The following studies illustrate the mixture of machine learning techniques with representational issues and diverse approaches to financial problem solving:

- Lam and Ho (Wai Lam & Kei Shiu Ho, 2001) used knowledge about stock valuation to support natural language processing of financial news articles. Their system learned through experience and was intended to identify data for an asset valuation system.
- Chen and Chen (A.P. Chen & M.Y. Chen, 2006) semi-manually took rules from experts and other sources, and then their genetic algorithm integrated those rules to predict values of a stock market index. Dhar and Chou (V. Dhar & D. Chou, 2001) prepared rule templates for their genetic algorithm that were specific to knowledge of the domain. For instance, their system might have been initiated with a rule such as "if the ER index is greater than the Pth *percentile*, and the *N day industry trend* exceeds *S standard deviations,* then the company will deliver *an earnings surprise of type T.*" The genetic algorithm was expected to find useful values for P, N, S, and T. Lajbcygier (P. Lajbcygier, 2004) incorporated the Black-Scholes options pricing model into the representation of his hybrid neural network.
- In the buying and selling of currencies, a natural symmetry exists that Bhattacharya et al (S. Bhattacharyya *et al.*, 2002) exploited to constrain the combinations of logical and numerical operators that their genetic program generated. Tsakonas et al (A. Tsakonas *et al.*, 2006) used neural logic networks that they argued were intrinsically suited for finance, and they constrained their genetic programming method to only produce syntactically correct neural logic nets.
- Dempster and Leemans (M.A.H. Dempster & V. Leemans, 2006) added a knowledge-based financial portfolio management layer to their neural network price predictor.

Substantial work has been done on the subject of computer systems to evaluate assets. Machine learning methods have been employed to fine tune the numerical parameters of asset valuation programs. However, too little work has been done on the subject of representing financial knowledge in such a way that a machine learning program can make meaningful changes in the asset valuation program beyond the level of numeric parameters. One of the few such papers (Bhattacharyya, Pictet, & Zumbach, 2002) showed how symmetry in financial markets could be exploited by a learning program.

Incomplete and Fragmented Support

Each of the reported Decision Making Support Systems, and thereby the delivered decision technology, focuses on a specific aspect of financial investing. System inputs, processing, and outputs will be limited to this aspect. For example, a DMSS designed to support asset valuation will have a data base of the pertinent asset information, an appropriate asset evaluation model and solution methodology, and perhaps some asset valuation knowledge. Processing will structure the evaluation model, simulate asset values, and generate forecasts of the asset values.

To support the entire financial decision making process, then, it would be necessary to have a more complete DMSS than has been offered in the literature or known practice. One possibility is to have several decision making support systems for financial investing. Such a fragmented approach, however, would require linkages between disparate systems that may have different data formats, various modeling approaches, and different computer software and hardware platforms. This fragmented approach also would negate the potential synergistic effects achievable from integrated decision making support systems (G Forgionne, 2000). The fragmented approach also would involve more time and cost for design, development, and implementation than the integrated approach and be less user-friendly than one integrated and complete system, like the architecture offered in Figure 1.

There is also a practical difficulty with incomplete and fragmented DMSS for finance. Most investors and practicing financial advisors will be unaware of the available decision making support or lack proficiency in DMSS usage. When there are multiple support tools available, the practitioner's lack of awareness and knowledge will necessitate education and training across several support tools and require personnel to provide such education. These impediments could deter practitioners from seeking the desired support and/or lead to inappropriate financial decisions.

The potential technical, economic, and practical problems can be alleviated, or even eliminated, by instantiating Figure 1's architecture for financial investing. Such instantiation can provide an effective and efficient decision making support system for financial investing.

DMSS FOR FINANCIAL INVESTING

Much data are potentially useful for financial investment analysis. Such data would include:

- qualitative information, such as the quality of management and a firm's reputation,
- stock market data, such as stock price and dividend yield,
- macroeconomic data (interest rates, exchange rates, inflation rates), and
- finance statements (balance sheets, income statements).

In addition, various models could assist a financial decision maker. Existing financial models include:

- financial accounting statement frameworks,
- economically-based financial and stock market ratios,
- portfolio theory models, and
- capital asset management models.

Existing statistical methods include descriptive methodologies, such as correlation, and inferential methods, such as principal components analysis. In addition, decision analysis can provide multiple criteria methods for implementing the financial theories, both for evaluating stocks and composing a portfolio. For instance, while the financial statement models speak to the features of attractive stocks, decision analysis can be used to identify a desirable set of stocks.

In any given circumstance, however, only a small portion of the available data will be pertinent to a specific investor's needs. Moreover, some statistical, economic, or accounting analysis may be needed to synthesize the available data and focus the results for the investor's needs. Similarly, the investor's situation may not require all available financial models and supporting decision technologies. As with the data, then, model filtering and focusing may be necessary.

Warehousing and Marting

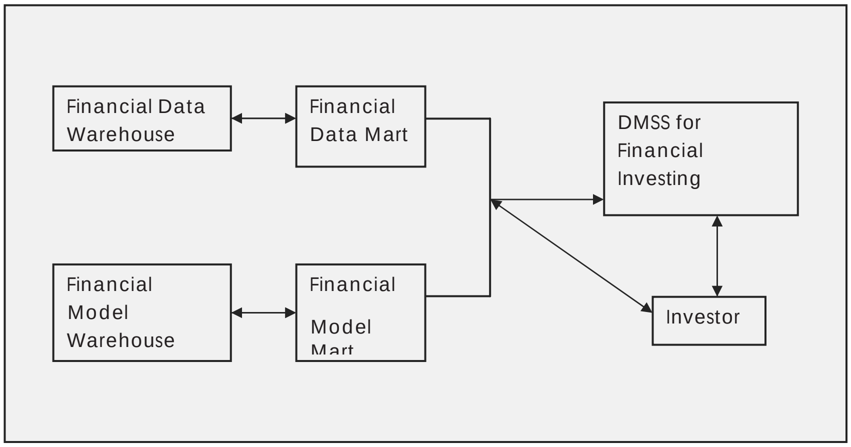
To support the range of needs likely to be encountered in financial investing, it would be useful to create warehouses of potentially relevant financial data and models. The financial data warehouse would draw from available external financial information data sets, such as those available from Standard & Poor's (www.standardandpoors.com) and Bloomberg (www.bloomberg.com), and internal sources, such as an organization's accounting ledgers, to form a repository of potentially relevant data for financial analysis. Similarly, the financial model warehouse would serve as a repository for reported theoretical financial analysis methodologies and methods and reported practice-based investment heuristics and methodologies.

Such data and model warehousing would become a primary activity in financial engineering, much as data warehousing has become common in information systems operations for modern organizations (Michael Mannino *et al*., 2008). Internal accounting transactions captured by information systems data warehouses also can, and often do, provide pertinent data for financial analyses (Arlen Khodadadi *et al*., 2006).

To meet the investment needs of a specific investor, pertinent data could be viewed in the financial data warehouse, and relevant models could be viewed in the financial model warehouse. Relevance could be defined interactively by the investor, predefined from the investor's financial profile and implemented through artificial intelligence, or be determined dynamically by artificial intelligence adjusted interactively by the investor. The views would form virtual data and model marts for the investor. Once the views are accepted by the investor, the accepted data could be extracted from the financial data warehouse to form the investing DMSS database. Similarly, accepted model views could be extracted from the financial model warehouse to form the investing DMSS model base. Captured views and extractions form the pertinent problem knowledge for the investing DMSS knowledge base.

Figure 2 illustrates the financial warehousing and marting process for the specific financial investment support. As this figure demonstrates, the investor-controlled data and model marting process ensures that the investing DMSS data, model, and knowledge bases are populated only with filtered and focused information directly relevant to the specific investor's financial inter-

Figure 2. Financial warehousing and marting relationship to DMSS for investing



ests and needs. Such filtering and focusing also means that the DMSS bases are likely to be small in volume but dynamic in nature and reflective of the investor's changing preferences as new knowledge is gained. Figure 2 also makes it clear that the investor, either directly or through a professional financial advisor, controls the financial marting process, either unassisted or with the aid of artificial intelligence.

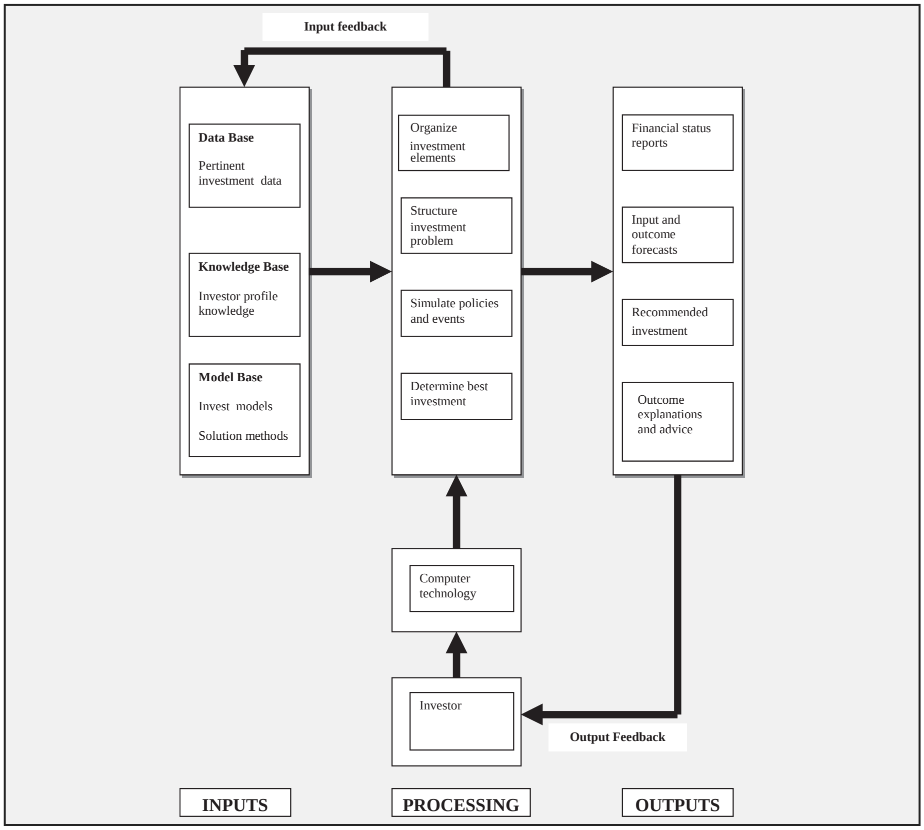
DMSS Architecture and Operations

In a typical scenario, the investor engages in a financial decision making process. Initially, the investor analyzes securities and identifies the subset of securities deemed worthy of investment. This analysis and identification corresponds to Simon's intelligence phase of decision making. Next, the investor develops a formal or informal evaluation model, consisting of financial performance measures, alternative investments, and economic and other events, and the relationships between these factors. Such modeling constitutes Simon's design phase of decision making. Then, the investor utilizes the designed investment model to determine the amount invested in the identified securities. This selection corresponds to Simon's choice phase of decision making.

While the financial decision making can be very dynamic in nature, the process is iterative. Design cannot occur without intelligence, and choice cannot precede design.

The decision making support system for investing, shown architecturally in Figure 3, can support the financial decision making process in a complete and integrated manner. As this figure shows, the DMSS for investing has a data base that consists of the financial information

Figure 3. DMSS for investing architecture



gleaned from the investor-controlled data marting illustrated in Figure 2. This marting also creates the investor profile that, along with any other previously captured investor-relevant facts and factual relationships, populates the DMSS knowledge base. Similarly, Figure 2's financial model marting generates the investor-relevant models and model solution methods captured in the DMSS model base.

The investor uses workstation-based computer technology and custom software to control the DMSS processing. Initially, the system offers a list of securities currently available for investment, and obtained from the financial data warehouse as part of the financial data marting illustrated in Figure 2. This listing supports the investor's intelligence phase of decision making. As the top feedback loop in Figure 3 demonstrates, the listing will be dynamic and recursive in nature, with the new data and knowledge captured in the system's databases and knowledgebases for further processing.

After obtaining the investor's desired list, the DMSS prompts the investor for her/his/their desired performance measures. These measures, pertinent uncontrollable inputs (such as economic indicators and organizational qualitative information), captured from the financial data marting, and investment models captured during financial model marting will be used by the DMSS to structure the investment problem. This structure will explicitly and precisely establish the relationships between the invested-specified performance measures, listed securities, and uncontrollable factors. During the structuring, pertinent parameters from the system's data base, and perhaps further estimated through statistical and other analyses, will be attached to the investor's specified model by the DMSS. The structuring, which supports the design phase of decision making, is likely to be assisted with artificial intelligence methods stored in the system's model base. As with the organizing of financial information, the structuring will be dynamic and recursive in nature with the new knowledge and models captured in the system's knowledge and model bases for further processing.

The DMSS will select from the model base, perhaps through artificial intelligence assistance, the solution methodology best suited to the investor's specified model. Depending on the model and selected methodology, the system will either simulate the outcomes from selected securities under specified financial conditions or recommend the portfolio that best meets the investor's stated performance measures. Since the results were generated from an explicit and precise model of the investment problem, the DMSS can provide a detailed explanation for the recommendations and advice by tracing the logic in the model's equations or other relationships. As indicated by the bottom feedback loop in Figure 3, the generated forecasts from the simulations or recommendations from the model optimization will be performed in a dynamic and recursive manner conducive to confidence building on the part of the investor. The simulations and/or optimizations support the choice phase of decision making.

Theoretical Methodolgy

The proposed decision and information technology and decision making support architecture have been developed and applied successfully to a closely related problem (Forgionne, 1997). In the approach, investor needs will be identified from a dialog session between the investor and the prototype system. Predefined production rules will map the selections to appropriate captured financial model components. The research also will explore the use of neural networks to refine the predefined production rules and the potential use of fuzzy logic as a knowledge representation scheme alternative to production rules for the mapping process. Intelligent agents, with encapsulated statistical, management science, accounting, and economic knowledge, will join the relevant captured model components to form a model specific to the investor's needs. Other intelligent agents search for the data pertinent to the investor's model from captured data warehouses and data marts, use appropriate statistical methods on the gleaned data to estimate the model's parameters, attach the estimated parameters to the investor's specific model, perform an appropriate model analysis, and report recommendations to the investor. The investor then can either accept the recommendations or request additional analysis through pertinent dialog with the prototype system. Further requests dynamically trigger model modifications, analyses, and new recommendations.

It should be clear that the successful operation of the theoretical DMSS for investing is based on strong supporting financial data and model warehouses. This link suggests that the methodology for developing the theoretical DMSS should follow the process outlined in Figure 4.

Professional organizations already gather much financial data, and the academic and practitioner literature reports many financial models. Moreover, there are several financial data warehouses in professional investment firms and other organizations, some of which may be available to investors (Hsin-Ginn Hwang *et al*., 2004). Still, the available warehouses may be incomplete and fragmented. Model warehouses are rare and usually not available to investors (I. Belov *et al*., 2006).

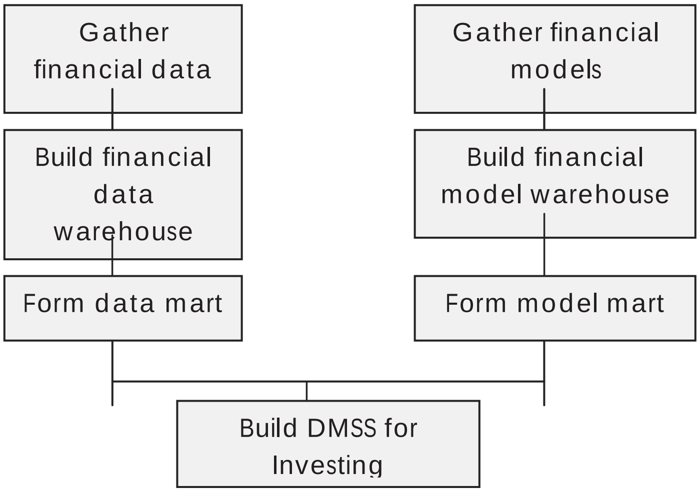
Financial data and model marting are underdeveloped areas and will be specific to the investor. The DMSS for investing, of course, is just a theoretical concept at this point. There are many information and decision technologies available and in use that could be adapted to these tasks (Shu-Heng Chen, 2006; Shu-Heng Chen & Paul P Wang, 2004).

ILLUSTRATIVE EXAMPLE

The implementation of the DMSS for investing concept will be specific to an investor with a particular financing problem. This concept, however, can be illustrated with the aid of an ongoing research project. In this research project, data, models, and knowledge (as suggested in Figure 3) have been identified and preliminary experiments are being done with a prototype iDMSS that is called the Intelligent Investing System (IIS).

IIS would ultimately include data from various asset classes, as well as macroeconomic information. Some of the asset classes would include

Figure 4. DMSS for investing development process



stocks, bonds, commodities, and real estate. The first prototype considers only stocks and relies on the licensed data set called Compustat from Standard & Poor's. Macroeconomic data sets have been identified on the US Department of Treasury site.

For the model base, the program attempts to collect, formalize, and categorize relevant financial models that look across entities and across time at one entity. For across-entity analysis, the thresholds and rules that are applied to financial ratios of (N.F. Matsatsinis et al., 1997) have been implemented. Those thresholds and rules are used to identify company financial viability based on the latest financial ratios. For modeling financial statements across time, IIS includes an implementation of the forecasting model presented in (Chandan Sengupta, 2004). The forecasts cover not only financial statement items, such as sales and long-term debt, but also stock data, such as stock price and dividends. With the dividend forecasts, the IIS can reach into the model base, grab the Dividend Discount Model, and further value a stock based on the forecast dividends.

For portfolio management, IIS includes various implementations of the optimally efficient portfolio. Particularly useful has been the method delineated initially by Merton (Robert Merton, 1972) as implemented in a spreadsheet by Holden (Craig W Holden, 2005). IIS also includes an implementation of the optimization technique presented in (William Sharpe, 2007). The single index approach to computation of the covariance matrix is also available to IIS.

The knowledge base provides guides for problem solving. For instance, when thousands of stocks are being considered, the computation of the covariance matrix is not practical because it requires the covariance to be laboriously computed for every pair of companies. The amount of computation can be reduced from being proportional to the square of the number of companies to being linear in the number of companies by using the simplifying assumption about the stock index. Accordingly, when the portfolio weights on more than one hundred stocks are to be computed, the portfolio optimization routine might use the index model.

More innovative examples of the knowledge base at work concern modifications to the forecasting based on financial statements. The knowledge base knows which aspects of the model of financial statements might be refined in which ways. The financial statement models have different types of components; for instance,

- Some relationships in the model are true by definition and entirely enclosed within the financial statement, such as "gross operating income = sales - cost of goods sold".
- However, other relationships in the model may be elaborated. For instance, interest expense approximately equals (short-term interest rate * short-term debt) + (long-term interest rate * long-term debt). Independent forecasts of interest rates can be obtained and connected to the financial statement forecasts. Furthermore, long-term debt is not strictly a single long-term interest rate times a single long-term debt quantity but is rather a complex function of the portfolio of company borrowings which also can be further investigated by IIS.
- Other relationships in the financial model may or may not apply to a particular company, depending on the company. For instance, some companies want to manipulate debt and equity to achieve certain target proportions. If the company has such a goal, then what its target proportions may be is not fixed across companies.

IIS formalizes these relationships so that the system can manipulate the model and test the impact on forecasting accuracy.

The knowledge base includes both financial-type data, such as industry classification of a company, and computational knowledge. The preceding description of the role of the index model in supporting fast computation of portfolio weights illustrates computational knowledge. However, a deeper example concerns knowledge about various functions that can be used to fit data. For instance, the financial statement forecasting will experiment with linear, polynomial, exponential, and sinusoidal functions to see which best captures certain time series in the financial statement.

The reasoning may be seen as occurring in the Processing Phase of the IIS (recall that Figure 3 shows an input phase, a processing phase, and an output phase). The user presents to IIS the user's investment constraints including the amount of money to invest, the amount of risk to take, and the types of asset classes preferred. The IIS then operates with this information and the data, models, and knowledge. In the processing phase, the IIS engages in extensive back-testing of its tentative recommendations. Compustat provides several decades of data which can be exploited to test hypotheses about assets relative to past performance.

Given that appropriate models to apply to a company's financial statements will depend among other things on the industry classification of the company, the IIS classifies a financial statement by the industry classification of the company and looks for similarities in models based on industry sector. Compustat classifies companies into the Global Industry Classification Standard (GICS), which consists of 10 sectors, 24 industry groups, 62 industries and 132 sub-industries. Reasoning is performed on the GICS structure to determine the appropriate level of generalization depending on the problem at hand.

The companies likely to produce the greatest surprise to investors are those companies which least fit any of the standard models. IIS would continually refine its modeling and backtest. A company whose data resisted being modeled would be further investigated.

The IIS also uses machine learning, particularly evolutionary computation. In IIS, the genetic algorithm has been used to experiment with the role of knowledge in financial asset evaluation, as suggested by (S. Bhattacharyya et al., 2002), and neural networks have been used to refine criteria, as suggested by (A. Tsakonas et al., 2006).

The IIS prototype has been developed in Excel 2007 with Visual Basic for Applications (VBA). The VBA code inserts commands in the worksheets which in turn invoke Compustat and download financial data. The VBA modules also enter formulas into the worksheets which indicate the relations among the data and ultimately are responsible for the asset valuation and portfolio management. Excel was chosen for the prototype for several reasons:

- many financial investors use Excel,
- existing financial models have often been implemented in Excel and thus can be imported into IIS,
- Excel has a large library of financial functions embedded within it,
- output in Excel is easily made visually appealing and the output can include simultaneously the number plus the formulas which computed the numbers (and users can select to immediately see the computation behind the number).

Future prototypes might connect other tools to Excel.

CONCLUSION

Financial investing is a very important problem that has a significant impact on individuals, groups, organizations, the economy, and society. While much wisdom and knowledge has been offered to guide investments, the support has been incomplete and fragmentary. This article proposes the DMSS for investing as a tool to improve support and suggests a methodology to develop the tool.

At this point the proposed system is conceptual and requires further system development. There is a need to: (a) establish a development plan and methodology, (b) identify software to implement the concept, (c) use the software to develop the system and implement a prototype, (d) utilize the prototype to test the efficiency and efficacy of the plan, and (e) establish an implementation plan.

The concept also establishes a theory that the DMSS for investing can improve financial decision making by offering complete and integrated support and guidance for the process. This theory suggests the following research question and hypotheses:

- **Research Question:** Can the DMSS for investing improve the process of, and outcomes from, financial investing?
- **Null Hypothesis:** The DMSS cannot improve the process of, and outcomes from, financial investing.
- **Alternative Hypothesis:** The DMSS can improve the process of, and outcomes from, financial investing.

The question can be answered by designing studies that will compare the process results and outcomes from DMSS for investing usage with the corresponding results and outcomes from existing forms of human and system guidance. There are a number of process and outcome measures from the literature that can be used in these studies (G Phillips-Wren *et al*., 2006). The studies can be executed through experimental approaches or by other means.

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Chapter 2.19

Exploring a UML Profile Approach to Modeling Web Services in Healthcare

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ABSTRACT

The Web services paradigm offers numerous potential benefits to the health care area. These include interoperability, portability, scalability, and compliance with universal standards. However, development of large-scale Web services applications in health care is relatively scarce. Multiple challenges are slowing the diffusion of information technology practices in health care, starting with the absence of modeling tools and methodologies that are the bases for building such technology. This article describes a UML profile approach to developing Web services applications in the health care area, emphasizing the use of such extensions as stereotyping and tagging to model the unique elements of health care processing. We apply these ideas to a health clinic example. From here, one can imagine building incrementally upon these ideas to develop frameworks for Web services applications in health care. The benefits would enhance the overall quality of health care delivery and lower costs.

INTRODUCTION

Web services are self-contained, Internet-enabled applications capable not only of performing healthcare-related activities independently, but also possessing the ability to engage other Web services to complete higher-order business (health) transactions (Papazoglou & Dubray, 2004). The key is modularity characterized by open standard and internet-oriented interfaces. Examples of such patient services include verifying appointment availability, producing a bill, ordering lab tests, prescribing medication, and discharge planning. The platform-neutral nature of Web services (Kreger, 2001) creates the opportunity for building composite services using existing elementary or complex services, possibly offered by different service providers (Meredith & Bjorg, 2003; Yang, 2003). On a larger scale, these services can be considered a set of interoperable technologies and standards, designed to support the integrating of several autonomous and heterogeneous systems. Web services are particularly geared toward the service-oriented computing paradigm, which can be considered a collection of services, coordinating, and communicating with each other to support a system's specific function or concept. Service-oriented computing has the potential to be the healthcare industry's new foundation for distributed systems and internet-based processing. Web services specifications, such as SOAP, WSDL and UDDI, facilitate open, XML-based methods to support application interoperability, service description, and service discovery (Estrella, McClatchey, Rogulin, Amendolia, & Solomonides, 2004).

The rapid adoption and diffusion of service-oriented architecture (SOA) and Web services in various industries indicate that the advantages and benefits (componentization, interoperability, platform-independence, modularity, reusability, etc.) therein could provide similar benefits for healthcare. Overall, there has been a major change in the way large scale software applications are designed, modeled, implemented and used (Stojanovic, Dahanayake, & Sol, 2004). Services are autonomous, platform-independent processes that can be identified and defined, published, discovered, choreographed, and programmed using universally accepted protocols for building health applications that work together seamlessly, both intra-enterprise (i.e. the healthcare delivery organization) and inter-enterprise (i.e. the consortium of healthcare delivery participants). When services are delivered via the Web we call them Web services. These have emerged as a framework for application-to-application interactions, making these applications available as Web services (Vara, De Castro, & Marcos, 2005). While Web applications via the Internet have been used in the healthcare industry for a few years now, these applications are mostly intra-enterprise, that is, services are within the specific healthcare organization using them. There is limited capability for supporting cross-functional and inter-enterprise applications. Recently, however, practitioners and researchers have started to address the distributed and inter-enterprise nature of healthcare delivery (the interaction arising out of the exchange of information among physicians, insurance companies, hospitals, labs, and pharmacies, for example). The desire to exploit the scalability of Web services within the SOA is understandable. Catley, Petriu, and Frize (2004) describe a prototype Web services architecture for physicians designed to provide clinical decision support. The objective is to integrate and access clinical decision support systems (CDSSs) and medical databases from various medical domains. Their rationale for integrating distributed databases is that different medical domains often exhibit complementary abilities in predicting medical outcomes. They give the example of the collective domains that include obstetrical, prenatal and neonatal databases. The overall goals have been multifold: the Web services are expected to integrate different types of CDSSs; provide for a way to link disparate distributed databases on multiple platforms; and making the CDSSs available locally as well as remotely (Catley et al., 2004).

Estrella et al. (2004) describe another application based on grid computing and the SOA. The MammoGrid project is expected to support collaborative medical image analysis. An important objective is to manage federated mammogram databases distributed across Europe. The framework would include regions with varying protocols, lifestyles and diagnostic procedures and would enable a range of functions including data mining, epidemiological studies, statistical analyses, and deployment of a standardized Standard Mammogram Form. The goal is to federate the distributed mammogram sources into a single virtual organization. While these applications are in very specific medical domains, they highlight the potential of SOA-enabled Web services in the health domain. The health domain is more encompassing than the medical domain because it includes business-related services such as patient billing, insurance approval, payment processing and case management. Even so, the groundwork is in place to scale up applications for more encompassing healthcare delivery systems, delivering services via the Internet. In this way, the industry may exploit the natural alignment of SOA-enabled Web services in healthcare processes. At the enterprise level, one can envision the strategic alignment of information technology with a healthcare organization's goal of delivering quality care.

But while the potential benefits are great, particularly the use of the Internet to deliver important health services, so are the challenges. A key issue is the need for robust modeling and development of Web services applications. Healthcare delivery is a highly complex process characterized by a multi-provider, multi-payer system. Modeling and representing healthcare processes—amidst the need for data integrity, privacy, security, real-time processing, interoperability (open system), portability, and scalability—is daunting. One solution is to extend existing techniques, such as the UML, which many consider the de-facto standard. A starting point is the standard UML modeling notation base defined by the W3C Web services group and OMG (Amir & Zeid, 2004). Aspects of the Web services applications across various platforms—such as the roles of service providers, requestors, and registries as well as the three operations of publish, find, and bind—need to be conceptualized in the SOA format. Further, a notation can be defined to support the actions. Moreover, the semantics of healthcare domain concepts have to be described to enable interpretation of their behavior. Additionally, the ontology of healthcare services must be developed.

These challenges in mind, we explore in this article the potential of a UML profile to model Web services in healthcare. We develop an application for a hypothetical health clinic, showing various elements that would comprise such a profile. This clinic is positioned to be an integral part of a larger, distributed healthcare delivery system that encompasses hospitals, labs, pharmacies, and insurance providers, such as HMOs. The diagrams that follow illustrate our model and visually identify its various parts. In this regard, one can use collaboration diagram notation. We propose a hierarchy of service components as the primary building blocks of the Web services architecture via concepts, meta models, and granularity types. Health service components are modeled as contract-based service providers and support the health organization's health processes through a formal orchestration. Simultaneously, they are realized as a composition of lower-level application service components (Skogan, Gronmo, & Solheim, 2004). These can be further mapped to more encompassing software artifacts. Fashioned in this way, the Web services architecture represents layers of abstraction between the healthcare processes and the operational information, minimizing inconsistencies. We introduce the concept of service component as the primary Web services building block. An important aspect of the article is the enunciation of a modeling approach that emphasizes the identification and specification of the service components of varied scope and granularity. This approach enables the evolution of a Web services healthcare solution.

The article is organized as follows. First, we discuss the potential of Web services in healthcare. Next, we explain the usefulness of the UML, particularly the profile in developing models. Then we develop the notion of a partial UML profile for a distributed health clinic example. Finally, we offer our conclusions for future applications and research

WEB SERVICES IN HEALTHCARE

Web services are defined as functional components (processes) situated in a particular domain and available over the Internet. In the healthcare area, these could include online query/response consultation with a physician, scheduling a patient visit, confirmation of a referral, and so on. The architecture would comply with a set of standards, such as those used with HTTP, XML SOAP, WSDL, or others (Vara et al., 2005). Alternatively, it is any service accessible over the Internet which takes XML as input and produces an XML result. The rationale behind a Web service composition is that many smaller tasks already identified as Web services can work together to execute a larger task. Such commands as VERIFY PATIENT DATA, CONFIRM PHYSICIAN, ROOM ASSIGNMENT, DATE/TIME AVAILABILITY, ASSIGN PATIENT TO SCHEDULE, and PROVIDE CONFIRMATION could collectively represent "PROCESS PATIENT VISIT SCHEDULE DATA." At the highest level a Web service implies delivery of high quality healthcare via the Internet. The services can be offered by multiple providers within the confines of the federation, a loosely coupled consortium of healthcare participants, and are typically published in a central repository. Finding the service is coordinated by a brokering mechanism. The Web services paradigm, then, enables the health services consortium to continue to function in a distributed fashion with localized control and use. In this way, applications extend beyond the intra-enterprise boundary to the inter-enterprise. Additionally, redundancy in services can be minimized by a repository. All participants in this "federation" can contribute to the creation of the services and use them. The benefits are numerous. Web services architecture mirrors the healthcare delivery mode and can be strategically dovetailed with the delivery organization functions. Also, middleware provides the interface so that legacy systems are not abandoned. Web services standards enforce compliance by vendors and platforms, thereby providing interoperability. This exploitation of the Internet would lead to maximal use of the health organization's capabilities and offerings, resulting quality patient care and satisfaction. That said, the application of Web services and SOA in the healthcare area is a relatively recent phenomenon. While knowledge about systems development can be transferred from other industries, the healthcare industry is more complex (fueled in part by the multiplicity of payers and providers) than most other industries. While the current trend towards universal electronic health records is a positive one, scalability and portability are important design challenges. Another hurdle is the minimal understanding of healthcare processes and workflow by application designers and vendors. Existing applications are ad hoc, incompatible system implementations. Plus, current standards are not at a level that Web services can be easily implemented. Methodologies and modeling tools are seriously lacking (Gronmo & Solheim, 2004).

But there is a bright side. UML-based approaches can be extended to the healthcare process modeling, providing a solid foundation for the implementation of Web services. For example, consensus on communication rules is important for all participants to succeed. This implies agreement on the ontology (Heuvel & Maamar, 2003). Anchoring the modeling of healthcare processes around the UML can minimize the learning curve because one can draw on the experience and knowledge currently available. The added advantage of bypassing legacy approaches and systems (especially in environments with no prior automation efforts) accrues.

Operationally, applications that are "services" must spell out their functional and non-functional (utility/procedural) requirements and capabilities in a prior agreement. Based on declarative service descriptions, automated service discovering, selection and binding provide the foundation for Web services applications. Therefore, an advantage arising from the dynamic binding is looser coupling between applications (Curbera, Khalaf, Mukhi, Tai, & Weerawarana, 2003). The componentized model emerging out of this process provides for "health services" forming the initial units for creating the application. Service composition and management become critical issues (Casati, Shan, Dayal, & Shan, 2003).

In healthcare, a service composition combines services and follows a certain pattern to achieve a healthcare goal, for example, properly discharging a patient from the hospital. An architecture that supports Web services includes the following aspects:

- The dynamic discovery of registered service, including searching for services that meet certain criteria, especially health criteria such as patient wait time, quality of care, and so forth;
- The intuitive organization of services so that one easily can understand what a service offers;
- The clear description of services, ensuring the proper use of each service.

This includes formats and protocols for invoking the Web service (Leymann, Roller, & Schmidt, 2002). A typical Web service follows this pattern: a service is created; the service is published; the service is located; the service is invoked. (Optionally, the service may be unpublished.) The complex services that a typical medical clinic provides vary widely across the patient group. An effective solution for the management of disparate medical data sources is federation of autonomous multi-center sites which transcends inter-enterprise boundaries. The resources in the federation—such as hospitals, diagnostic labs, and pharmacies—would be governed by the same sharing rules with respect to authentication, authorization, resource, and data access. These rules (protocols) create a highly controlled environment which dictates what is shared, who is allowed to share, and the conditions under which sharing occurs among the medical sites. Federation in this application implies cooperation of independent medical sites. Individually, these sites are autonomous in that they have separate and independent control of their local data. Collectively, those sites participate in a federation, and the federation is governed by the umbrella organization (let's say, a consortium of health providers) (Estrella et al., 2004). The ability of Web services to go beyond the health entity boundary (i.e. the firewall), the loose coupling between applications encouraged by Web service interfaces, and the wide support for core Web service standards by major enterprise software vendors are the key reasons why Web services have the potential to make integration of health applications both within and between health enterprises significantly more effective in terms of ease of implementation and cost savings. Loose coupling means that not only can applications be implemented on different platforms and operating systems, but also that the implementation can be changed readily without affecting the interfaces (Jiang, Xing, He, & Yang, 2005). One of the important modeling and design issues in building Web services is determining the type, scope, and granularity of service components necessary for representing the main architectural abstractions. Moreover, these different types of service components must be put in the wider context of a development process to provide that traceable business requirements are mapped to the software artifacts supporting them.

Having discussed the potential and implications of Web services in healthcare, we now turn to the examination of UML, its extensions and profile to model heath care processes in a robust fashion. How do we derive good service abstractions from high level healthcare domain requirements and health process models?

As a corollary, additional questions arise. What are good (health) services? For example, what is the right service granularity, and what does health process and information technology alignment mean from a modeling standpoint? How can the healthcare automation landscape be transformed into an integrated healthcare ecosystem? From a modeling standpoint, how can well-designed and meaningful service abstractions be characterized and constructed systematically? How are services in a Web service application identified and described? What is the process for developing Web services? How are health processes realized in terms of Web services? Which development approaches are relevant to a Web service? How can legacy systems and packaged applications be adapted as services? All of these questions emphasize the need to use an appropriate modeling approach.

UML PROFILE APPROACH TO MODELING WEB SERVICES IN HEALTHCARE

The identification and construction of a modeling language for Web services pose significant challenges. To provide rich and robust functionality there is a need to focus on the architecturally significant components particular to the Web services in a specific health system and to somehow model them with UML extensions. One way to manage the complexity of Web services is to abstract and model them. In a typical system there are multiple models, each representing a different perspective, layer of abstraction, and detail. Models help us understand systems by simplifying some of their details. But the decision as to what to model has a significant effect on the understanding of the problem (What are the health processes amenable to Web services modeling?) and solving it (How do you enable them?). UML has the potential to answer these challenges (Jiang et al., 2005). UML models and other architectural artifacts such as system context, component interaction and collaboration diagrams can play a key role during analysis and early design (Gronmo, Skogan, Skolheim, & Oldevik, 2004; Zimmermann, Schlimm, Waller, & Pestel, 2005). Also, use case, sequence, and class diagrams can help represent various modeling elements (Conallen, 2003).

A natural starting point for modeling Web services is component-based and interface-based modeling and the standard UML. But to what extent can component-based approaches and the UML fulfill requirements and provide necessary concepts and mechanisms for modeling the Web services, such as componentization, low coupling, high cohesion, interface-based design, hidden implementation, as well as flow of objects and actions? One can develop high-level models in UML, define conversion rules from UML to a target platform, and then use code generation to derive much of the implementation code for a desired platform.

Two key aspects have to be modeled: the service itself, and the workflow. Service modeling identifies which services are to be exposed with their interfaces and operation, while workflow modeling identifies the control and data flows from one service to the next. In a typical inter-enterprise application, one may first discover existing Web services, if any, from a registry. Then, service modeling identifies the interface of the composite Web service and the workflow focuses on reusability. Transformation rules from both models can be specified (Foster, Uchitel, Magee, & Kramer, 2003). The former is mapped to a WSDL document and the latter to a XML document. Finally, the XML document generates the code via a workflow engine. The WSDL document is published as a Web service registry. The UML, having evolved into a standard modeling language, is appropriate to model the service and the workflow. Given its visual format and wide use, the UML is a good candidate for diagramming comprehensible models. Diagrams are a natural part of UML and are used for workflow modeling of Web service compositions. Building composite Web services lacks sufficient support in traditional workflow modeling. Further, the UML seems suitable for expressing Web service patterns (Gronmo & Solheim, 2004). The diagrams and modeling elements can be extended to develop a high level profile of the healthcare process.

UML Profile

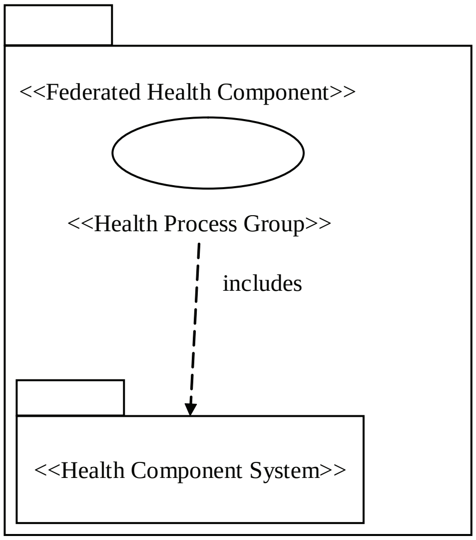
One strength of the UML is its adaptability to specific vertical markets with specific concepts and needs. In the UML standard these are called profiles (Heckel, Lohmann, & Thone, 2003). Various groups working with UML have started to address the customization of UML models for various domains by defining "profiles." The objective for the healthcare process domain is the definition of a generalized UML subset, embellished with UML-compliant extensions, which would permit the annotation of such concepts (Baresi, Garzotto, & Paolini, 2001). Thus, the resulting profile corresponds not to specific domains in healthcare (e.g. diabetes monitoring) but to healthcare processing wherein diabetes monitoring is one service component. While profiles may be standardized in the future, stable initiatives from various groups can form the basis for the definition and standardization of UML profiles (Thone & Varro, 2003). Profiles thus facilitate consideration of the key issues in healthcare processing, namely interoperability, portability, scalability, and universal standards. UML being a complex language, additional features cannot be described easily in the current version, though Version 2.0 may provide extensions. Therefore, UML provides mechanisms such as stereotypes and tagged values to enable extensions (Fontoura, Pree, & Rumpe, 2002; OMG.), and the defined extensions can be grouped into profiles. A UML profile is further defined as an extension of the UML standard language with specific elements. The profile provides new notational elements and typically facilitates specialization of the semantics of some of the elements. Usually the profile builds a hierarchy. The creators of the UML realized that there would always be situations in which, out of the box, the UML would not be sufficient to capture the relevant semantics of a particular domain or architecture. To address this issue, a formal extension mechanism was defined to allow practitioners to extend the semantic of the UML. UML provides two extension mechanisms—stereotypes and tagged values—for describing specific properties of the elements, such as classes, associations and methods (for example, role of "human" as "patient", a patient "visit", and a patient "schedule" in the context of healthcare). The roles and artifacts of the service-oriented style are represented in several diagrams that follow. The mechanism enables one to define stereotypes, tagged values and constraints that can be applied to model elements. A stereotype is an elaboration that allows one to define a new semantic meaning for a modeling element. Stereotypes indicate that the class is an abstraction of the logical behavior of a Web service on either the client or the server. Tagged values are key value pairs that can be associated with a modeling element and allow us to tag any value onto that element. Tagged values are used to define the parameters that are passed along with a link request. The <<link>> association tagged value "parameters" is a list of parameter names (and optional values) that are expected and used by the server page that processes the request. Constraints are rules that define the structure of a model (Fontoura et al., 2002).

One could say each Web service is a UML class. The server side of a Web service can be modeled with one class and the client side with another, distinguishing the two by using UML's extension mechanism to define stereotypes and icons for each <<server page>> and <<client page>>. Using stereotypes makes its easier to model a service's actions and its relationships. Class stereotypes used to model the logical behavior of Web pages means their collaboration with the server side components can be expressed in much the same way as any other server side collaboration (Conallen, 1999). While UML was not originally devised to model health processes or services, one can use the stereotyping capability to develop new extensions to UML. The UML business profile, designed to facilitate business process modeling purposes, is one example.

The Health Clinic Example

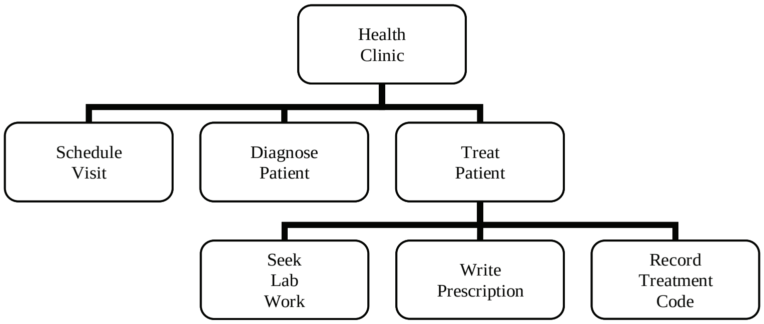
It is possible to provide a UML extension for health service modeling using typical stereotypes. Figure 1 shows the general relationships amongst some of the UML elements. A federated healthcare component performs specialty activities as its services. On the other hand, the specialty itself is decomposed to lower level services, encompassed within a medical entity. It is also similar for other levels of service/process granularity hierarchy. At the architectural level, other types of diagrams are involved, such as class diagrams with interfaces to define signatures and data types of operations, and sequence diagrams as alternative presentations of interactions (Heuval & Maamar, 2003). The Web service domain can be mapped by UML modeling concepts, providing platform independent representation as UML activity and component diagrams. Additionally, a collaboration diagram selected to represent the encapsulation of the binding mechanism as semantically precise as possible and provide all the necessary concepts and capabilities for representing integrations and collaborations of its participating parts. The diagrams, along with structured classes, can support the representation of the composition of interconnected elements representing run time instances, and the collaboration over communication links to achieve common objectives. In particular, collaborations provide the means to define common interactions between objects and other classifiers and assign roles and responsibilities to each. The interaction is similar to providing a pattern of communication between objects playing defined roles. Alternatively, the profile is equated with equivalent meta models. By defining their meta model relationships and interaction mechanisms, one can support the integration and interoperability of their models. In that way one can design complete system models having formalized interaction points and perform model transformations across multiple connected meta models (Staikopoulos & Bordbar, 2005). For example, UML and its standard profiles (CORBA, EJB, and EDOC) can be used to model PIM (Platform Independent Model) or PSM (Platform Specific Model) in the Model Driven Architecture (Brown, 2004). Design decisions can be defined by the UML profile, which provides a set of extensions to UML using the built-in extension facilities of UML, stereotypes and tagged values. The profiles provide a mechanism for managing stereotypes. The profile for healthcare would comprise the range of models derived from UML modeling. The same profile can be used across many projects. Using profiles in this manner (i.e. packages can be exchanged between models) will ensure a standardized approach to problem solving. UML extension mechanisms can help bridge between various models. Using the basics of the class diagram, the systems engineer can model the stack with relative ease. However, for the developer to implement it, he or she will need additional information. UML stereotypes can help clarify the stack requirements. In this context, stereotype is a "label" that can be used to "characterize" a model item in some way. For example, an actor

Figure 1. A sample UML representation for health processes and services (adapted from Fatolahi & Shams, 2005)



could be stereotyped as <<Patient>> <<Clinic>> or <<Service>>. A stereotype is a model element that defines additional values (based on tag definitions) and additional constraints. These can be applied to any model element. Stereotypes label a model element to denote that the element has some particular semantics. UML allows an application model to be constructed, viewed, developed, and manipulated in a standard way at analysis and design time. Just as blueprints represent the design for an office building, UML models represent the design for an application, allowing business functionality and behavior to be represented clearly by business experts at the first stage of development and away from vendor-driven preconceptions. The abstract syntax in UML's meta model is described by UML's class diagram which can represent the abstract syntax structure strictly and precisely (Jiang et al., 2005). For the purpose of health component identification, domain object analysis, and use case analysis are useful sources of input. Domain object analysis defines a domain vocabulary of the system being developed, in other words, information about health concepts in the problem area that should be handled by the system together with their attributes and relationships. Use case analysis is an effective mechanism for defining cohesive sets of features and services on the system boundary because they capture the intended behavior of the system without having to specify how that behavior is implemented. The use cases of the appropriate granularity correspond to the provider's health goals and activities, otherwise known as Elementary Health Processes (EHPs). The cases can be specified in detail according to the use case template that includes name, description, involved actors, goal in the context, scope, level, pre-condition, post-conditions, triggers, main success scenario, extensions, sub-scenarios priority, frequency, performance, etc. Figure 2 depicts a healthcare process hierarchy for this sample case. For simplicity only one thread is decomposed into its EHPs. The stereotyping helps translate the somewhat abstract class diagram into a domain specific platform independent model and platform specific model. For each use case, the use cases that precede it, follow it, perform in parallel with it or are synchronized in other ways with it should be defined. Furthermore, for each use case its super ordinate and subordinate use cases should be defined, providing a composite hierarchy of use cases, (i.e. corresponding business goals). This can be illustrated using a sequence diagram enriched to express the action semantics with the use cases on the horizontal axis of the diagram. Finally, domain information types resulting from domain analysis are cross-referenced with the use cases. In this way, for each use case the information types needed for its performance are defined. A healthcare service may be seen as a component, which in turn is defined as a self contained health process or service with predetermined functionality that may be exposed through a provider or technology interface. This indicates an implicit relationship between the notions of

Figure 2. Healthcare process hierarchy



service, process and component. One can then match the hierarchy of service-components with the hierarchy of healthcare processes in order to gain effective services. Since healthcare processes are significant components of the health delivery architecture and services are the major elements of a Web services' architecture, mapping may be seen as a bridging mechanism between the abstract health service models and the system architectures. A primary healthcare process, called a process group, may contain a series of sequencing process threads. Each thread results in a major added value for a healthcare delivery organization (called a provider), and is composed of its offspring elementary health processes (EHPs), which are the smallest meaningful units of activity for the end user, and which when complete leaves the information area in a self-consistent state. Each EHP may transform to some use cases when designing systems to support its holding thread. Therefore, a process group may decompose to a series of process threads each of which in turn may hold several EHPs. It is necessary to base the services on EHPs. An EHP can indicate which services are required by the enterprise and which of them are provided by the enterprise. Operationally, a health process may be a collection of services. The concepts are illustrated using a "Health Clinic" application that is distributed in residence of the data as well as functionality and use. Table 1 shows the service component hierarchy in the context of healthcare.

A federated health component is a set of services which are common to the various healthcare delivery organizations, including clinics, hospitals, HMOs, labs, and pharmacies. A health component system is a set of health service components assembled to deliver a healthcare solution, such as, providing quality healthcare to a patient. A health component is itself an independent concept, process or service. Distributed components and language classes are physical software components (e.g. an underlying database) and classes designed for implementation. It is sufficient to follow the hierarchy of health processes in order to record included services at each level. But this does not mean every process is a service. Identifying the specific services to be implemented using a specific technology, such as a Web service, it may be enough to verify EHPs and decompose each EHP into Derived Logical Processes (DLPs). Each DLP can be a stand-alone process that does not require human intervention. The hierarchy provides a means to package services in well-defined components that are of interest to different users at various levels (Fatolahi & Shams, 2005). Table 2 shows the generic UML stereotyping for healthcare. An EHP included by the schedule is developed here. Figure 3 shows the UML stereotyping for the SCHEDULE VISIT thread for the clinic example. It indicates how the UML stereotyping mechanism may help us in modeling the services in the healthcare processes. The diagram presents the schedule visit thread and some of the linked services. Now consider the

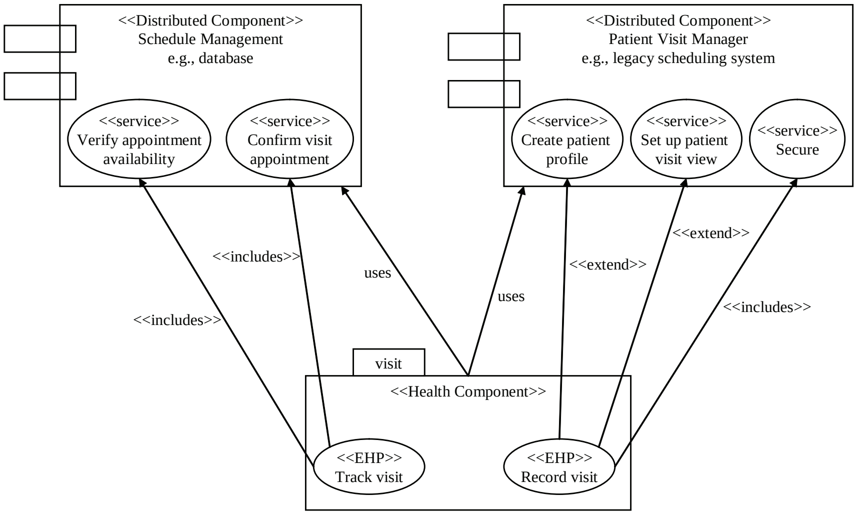
Table 1. Service component hierarchy classifies health services through a hierarchy of granularity/service (adapted from Fatolahi & Shams, 2005).

Health Service Component Granularity	Example
Federated health component	Process group – Consortium of health care delivery participants
Health component system	Process thread – Health clinic
Health component	Use case (EHP) – Process Patient Schedule
Distributed component	Distributed database
Language Class	Method – Verify schedule availability

Table 2. UML stereotyping for health care (adapted from Fatolahi & Shams, 2005)

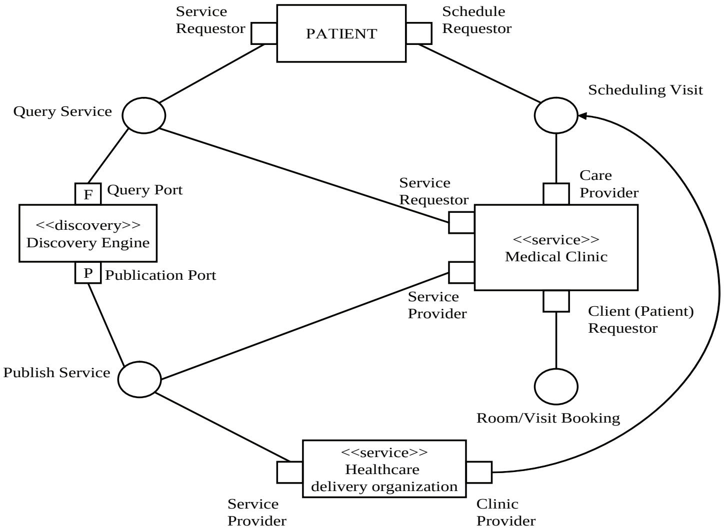
Service Component Stereotype	UML Element
Federated health component	Package
Health component system	Package
Health component	Package
Distributed component	Component (e.g., database)
Language Class	Class

Figure 3. UML stereotyping for the Schedule Visit thread (adapted from Fatolahi & Shams, 2005)



medical clinic application that serves as a manager (coordinator) of scheduling and coordinating patient visits. For simplicity, we restrict the functionality to scheduling a patient visit. For this purpose, the clinic software should be able to connect to third party (e.g. referring physician, hospital) information systems. After a patient requests a visit, the system has to query the third party systems as well as internal systems to select appropriate dates/place/location and schedule the patient visit. These requirements lead to a dynamic distributed system where new components can be brought up by the medical facility (e.g. hospitals) at execution-time. The application can be implemented as a Web service as modeled with the UML profile. Models can be differentiated at the various type levels (Baresi, Heckel, Thone, & Varro, 2004). Component diagrams can be used to show the component types of the applications, including the interfaces at the ports. Figure 4 is a partial component diagram of the health clinic example. The patient (or representative) requests to schedule a visit from the clinic. This action links to different delivery organizations. All healthcare delivery organizations need to publish Web services to accept the queries from external clinic systems in a healthcare UDDI Web services registry. When the clinic system queries third party systems, it discovers the Web services in the UDDI Web services registry, then binds the Web services at their particular Web location, and finally obtains the requested information by

Figure 4. Web services specific component diagram (adapted from Baresi et al., 2004)



execution of the Web services. The UDDI helps integrate the healthcare service across various healthcare delivery organizations in an open environment. While WSDL and SOAP describe the service interface and communication protocol once a specific service is located, UDDI enables the service consumer to reach the service provider through a multitude of Web services available. The Service Provider registers the information about the service in the UDDI Registry by publishing the service, and the Service consumer queries the UDDI Registry to discover services matching certain criteria, all through standard defined UDDI APIs (UDDI.org, 2002).

UDDI becomes a key element in Web services runtime environment and life cycle when the services are dynamic and evolving, and the binding for a service is non-deterministic. It is conceivable that service consumer will eventually discover and use the most desirable service through a streamlined find-bind-execute process without human interaction.

Additionally, the details of the port types and the interfaces may be defined by class diagrams. A partial class diagram is shown in Figure 5. The class diagram also contains stereotyped associations. These define types for links that are available to connect to the various ports. We also need to model packages of the component instances in a run-time scenario. UML collaboration diagrams can be used for this purpose. Figure 6 is an example collaboration diagram for the health clinic. Various labels can be applied to the changed instances and links during run-time. The communication features are shown by assigning messages to the link symbols. Numbers are used to indicate the sequence of the messages. The displayed specification artifacts, such as service descriptions and service requirements, are needed to enable the Web service-specific capability of dynamic service discovery (Baresi et al., 2004). An objective of the health clinic system is to provide integrated scheduling and visit services for patients by loose coupling of providers, customers (patients) and related-entities solutions already residing at their sites. Each of these can be accessed via Web service interfaces, and incoming requests are forwarded to all known services (medical; participants). Figure 7 shows a collaboration diagram modeling a hypothetical scenario to execute a query on the meta scheduling system (schedule/visit). Prior to dispatching a query, the client (patient) has to

Figure 5. Web services specific class diagram (adapted from Baresi et al., 2004)

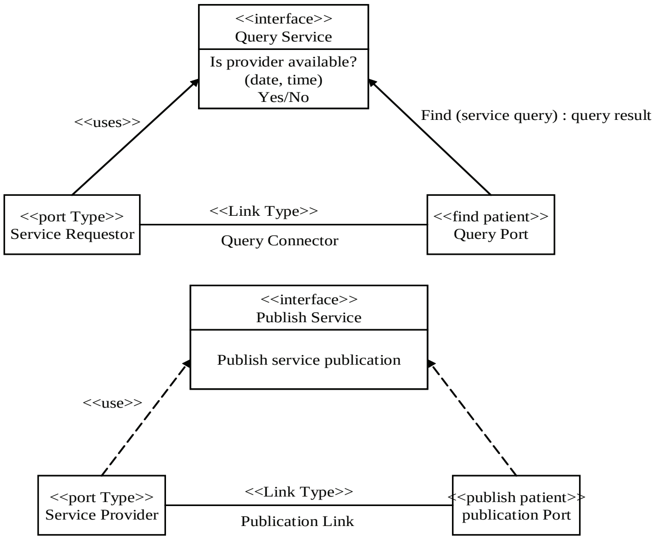
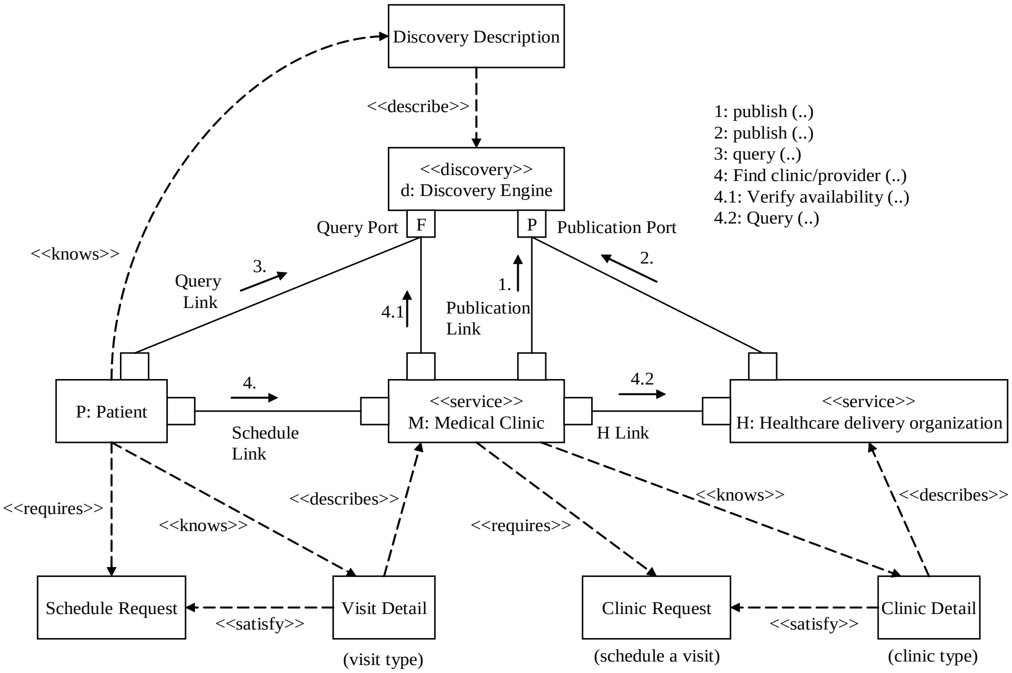


Figure 6. Web services specific collaboration diagram (adapted from Baresi et al., 2004)



choose the local scheduling systems where the query ought to be run. Then the client retrieves a list of scheduling systems that are registered with the meta scheduling system ("discovery"), for example, the lab, and surgery. The search string is sent simultaneously to all selected scheduling systems. For this situation, a UML component diagram can identify the various components and interfaces for the given system. From the scenario in Figure 7 one can derive the UML component diagram in Figure 8 to identify the (types of) components and interfaces used in the application. The objective to develop UML profiles for healthcare frameworks is a potential definition of UML subsets incorporating extensions and annotating the artifacts. The examples represented by the various diagrams contribute to the overall development of profiles in healthcare.

CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

While the Web services paradigm is gaining attention in the development and integration of complex healthcare applications, there is an almost complete lack of modeling approaches. Web services modeling is a challenging task because the service concept further raises the level of abstraction and actually aims at narrowing the gap between the healthcare process and the software. Therefore, for the purpose of Web services modeling, the best practices from object-orientation and component-based design as well as work flow and health process modeling, must be considered and thoroughly integrated. In this article, we propose a UML profile for modeling Web services in healthcare. We describe the various components of such a profile for a hypothetical medical clinic whose interactions are characterized by distributed ness, need for interoperability, portability and scalability. Such profiles developed and standardized over time, will assist the healthcare industry in implementing robust Web services applications for a range of healthcare processes. The paradigm of Web services enables healthcare organizations to shift from tightly coupled and coarse-grained applications to more dynamic and loosely coupled ones. The UML profile outlined in this article requires further refinement especially if platform-specific details are added. The article has proposed a way to model the services components in a healthcare scenario that enable their realization and the orchestration as the primary building blocks of the Web services architecture. While the research is exploratory one can build on the concepts outlined here to develop comprehensive UML profiles for the various services in healthcare. This would advance the goal of uniform standards for interoperability as health related organizations rapidly develop electronic health record systems, clinical decision support systems and other applications. We advocate the notion of a profile along with the concept of a service component, a paradigm shift from components as static objects to components as dynamic service coordinators. In the future, specific mapping rules for transforming platform-

Figure 7. Collaboration diagram modeling executing of a query (adapted from Heckel et al., 2004)

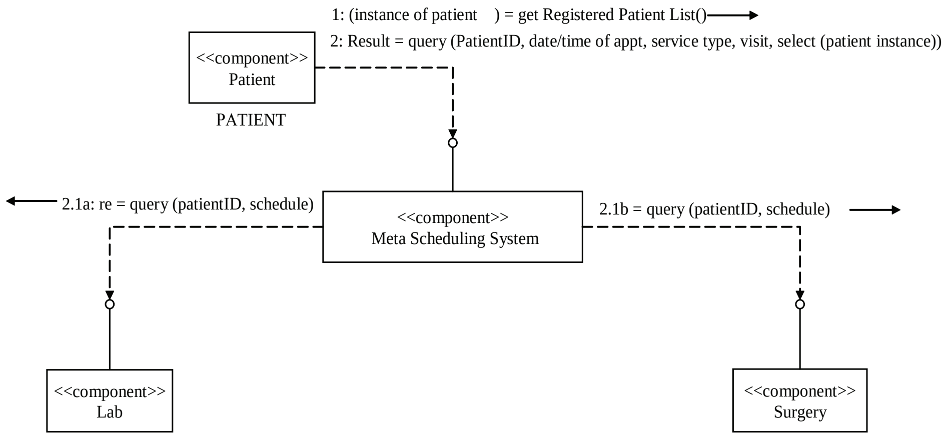
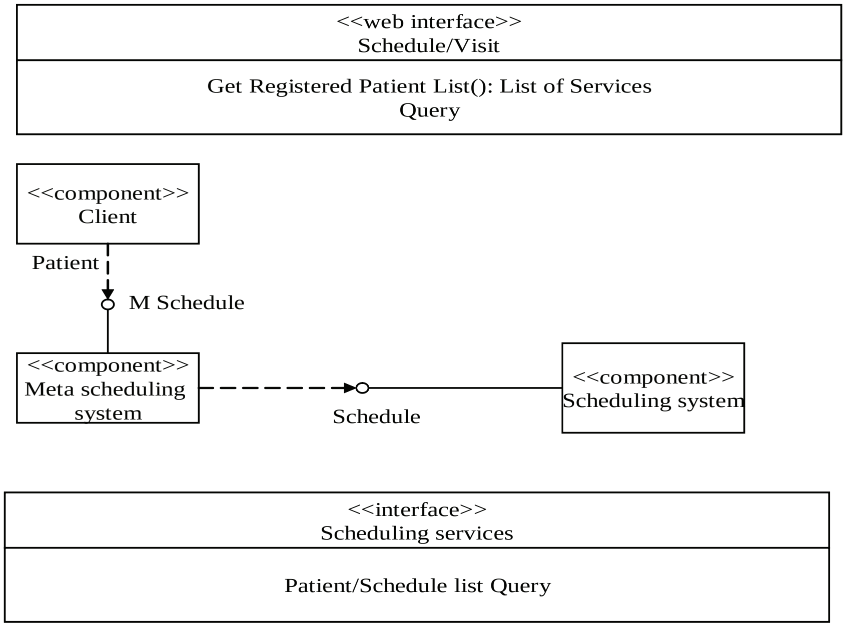


Figure 8. Partial health services architecture derived from collaboration diagram (*adapted from Heckel et al., 2004)*



independent models into platform-specific models have to be identified (Stojanovic et al., 2004). We envision health processes as reliable resources to discover services in SOA-enabled Web services (Fatolahi & Shams, 2005) architecture for healthcare delivery organizations (for both, profit and non profit sectors). Also, in the future the UML profile approach developed here can be extended and standardized to facilitate reusability and universal application of Web services in healthcare. Additional research can provide insight into UML extensions and stereotyping in health services as well as enable definition of standards for open source development of applications in healthcare. Finally, integration with HL7 standards has to be addressed. In this way, there is incremental contribution to the advancement of global applications of information technology in healthcare. Loosely federated Web-enabled systems at this level could help track and monitor health issues, such as pandemics, on a global scale.

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Chapter 2.20

Data Warehouse Design to Support Customer Relationship Management Analysis

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ABSTRACT

CRM is a strategy that integrates concepts of knowledge management, data mining, and data warehousing in order to support an organization's decision-making process to retain long-term and profitable relationships with its customers. This research is part of a long-term study to examine systematically CRM factors that affect design decisions for CRM data warehouses in order to build a taxonomy of CRM analyses and to determine the impact of those analyses on CRM data warehousing design decisions. This article presents the design implications that CRM poses to data warehousing and then proposes a robust multidimensional starter model that supports CRM analyses. Additional research contributions include the introduction of two new measures, percent success ratio and CRM suitability ratio by which CRM models can be evaluated, the identification of and classification of CRM queries, and a preliminary heuristic for designing data warehouses to support CRM analyses.

INTRODUCTION

It is far more expensive for companies to acquire new customers than it is to retain existing customers. In fact, acquiring new customers can cost five times more than it costs to retain current customers (Massey, Montoya-Weiss & Holcom, 2001). Furthermore, according to Winer (2001), repeat customers can generate more than twice as much gross income as new customers. Companies have realized that instead of treating all customers equally, it is more effective to invest in customers that are valuable or potentially valuable, while limiting their investments in non-valuable customers (i.e., not all relationships are profitable or desirable). As a result of these types of findings as well as the fact that customers want to be served according to their individual and unique needs, companies need to develop and manage their relationships with their customers such that the relationships are long-term and profitable. Therefore, companies are turning to Customer Relationship Management (CRM) techniques and CRM-supported technologies.

In our earlier work (Cunningham, Song, Jung, & Chen, 2003), we defined CRM as a strategy that utilizes organizational knowledge and technology in order to enable proactive and profitable long-term relationships with customers. It integrates the use of knowledge management, or organizational knowledge, and technologies to enable organizations to make decisions about, among other things, product offerings, marketing strategies, and customer interactions. By utilizing a data warehouse, companies can make decisions about customer-specific strategies such as customer profiling, customer segmentation, and cross-selling analysis. For example, a company can use a data warehouse to determine its customers' historic and future values and to segment its customer base. shows four quadrants of customer segmentation: (1) customers that should be eliminated (i.e., they cost more than what they generate in revenues); (2) customers with whom the relationship should be re-engineered (i.e., those that have the potential to be valuable, but may require the company's encouragement, cooperation, and/or management); (3) customers that the company should engage; and (4) customers in which the company should invest (Buttle, 1999; Verhoef & Donkers, 2001). The company then could use the corresponding strategies, as depicted in Table 2, to manage the customer relationships. Table 1 and Table 2 are only examples of the types of segmentation that can be performed with a data warehouse. However, if used, a word of caution should be taken before categorizing a customer into Segment I, because that segment can be further segmented into (a) those customers that serve as benchmarks for more valuable customers, (b) those customers that provide the company with ideas for product improvements or efficiency improvements, and (c) those customers that do not have any value to the company.

It is important to point out that customer segmentation can be further complicated by the concept of extended households. The term *extended household* refers to the relationship that exists between companies (e.g., parent company and subsidiary). The analysis of the relationships that exist between customers (i.e., lines of potential customer influence) is known as household analysis. It is important to understand and manage extended households, because a company's decision to treat a member of one segment potentially could have a negative impact on a related customer. For example, if a customer is in a non-profitable segment, then the company may decide to increase the customer's price. However, if the company is aware that the same non-profitable customer has influence over another customer (e.g., a parent or small business) that is in a more profitable segment, then the company may decide to not increase the customer's price rather than to risk losing both of the customers. Clearly, these social networks of influence are

Table 1. Customer segments

		Historic Value	
		Low	High
Future Value	High	II. Re-Engineer	IV. Invest
	Low	I. Eliminate	III. Engage

Table 2. Corresponding segmentation strategies

		Historic Value	
		Low	High
Future Value	High	Up-sell & cross-sell activities and add value	Treat with priority and preferential
	Low	Reduce costs and increase prices	Engage customer to find new opportunities in order to sustain loyalty

important for companies to identify and manage because of the impact that they can have on the company's ability to retain customers.

Currently, however, there are no agreed upon standardized rules for how to design a data warehouse to support CRM. Yet, the design of the CRM data warehouse model directly impacts an organization's ability to readily perform analyses that are specific to CRM. Subsequently, the design of the CRM data warehouse model contributes to the success or failure of CRM. In fact, recent statistics indicate that between 50% and 80% of CRM initiatives fail due to inappropriate or incomplete CRM processes and poor selection of technologies (Myron & Ganeshram, 2002; Panker, 2002). Thus, the ultimate long-term purpose of our study is to systematically examine CRM factors that affect design decisions for CRM data warehouses in order to build a taxonomy of CRM analyses and to determine the impact of those analyses on CRM data warehousing design decisions.

The taxonomy and heuristics for CRM data warehousing design decisions then could be used to guide CRM initiatives and to design and implement CRM data warehouses. The taxonomy also could be used to customize a starter model for a company's specific CRM requirements within a given industry. Furthermore, that taxonomy also would serve as a guideline for companies in the selection and evaluation of CRM data warehouses and related technologies.

In order to objectively quantify the completeness and suitability of the proposed CRM model (and alternative models), we propose two new metrics: *CRM success ratio* ($r_{success}$) and *CRM suitability ratio* ($r_{suitability}$). The *CRM success ratio* ($r_{success}$) is defined as the ratio of queries that successfully executed to the total number of queries issued against the model. A query is executed successfully if the results that are returned are meaningful to the analyst. The *CRM success ratio* cannot be used only to evaluate our proposed CRM model, but it also can be used to evaluate other CRM data warehouse models, as well. The range of values for $r_{success}$ is between 0 and 1. The larger the value of $r_{success}$, the more successful the model. The following equation defines the CRM success ratio:

$$r_{success} = Q_p / Q_n \tag{1}$$

where Q_p is the total number of queries that successfully executed against the model, and Q_n is the total number of queries issued against the model.

The *CRM suitability ratio* ($r_{suitability}$) is defined as the ratio of the sum of the individual suitability scores to the sum of the number of applicable categories. The following equation defines the CRM suitability ratio:

$$r_{suitability} = \sum_{i=1}^{N} (\mathrm{X_i C_i}) / \mathrm{N} \tag{2}$$

where N is the total number of applicable analysis criteria, C is the individual score for each analysis capability, and X is the weight assigned to each analysis capability.

The range of values for the $r_{suitability}$ ratio is between 0 and 1, with values closer to 1 being more suitable. Unlike the $r_{success}$ ratio, which can be used to evaluate and compare the richness and completeness of CRM data warehouse models, the $r_{suitability}$ ratio, however, can be used to help companies to determine the suitability of the model based upon the contextual priorities of the decision makers (i.e., based upon the company-specific CRM needs). We utilize the two metrics to evaluate the proposed CRM data warehouse model in our case study implementation.

A brief review of CRM literature is presented in the next section. The section on schema design introduces the analytical CRM analyses requirements that the data warehouse must support as well as provides guidelines for designing the fact tables and the dimensions. The experiment, which is subsequently described with the results in the following section, tests the completeness of the model. The flexibility of the model, the utilization of the CRM analyses, as well as the initial heuristics for designing a CRM data warehouse are presented in the discussion. Finally, the research contributions and future work are discussed in the conclusions

CRM LITERATURE REVIEW

The shift in marketing paradigms from mass marketing to target marketing to the customer-centric one-to-one marketing (known as relationship marketing) is driving CRM (Bose, 2002). Mass marketing is a product-focused approach that allows companies to reach a wide audience with little or no research, irrespective of the consumer's individual needs. Unlike mass marketing, target marketing focuses on marketing to segmented groups that share a similar set of characteristics (e.g., demographic information and purchasing habits). While both approaches are cost-effective, they do not allow for personalization. On the other hand, one-to-one marketing (relationship marketing) enables companies to treat customers individually according to their unique needs. Since not all relationships are profitable or desirable, relationship marketing allows companies to focus on customers that have the best potential lifetime value. In order to identify the appropriate customer-specific approach for managing individual customers, we first must classify customers into one of the four quadrants in Table 1 and subsequently apply the appropriate strategy. In the literature, researchers use the total historical value, total potential future value, and customer lifetime value (CLV). In fact, managing the CLV is essential to the success of CRM strategies (Bose, 2002), because companies that understand and utilize CLV are 60% more profitable than those that do not (Kale, 2004). There are many ways to define and calculate those measures (Hawkes, 2000; Hwang, Jung & Suh, 2004; Jain & Singh, 2002; Rosset, Neumann, Eick & Vatnik, 2003). For the purposes of this article, CLV is the sum of the total historical value and the total potential value for each customer. The following equation defines the *total historical value*:

$$\text{Historical Value} = \sum_{i=1}^{N} (\text{Revenue}_j - \text{Cost}_j) \quad (3)$$

where j is the individual products that the customer has purchased.

In Equation (3), the historical value is computed by summing the difference between the revenue and total cost over every product (j) that the customer has purchased in the past. The cost would include such things as product cost, distribution cost, and overhead cost. Using the same calculation as defined by Hwang et al. (2004), the following equation defines the *potential future value* for a customer:

$$\text{Potential Future Value} = \sum_{i=1}^{N} (\text{Probability}_j \times \text{Profitability}_j) \quad (4)$$

where j is the individual products that the customer potentially could purchase.

In Equation (4), the profitability represents the expected revenues minus the sum of the expected costs that would be incurred in order to gain the additional revenues. The probability represents the likelihood that the customer would purchase the product. Thus, the total potential future value would be the sum of individual potential future value of each product that the customer could potentially purchase. The sum of all of the individual customer lifetime values is known as *customer equity* (Rust, Lemon & Zeithaml, 2004).

One of the goals of companies should be to increase their customer equity from one year to the next. By incorporating the ability to compute the CLV into the CRM data warehouse, companies can utilize the CRM data warehouse to determine their customer growth. Additionally, companies can use key performance indicators (KPIs) to identify areas that could be improved. Specific KPIs should relate to the goals of the organization. For example, if a company wants to minimize the number of late deliveries, then an on-time delivery KPI should be selected. Some known KPIs that are relevant to CRM include, but are not limited to, margins, on-time deliveries, late-deliveries, and customer retention rates. Other KPIs that are relevant to CRM include, but are not limited to, marketing cost, number and value of new customers gained, complaint numbers, and customer satisfaction rates (Kellen, 2002).

SCHEMA DESIGN FOR CRM

The first step in any design methodology is to understand the requirements. As such, the minimum requirements for CRM analyses are presented in the CRM analysis requirements section. The specific CRM analysis requirements as well as the need to classify customers according to the four CRM quadrants presented in Table 1 then are used to identify the specific fact tables and dimensions. The heuristics (or guidelines) for modeling the fact tables and dimensions then are explored in the design rationale for the fact tables and design rationale for the dimensions subsections.

CRM Analysis Requirements

The purpose of a data warehouse is not just to store data but rather to facilitate decision making. As such, the first step to designing the schema for the CRM data warehouse is to identify the different types of analyses that are relevant to CRM. For example, some typical CRM analyses that have been identified include customer profitability analysis, churn analysis, channel analysis, product profitability analysis, customer scoring, and campaign management.

In addition to identifying what CRM analyses the data warehouse needs to support, we also must understand how the data analyses are used by the business users. Often, understanding the business use of the data analyses provides additional insights as to how the data should be structured, including the identification of additional attributes that should be included in the model.

Once the specific types of CRM analyses as well as the intended uses of those analyses have been identified, they can be decomposed into the data points that are needed to support the analyses. Moreover, additional data points also can be identified from both experience and literature (Boon, Corbitt, & Parker, 2002; Kellen, 2002; Rust et al., 2004). It should be noted that the additional data points could include non-transactional information such as customer complaints, support calls, and other useful information that is relevant for managing the customer relationships. Furthermore, the non-transactional information could exist in a variety of formats, such as video and graphics (Bose, 2002). Such data formats are beyond the scope of this article. Table 3 identifies the types of analyses that are relevant to CRM as well as some of the data maintenance issues that must be considered. In other words, Table 3 identifies the minimum design requirements for a CRM data warehouse (DW). It should be noted that there is no significance to the order in which the items are listed in Table 3. The design rationale in the following section is based on the minimum design requirements in Table 3.

Design Rationale for the Fact Tables

The model needs to have fact tables that can be used to compute the historical and future values for each customer, because they are used to classify customers. As such, the model consists

Table 3. Minimum design requirements for CRM DWs

No.	**Analysis Type/Data Maintenance**	**Description**
3.1	Customer Profitability	Ability to determine profitability of each customer
3.2	Product Profitability	Ability to determine profitability of each product
3.3	Market Profitability	Ability to determine profitability of each market
3.4	Campaign Analysis	Ability to evaluate different campaigns and responses over time
3.5	Channel Analysis	Ability to evaluate the profitability of each channel (e.g., stores, web, and phone)
3.6	Customer Retention	Ability to track customer retention
3.7	Customer Attrition	Ability to identify root causes for customer attrition
3.8	Customer Scoring	Ability to score customers
3.9	Household Analysis	Ability to associate customers with multiple extended household accounts
3.10	Customer Segmentation	Ability to segment customers into multiple customer segmentations
3.11	Customer Loyalty	Ability to understand loyalty patterns among different relationship groups
3.12	Demographic Analysis	Ability to perform demographic analysis
3.13	Trend Analysis	Ability to perform trend analysis
3.14	Product Delivery Performance	Ability to evaluate on-time, late and early product deliveries
3.15	Product Returns	Ability to analyze the reasons for and the impact of products being returned
3.16	Customer Service Analysis	Ability to track and analyze customer satisfaction, the average cost of interacting with the customer and the time it takes to resolve customer complaints
3.17	Up-selling Analysis	Ability to analyze opportunities for customers to buy larger volumes of a product or a product with a higher profitability margin
3.18	Cross-selling Analysis	Ability to identify additional types of products that customers could purchase, which they currently are not purchasing
3.19	Web Analysis	Ability to analyze metrics for web site
3.20	Data Maintenance	Ability to maintain the history of customer segments and scores
3.21	Data Maintenance	Ability to integrate data from multiple sources, including external sources
3.22	Data Maintenance	Ability to efficiently update/maintain data

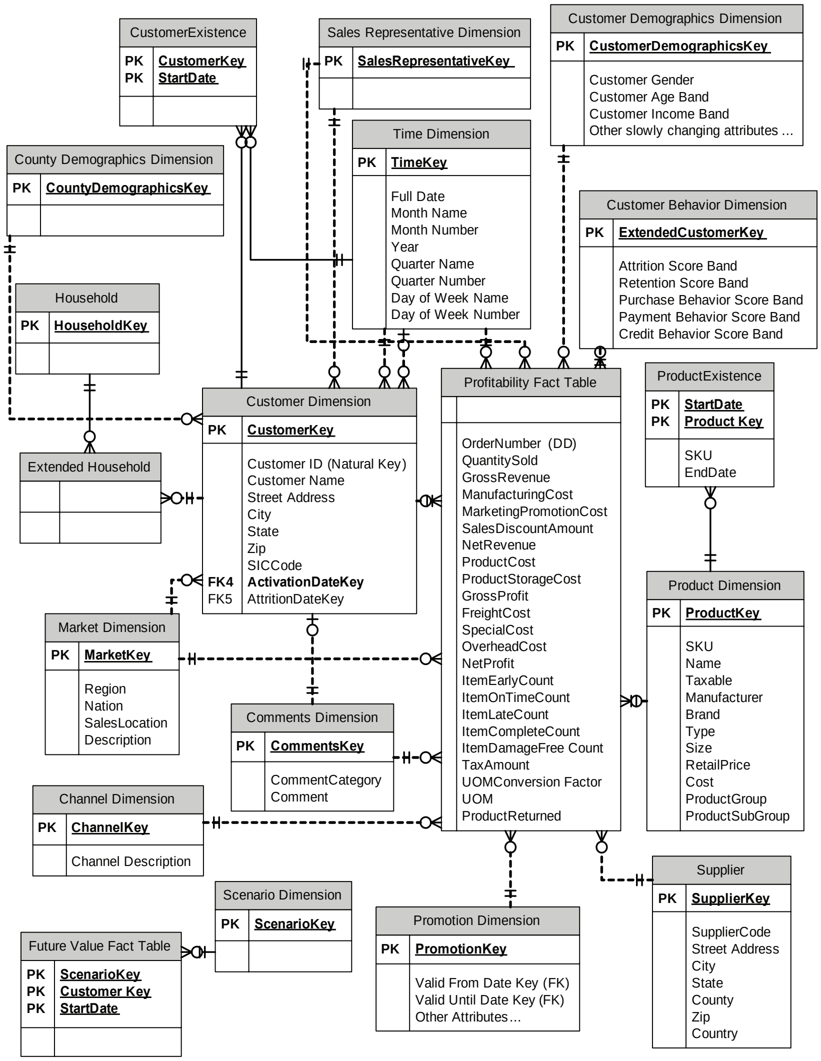
of a profitability fact table, a future value fact table, a customer service fact table, and various dimensions, which are defined in Table 4. We note that not all of the fact tables and dimensions are included in Figure 1. The profitability fact table includes the attributes (e.g., revenues and all costs—distribution, marketing, overhead, and product) that are required to compute the historical profitability of each transaction in the profitability fact table with the minimum number of joins.

Table 4. Starter model dimension definitions

Dimension Name	Dimension Definition
Channel Dimension	Stores the different modes for interacting with customers
Customer Dimension	Stores the static information about the customer
Customer Behavior Dimension	Stores the dynamic scoring attributes of the customer
Customer Demographics Dimension	Stores the dynamic demographic characteristics of the customer
CustomerExistence	Tracks the periods in which the customer is a valid
CustomerMarket	Tracks changes in the relationship between the customer and market dimensions
Comments Dimension	Stores the reasons for customer attrition and product returns
Company Representative	Stores the company representatives (sales representatives)
County Demographics Dimension	Stores external demographics about the counties
Extended Household	Represents the fact that the customer may belong to one or more extended households
Market Dimension	The organizational hierarchy and regions in which the customer belongs
Product Dimension	Represents the products that the company sells
ProductExistence	Tracks the periods in which the products are valid
Promotion Dimension	Represents the promotions that the company offers
Prospect	Stores information about prospects
Scenario Dimension	Used to analyze hypothetical up-selling and cross-selling scenarios
Supplier Dimension	Represents the vendors that supply the products
sTime Dimension	The universal times used throughout the schema
Time Dimension	Universal dates used throughout the schema

That, in turn, improves the performance when querying the data warehouse. Additionally, storing the detailed transactions facilitates the ability to compute the CLV for each customer across each product. Moreover, the model depicted in Figure 1 can be used to calculate KPIs for delivery, such as the number of on-time items and the number of damage-free items. The complement measures

Figure 1. Proposed CRM data warehouse model



are calculated by subtracting the explicitly stored KPI measures from the total quantity. These KPIs are important to track and manage, because they can help organizations to identify internal areas for process improvements and ultimately influence customer satisfaction and possibly customer retention.

The customer service fact table contains information about each interaction with the customer, including the cost of the interaction, the time to resolve the complaint, and a count of customer satisfaction or dissatisfaction. The total historical value of each customer is computed by summing the historical value of each transaction (i.e., the net revenue from the profitability fact table) and then subtracting the sum of the cost of interacting with the customer (i.e., the service cost from the customer service fact table).

In accordance with Equation 4, the future value fact table stores measures that are needed to compute the potential future lifetime value for each customer. For example, among other things, the future value fact table contains the expected gross revenue, costs, expected purchasing frequency, and the probability of gaining additional revenue. It also contains other descriptive attributes that can be used to analyze and categorize the customer's future lifetime value. The customer lifetime value, which is used to classify each customer in one of the four quadrants in Table 1, is computed by summing the historical value for each customer and the future value for each customer.

Design Rationale for the Dimensions

Dimensions are very important to a data warehouse, because they allow the users to easily browse the content of the data warehouse. Special treatment of certain types of dimensions must be taken into consideration for CRM analyses. Each of those dimension types and their special treatments are discussed in the following subsections.

Existence Dimensions and Time

Customer Relationship Management is a process. As with any business process, the CRM process needs to be changed periodically to reflect changes in and additions to the business process (e.g., organizational restructuring due to territory realignments or mergers and acquisitions, new or modified business rules, changes in strategic focus, and modified or new analysis requirements). Thus, time is an inherent part of business systems and must be modeled in the data warehouse. Traditionally, the time dimension primarily participates in a relationship with the fact tables only. Additionally, there are two ways of handling temporal changes: tuple versioning and attribute versioning (Allen & March, 2003). Tuple versioning (or row time stamping) is used in multiple ways to record (1) changes in the active state of a dimension, (2) changes to the values of attributes, and (3) changes in relationships (Todman, 2001). As such, traditional tuple versioning has limitations within the context of CRM. For example, periods of customer inactivity can be determined only by identifying two consecutive tuples where there is a gap in the timestamp. Additionally, queries that involve durations may be spread over many tuples, which would make the SQL statement complex with slow response times (Todman, 2001).

In order to alleviate the issues with traditional time stamping in the context of CRM, each dimension is examined carefully to determine if the dimension (1) contains attributes whose complete set of historical values have to be maintained, or (2) is subject to discontinuous existence (i.e., only valid for specific periods).

If either (1) or (2) is applicable, then a separate dimension is created called an existence dimension. The existence dimensions are implemented as outriggers, and two relationships are created between the time dimension and each outrigger dimension. The two relationships are formed in order to record the date period in which the data instances are valid. In doing so, this facilitates the ability to perform state duration queries and transition detection queries (Todman, 2001). State duration queries contain a time period (start date and end date) in the *where* clause of the query, whereas transition detection queries identify a change by identifying consecutive periods for the same dimension (Todman, 2001).

Careful consideration is given to this step in the design process, because the fact table only can capture historical values when a transaction occurs. Unfortunately, the reality is that there may be periods of inactivity, which would mean that any changes that occur during those periods of inactivity would not be recorded in the data warehouse. This would, in turn, impact the types of analyses that could be done, since one cannot analyze data that one has not recorded.

Mini-Dimensions

If a dimension contains attributes that are likely to change at a different rate than the other attributes within the dimension, then a separate dimension is created as a mini-dimension. The new dimensions are implemented as mini-dimensions as opposed to outriggers in order to allow the user to readily browse the fact table. One benefit of this approach is that the history of the changes in the customer's behavior scores and demographics are stored as part of the fact table, which facilitates robust analyses without requiring the use of Type 1, 2, or 3 techniques (Kimball & Ross, 2002) for the Customer Demographics or Customer Behavior dimensions.

Customer Dimension

The customer must be at the heart of the customer-centric data warehouse. As such, careful attention must be given to the design of the customer dimension, which will force attention on the customer. Direct relationships are formed between the Customer dimension and the Sales Representative, Market, Comment, and Time dimensions in order to allow the user to readily determine the most current values for the sales representative, market, activation date, attrition date, and attrition comments by simply browsing the Customer dimension without having to include a time constraint in the query statement.

Other Dimensions

There is a Household dimension as well as an extended household dimension in order to analyze the potential lines of influence that exists between customers. In accordance with the types of CRM analyses that the data warehouse must support, other dimensions are identified according to the dimensions along which the fact tables are analyzed. For example, other dimensions include the Product, Supplier, Channel, Promotion, Market, and Sales Representative dimensions in order to facilitate the CRM analyses described in the CRM Analysis Requirements section.

As a result of this approach to modeling the dimensions, the only slowly changing dimensions in the model are the County Demographics dimension, the Product dimension, the Supplier dimension, and the Customer dimension.

The model depicted in Figure 1, which is based upon the minimum design requirements and the design rationale presented in this section, is tested to determine its completeness and flexibility for CRM analyses. The experiment that is used to test the model is described in the following section.

EXPERIMENT

The purpose of the experiment is to test the completeness and flexibility of the proposed CRM data warehouse model. Our hypothesis is that the proposed data warehouse starter model has a positive impact on the ability to perform CRM analyses. The implementation, methodology, and selection of the queries that are used in the experiment to test our hypothesis as well as the results are discussed in the specific subsections that follow.

Implementation

We perform a case study to test the validity of our proposed starter model. The proposed CRM data warehouse model is implemented in SQL Server 2000 running on a Windows 2000 server. The hardware computer is a DELL 1650 database server with a single processor and 2.0 MHz. The schema is populated with 1,685,809 rows of data from a manufacturing company.

Methodology

In the experiment, a series of CRM queries are executed against the proposed data warehouse schema. The success rate of the proposed schema is computed as a ratio of the number of successful queries executed divided by the total number of queries used in the investigation. Furthermore, the proposed CRM data warehouse model is tested to determine if it could or could not perform the analyses listed in Table 3. For each analysis in Table 3 that the model could perform, it is given a score of one point; otherwise, the model is given a score of zero points. The sum of the points for the model is computed in order to determine an overall CRM-analysis capability score. The selection of the queries that are used to study the model is discussed in the following section.

Selection of Queries to Test

Since we believe that the proposed data warehouse starter model has a positive impact on the ability to perform CRM analyses, special care was taken in the selection of the queries used for testing in order to avoid any biases in the types of queries used to test the model. Stratified random sampling is used to select the specific queries for the experiment. The stratified random sampling is conducted as follows: (1) representative queries for CRM are gathered from literature and experience; (2) the queries are grouped into categories based upon the nature of the query; (3) within each category, each query is numbered; (4) a random number generator is used to select queries from each category; and (5) the queries whose assigned number corresponds to the number generated by the random number generator are selected. The specific queries that are selected are listed in Table 5. It is important to note that since the queries are randomly selected from a pool of CRM-related queries, it is possible that the $r_{success}$ ratio can be less than one for our proposed model. It is also important to note that the representative CRM queries are queries that equally apply to different industries and not queries that are specific to only one industry. This aspect of the sampling procedure is important in order to make generalizations about the characteristics of the data warehouse schema that should be present in order to perform CRM analyses across different industries.

Results

Our preliminary finding is that the proposed CRM data warehouse model can be used to successfully perform CRM analyses. Based upon the sample queries, our model has a value of 1 and 0.93 for the $r_{success}$ and $r_{suitability}$ ratios, respectively. The individual scores for successfully executing the queries against the model are listed in Table 5. The individual and cumulative scores for the suitability of the proposed CRM data warehouse model are listed in Table 6. It should be noted that there is no significance to the order in which the items are listed in the table.

The scores for items 6.1 through 6.11 in Table 6 are based upon whether or not queries are successfully executed in those categories. The scores for items 14 and 15 are determined while loading data from multiple sources and updating customer scores. Each of the queries that were successfully executed in the experiment is discussed in further detail in the following section in order to highlight the completeness and flexibility of the model.

DISCUSSION

In addition to discussing the completeness and flexibility of the model, this section also presents potential uses of the specific analyses, including KPIs. This section also describes the data quality issues pertaining to CRM data warehouses before presenting a summary of the heuristics for designing data warehouses to support CRM analyses.

Model Completeness and Flexibility

The starter model depicted in Figure 1 can be used for a variety of CRM analyses, including customer profitability analysis, household profitability analysis, demographics profitability analysis, product profitability analysis, channel profitability analysis, and promotion profitability analysis simply by including the appropriate dimensions in the query statement. Furthermore, each query can be modified to include additional measures and descriptions simply by including additional

Table 5. Sample CRM analyses

No.	Category	Analysis	Pass	Fail
5.1	Channel Analysis	Which distribution channels contribute the greatest revenue and gross margin?	1	0
5.2	Order Delivery Performance	How do early, on time and late order shipment rates for this year compare to last year?	1	0
5.3	Order Delivery Performance and Channel Analysis	How do order shipment rates (early, on time, late) for this year compare to last year by channel?	1	0
5.4	Customer Profitability Analysis	Which customers are most profitable based upon gross margin and revenue?	1	0
5.5	Customer Profitability Analysis	What are the customers' sales and margin trends?	1	0
5.6	Customer Retention	How many unique customers are purchasing this year compared to last year?	1	0
5.7	Market Profitability Analysis	Which markets are most profitable overall?	1	0
5.8	Market Profitability Analysis	Which products in which markets are most profitable?	1	0
5.9	Product Profitability Analysis	Which products are the most profitable?	1	0
5.10	Product Profitability Analysis	What is the lifetime value of each product?	1	0
5.11	Returns Analysis	What are the top 10 reasons that customers return products?	1	0
5.12	Returns Analysis	What is the impact of the value of the returned products on revenues?	1	0
5.13	Returns Analysis	What is the trend for product returns by customers by product by reason?	1	0
5.14	Customer Attrition	What are the top 10 reasons for customer attrition?	1	0
5.15	Customer Attrition	What is the impact of the value of the customers that have left on revenues?	1	0

fields from the fact table and the dimensions. Some of those queries are discussed next.

The SQL statement in Figure 2 is used to identify the most profitable customers based upon total revenue and gross margin. By excluding the time dimension, the customer profitability SQL statement identifies the customer's historical lifetime value to the company. This is an important analysis that, in conjunction with the customer's future value and the customer service interaction costs, is used to classify customers in one of the four CRM quadrants (Table 1), which subsequently can be used to determine the appropriate strategy for managing the customer.

The SQL statement in Figure 3 is used to determine the margins for each product and subsequently identifies products that potentially may be eliminated from the company's product line. The ability to be able to determine the lifetime value of each product (irrespective of market) merely by modifying the SQL statement in Figure 3 to exclude the product code further illustrates

Table 6. Sample suitability for CRM analyses scores

No.	Criteria	Score
6.1	Ability to track retention	1
6.2	Ability to identify root causes for customer attrition	1
6.3	Ability to score customers	1
6.4	Ability to associate customers with multiple extended household accounts.	1
6.5	Ability to segment customers into multiple customer segmentations	1
6.6	Ability to maintain the history of customer segments and scores.	1
6.7	Ability to evaluate different campaigns and responses over time	1
6.8	Ability to analyze metrics for website	0
6.9	Ability to understand loyalty patterns among different relationship groups	1
6.10	Ability to perform demographic analysis	1
6.11	Ability to perform trend analysis	1
6.12	Ability to perform customer profitability analysis	1
6.13	Ability to perform product profitability analysis	1
6.14	Ability to integrate data from multiple sources, including external sources	1
6.15	Ability to efficiently update/maintain data.	1
	Total	**14**

Figure 2. Customer profitability analysis query — Which customers are most profitable based upon gross margin and revenue?

```
SELECT b.CustomerKey, b.CustomerName, Sum(a.GrossRevenue) AS TotalRevenue,
Sum(a.GrossProfit) AS TotalGrossProfit, TotalGrossProfit/TotalRevenue AS GrossMargin
FROM tblProfitabilityFactTable a, tblCustomer b
WHERE b.CustomerKey=a.CustomerKey
GROUP BY b.CustomerKey, b.CustomerName
ORDER BY Sum(a.GrossRevenue) DESC;
```

Figure 3. Product profitability analysis query — Which products in which markets are most profitable?

```
SELECT c.Year, b.MarketKey, b.LocationCode, b.Location, b.Description,
b.CompetitorName, d.ProductCode, d.Name, Sum(a.GrossRevenue) AS TotalRevenue,
Sum(a.GrossProfit) AS TotalGrossProfit, TotalGrossProfit/TotalRevenue AS GrossMargin
FROM tblProfitabilityFactTable a, tblMarket b, tblTimeDimension c, tblProductDimension d
WHERE b.MarketKey=a.MarketKey And a.TimeKey=c.TimeKey And
a.ProductKey=d.ProductKey
GROUP BY c.Year, b.MarketKey, b.LocationCode, b.Location, b.Description,
b.CompetitorName, d.ProductKey, d.ProductCode, d.Name, b.MarketKey
ORDER BY Sum(a.GrossRevenue) DESC;
```

the flexibility and robustness of the proposed CRM model.

The SQL statement in Figure 4 is used to determine and compare Key Performance Indicators (KPIs) for overall on-time, early, and late shipment percentages for different years.

By modifying the statement in Figure 4 to include the Channel Dimension, the performance of each channel from one year to the next is determined. The modified SQL statement can be seen in Figure 5.

The SQL statement in Figure 6 is used to determine the overall profitability of each market. By eliminating the market key from the SQL statement, the profitability for each location is obtained for each location within the organizational hierarchy that is defined in the market dimension.

The SQL statement in Figure 7 demonstrates that by including the product code from the product dimension in the previous SQL statement, the profitability of each product by market is obtained.

Figure 4. Order delivery performance query — How do early, on time, and late order shipment rates for this year compare to last year?

```
SELECT b.Year, Sum(a.ItemOnTimeCount) AS OnTime, Sum(a.ItemEarlyCount) AS
Early, Sum(a.ItemLateCount) AS Late,
Sum(a.ItemOnTimeCount+a.ItemEarlyCount+a.ItemLateCount) AS TotalCount,
OnTime/Late*100 AS PercentOnTime, Early/TotalCount*100 AS PercentEarly,
Late/TotalCount*100 AS PercentLate

FROM tblProfitabilityFactTable a, tblTimeDimension b

WHERE b.TimeKey = a.TimeKey

GROUP BY b.Year;
```

Figure 5. Order delivery performance and channel analysis query — How do order shipment rates (early, on-time, late) for this year compare to last year by channel?

```
SELECT b.Year, c.ChannelCode, Sum(a.ItemOnTimeCount) AS OnTime,
Sum(a.ItemEarlyCount) AS Early, Sum(a.ItemLateCount) AS Late,
Sum(a.ItemOnTimeCount+a.ItemEarlyCount+a.ItemLateCount) AS TotalCount,
OnTime/Late*100 AS PercentOnTime, Early/TotalCount*100 AS PercentEarly,
Late/TotalCount*100 AS PercentLate

FROM tblProfitabilityFactTable a, tblTimeDimension b, tblChannelDimension c

WHERE b.TimeKey=a.TimeKey And c.ChannelKey = a.ChannelKey

GROUP BY b.Year, c.ChannelCode;
```

Figure 6. Market profitability analysis query — Which markets are most profitable overall?

```
SELECT c.Year, b.MarketKey, b.LocationCode, b.Location, b.Description,
b.CompetitorName, Sum(a.GrossRevenue) AS TotalRevenue, Sum(a.GrossProfit) AS
TotalGrossProfit, TotalGrossProfit/TotalRevenue AS GrossMargin

FROM tblProfitabilityFactTable a, tblMarket b, tblTimeDimension c

WHERE b.MarketKey=a.MarketKey And a.TimeKey=c.TimeKey

GROUP BY c.Year, b.MarketKey, b.LocationCode, b.Location, b.Description,
b.CompetitorName, b.MarketKey

ORDER BY Sum(a.GrossRevenue) DESC;
```

The SQL statement in Figure 8 is used to determine the top reasons for product returns. In this case, the basis for the top reasons is merely the count of the number of reasons that products are returned. By first grouping the products that are returned according to the reason for their return and the product code and then including the number of returns, revenue, gross profit, and gross margin for each group, the SQL statement in Figure 8 identifies areas upon which the company should improve in order to minimize the number of returns and to improve overall customer satisfaction. Specifically, since companies have limited resources, a company can use the result set to create Pareto charts according to the most frequently occurring problems that have the largest associated gross profits. Management teams then can use the Pareto charts to determine which problems to address first with corrective actions. It should be noted that in order to facilitate quick identification of the most frequently occurring problems that have the largest associated gross profits, the SQL statement in Figure 8 includes an ORDER BY clause.

Furthermore, simply by modifying the SQL statement in Figure 8 to include the year of the transaction from the profitability fact table in the SELECT clause and the GROUP BY clause, companies can use the results of the modified query to monitor the trend of return reasons over time. Stated differently, companies can use the results of the modified query statement to monitor the impact of the corrective actions over time. Not only can the return analyses be used to monitor the impact of corrective actions, but they also can be used to identify improvement targets, which can be tied to employee (and/or departmental) performance goals.

Figure 7. Product profitability analysis query — Which products in which markets are most profitable?

```
SELECT c.Year, b.MarketKey, b.LocationCode, b.Location, b.Description,
b.CompetitorName, d.ProductCode, d.Name, Sum(a.GrossRevenue) AS TotalRevenue,
Sum(a.GrossProfit) AS TotalGrossProfit, TotalGrossProfit/TotalRevenue AS
GrossMargin

FROM tblProfitabilityFactTable a, tblMarket b, tblTimeDimension c,
tblProductDimension d

WHERE b.MarketKey=a.MarketKey And a.TimeKey=c.TimeKey And
a.ProductKey=d.ProductKey

GROUP BY c.Year, b.MarketKey, b.LocationCode, b.Location, b.Description,
b.CompetitorName, d.ProductKey, d.ProductCode, d.Name, b.MarketKey

ORDER BY Sum(a.GrossRevenue) DESC;
```

Figure 8. Returns analysis — What are the top reasons that customers return products?

```
SELECT b.CommentsKey, c.ProductCode, c.Name, d.Comment, Sum(a.GrossRevenue)
AS TotalRevenue, Sum(a.GrossProfit) AS TotalGrossProfit,
TotalGrossProfit/TotalRevenue AS GrossMargin, Count(*) AS MembershipCount

FROM tblProfitabilityFactTable a, tblTimeDimension b, tblProductDimension c,
tblCommentDimension d

WHERE a.TimeKey=b.TimeKey And a.ProductKey=c.ProductKey And
a.CommentsKey=d.CommentsKey And a.ProductReturned=Yes

GROUP BY d.CommentsKey, c.ProductCode, c.Name, d.Comment, c.ProductKey

ORDER BY Count(*) DESC, Sum(a.GrossProfit) DESC;

ORDER BY Sum(a.GrossRevenue) DESC;
```

The SQL statement listed in Figure 9 is used to determine the impact of the returned products on revenues.

The SQL statement listed in Figure 10 is used to identify the trend for product returns by customer, by product, and by reason. The results can be used to identify whether or not a problem is systematic across all customers, many customers, or a few specific customers. This query also can be used to help management make an informed decision with respect to allocating resources to address problems that lead to customers returning products. Additionally, the results can be used by the sales team to gain further insights into why their customers have returned products. The sales team potentially can use that information to work with the customer to resolve the issue(s) in cases where the customer repeatedly has returned products for reasons that cannot be considered the company's mistake. Alternatively, the sales team can use the results to identify accounts that could (should) be charged additional fees if the customer repeatedly returns products.

The SQL statement in Figure 11 is used to identify the top reasons for customer attrition. Figure 12 is used to analyze the impact of customer attrition on the total revenues. By analyzing customer attrition, companies can gain further insights into areas for improvement in order to reduce the attrition rate and thereby improve its overall company value.

Table 7 summarizes some of the possible uses for the CRM analyses that are presented in Table 5.

Figure 9. What is the impact of the value of the returned products on revenues?

```
SELECT b.CommentsKey, c.ProductCode, c.Name, d.Comment, Sum(a.GrossRevenue)
AS TotalRevenue, Sum(a.GrossProfit) AS TotalGrossProfit,
TotalGrossProfit/TotalRevenue AS GrossMargin, Count(*) AS MembershipCount

FROM tblProfitabilityFactTable a, tblTimeDimension b, tblProductDimension c,
tblCommentDimension d

WHERE a.TimeKey=b.TimeKey And a.ProductKey=c.ProductKey And
a.CommentsKey=d.CommentsKey And a.ProductReturned=Yes

GROUP BY d.CommentsKey, c.ProductCode, c.Name, d.Comment, c.ProductKey

ORDER BY Count(*) DESC;

ORDER BY Sum(a.GrossRevenue) DESC;
```

Figure 10. What is the trend for product returns by customers by product by reason?

```
SELECT e.CustomerName, b.Year, b.CommentsKey, c.ProductCode, c.Name,
d.Comment, Sum(a.GrossRevenue) AS TotalRevenue, Sum(a.GrossProfit) AS
TotalGrossProfit, TotalGrossProfit/TotalRevenue AS GrossMargin, Count(*) AS
MembershipCount

FROM tblProfitabilityFactTable a, tblTimeDimension b, tblProductDimension c,
tblCommentDimension d, tblCustomerDimension e

WHERE a.TimeKey=b.TimeKey And a.ProductKey=c.ProductKey And
a.CommentsKey=d.CommentsKey And a.ProductReturned=Yes

GROUP BY e.CustomerName, b.Year, d.CommentsKey, c.ProductCode, c.Name,
d.Comment, c.ProductKey

ORDER BY Count(*) DESC, Sum(a.GrossProfit) DESC;

ORDER BY Sum(a.GrossRevenue) DESC;
```

Figure 11. What are the top 10 reasons for customer attrition?

```
SELECT  b.Comment, Count(a.CommentsKey) AS CountReasons
FROM tblCustomer AS a, tblCommentDimension AS b
WHERE a.CommentsKey=b.CommentsKey
GROUP BY  b.Comment
ORDER BY Count(a.CommentsKey) DESC;
```

Figure 12. What is the impact of the value of the customers that have left on revenues?

```
SELECT b.Comment, Count(a.CommentsKey) AS NumberOfTransactions,
Sum(c.GrossRevenue) AS TotalGrossRevenue
FROM tblCustomer AS a, tblCommentDimension AS b, tblProfitabilityFactTable
AS c
WHERE a.CommentsKey=b.CommentsKey AND c.CustomerKey=a.CustomerKey
GROUP BY b.Comment
ORDER BY Count(a.CommentsKey) DESC;
```

Data Quality

Given the range of decisions that the CRM data warehouse must be able to support and given the potential impact on companies' profitability, it is imperative that the data are accurate. The data that are used in the CRM analyses originate from disparate data sources that must be integrated into the data warehouse. Under such circumstances, the issue of dirty data arises. Analyzing dirty data, particularly in the context of systems that support corporate decision-making processes (e.g., CRM analyses and subsequent decisions), would result in unreliable results and potentially inappropriate decisions. As such, ensuring data quality within the data warehouse is important to the overall success of subsequent CRM analyses and decisions. Data quality should not be considered a one-time exercise conducted only when data are loaded into the data warehouse. Rather, there should be a continuous and systematic data quality improvement process (Lee, Pipino, Strong, & Wang, 2004; Shankaranarayan, Ziad, & Wang, 2003).

One way of minimizing data quality issues is to carefully document the business rules and data formats that then can be used to ensure that those requirements are enforced. Too often, however, thorough documentation of the business rules and data formats is not available in a corporate setting. Therefore, routine data quality audits should be performed on the data in the CRM model in order to identify data quality issues that are not addressed during the ETL process. For example, missing data can be identified during data quality audits and consequently addressed by consulting with a domain expert.

Some forms of dirty data (e.g., outliers) can be identified using data mining techniques and statistical analysis, while other forms of dirty data (e.g., missing data values) are more problematic. Although Dasu, Vesonder, and Wright (2003) assert that data quality issues are application-specific, Kim, Choi, Kim, and Lee (2003) developed a taxonomy of dirty data and identified methods for addressing dirty data based upon their taxonomy. Kim et al. (2003) identified three broad categories of dirty data: (1) missing data; (2) not missing, but wrong data; and (3) not missing and not wrong, but unusable data. They then further decompose

Table 7. Initial taxonomy of CRM analyses (S = strategic and T = tactical)

#	Decision Class	Category	Analysis	Potential Use(s)	KPI
1	S	Channel Analysis	Which distribution channels contribute the greatest revenue and gross margin?	Resource allocation	
2	S, T	Order Delivery Performance	How do early, on time and late order shipment rates for this year compare to last year?	Setting performance goals	early delivery, on-time delivery, late delivery
3	S	Order Delivery Performance and Channel Analysis	How do order shipment rates (early, on time, late) for this year compare to last year by channel?	Setting performance goals, monitoring trends	early delivery, on-time delivery, late delivery
4	S	Customer Profitability Analysis	Which customers are most profitable based upon gross margin and revenue?	Classify customers	gross margin, revenue
5	S	Customer Profitability Analysis	What are the customers' sales and margin trends?	Classify customers	gross margin, revenue
6	S	Customer Retention	How many unique customers are purchasing this year compared to last year?	Identify the threshold to overcome with new customers	unique customers/ year
7	S, T	Market Profitability Analysis	Which markets are most profitable overall?	Setting performance goals, allocate marketing resources	gross margin/ market
8	S, T	Market Profitability Analysis	Which products in which markets are most profitable?	Setting performance goals, allocate marketing resources	gross margin/ products/ market
9	S, T	Product Profitability Analysis	Which products are the most profitable?	Managing product cost constraints, identify products to potentially eliminate from product line	gross margin/ product
10	S, T	Product Profitability Analysis	What is the lifetime value of each product?	Managing product cost constraints, identify products to potentially eliminate from product line	gross margin/ product
11	S, T	Returns Analysis	What are the top 10 reasons that customers return products?	Create Pareto charts to identify problems to correct, setting performance goals	count
12	S, T	Returns Analysis	What is the impact of the value of the returned products on revenues?	Create Pareto charts to identify problems to correct, setting performance goals	count, revenue, profit
13	S, T	Returns Analysis	What is the trend for product returns by customers by product by reason?	Create Pareto charts to identify problems to correct, setting performance goals, identify problematic accounts (identify customers that may leave), assess additional service fees	count, revenue, profit

continued on following page

Table 7. continued

#	Decision Class	Category	Analysis	Potential Use(s)	KPI
14	S, T	Customer Attrition	What are the top 10 reasons for customer attrition?	Insights for process improvements	attrition rate
15	S, T	Customer Attrition	What is the impact of the value of the customers that have left on revenues?	Insights for process improvements	attrition rate

each category of dirty data. However, they did not include composite types of dirty data. They provided some suggestions to address the issue of dirty data that can be used to clean dirty data in the CRM model during the ETL process. For example, the use of constraints can be valuable for avoiding instances of missing data (e.g., not null constraints) or incorrect data (e.g., domain ranges and check constraints). It is important to point out that the ability to enforce integrity constraints on inconsistent spatial data (e.g., geographical data such as sales territory alignments) and outdated temporal data is not supported in current database management systems.

Initial Heuristics for Designing CRM Data Warehouses

Once the types of CRM analyses that the data warehouse needs to be able to support have been identified, the data points have been identified, and the granularity has been selected, the next step is designing the data warehouse model to support the analyses that were identified. Based upon our initial findings, Table 8 lists initial heuristics for designing a data warehouse in order to successfully support CRM analyses.

CONCLUSION

In this article, we first present the design implications that CRM poses to data warehousing and then propose a robust multidimensional starter model that supports CRM analyses. Based upon sample queries, our model has a value of 1 and 0.93 for the $r_{success}$ and $r_{suitability}$ ratios, respectively. Our study shows that our starter model can be used to analyze various profitability analyses such as customer profitability analysis, market profitability analysis, product profitability analysis, and channel profitability analysis. In fact, the model has the flexibility to analyze both trends and overall lifetime value of customers, markets, channels, and products simply by including or excluding the time dimension in the SQL statements. Since the model captures rich descriptive non-numeric information that can be included in the query statement, the proposed model can return results that the user easily can understand. It should be noted that such rich information then can be used in data mining algorithms for such things as category labels. As such, we have demonstrated that the robust proposed model can be used to perform CRM analyses.

Our contributions also include the identification of and classification of CRM queries and their uses, including KPIs; the introduction of a sampling technique to select the queries with which the model is tested; the introduction of two measures (percent success ratio and CRM suitability ratio) by which CRM data warehouse models can be evaluated; and the identification of the initial heuristics for designing a data warehouse to support CRM. Finally, in terms of future work, we plan to classify and test additional CRM analyses, evaluate alternative models using the same set of queries and the $r_{success}$ and $r_{suitability}$ ratios, identify

Table 8. Initial heuristics for designing CRM DWs

#	**Heuristic**	**Benefit**
1	Identify the types of CRM analyses, their uses and the data elements required to perform the analyses	The model will be able to support the intended purpose of the analyses
2	Include all attributes required to compute the profitability of each individual transaction in the fact table(s)	The ability to generate a profit & loss statement for each transaction, which can then be analyzed along any dimension
3	Each dimension that will be used to analyze the Profitability fact table should be directly related to the fact table	Provides improved query performance by allowing the use of simplified queries (i.e., support browsing data)
4	Pay careful attention to the Customer dimension	It forces attention to the customer to the center of CRM
5	Create a relationship between the Customer dimension and the Market and Sales Representative dimensions	Provides the ability to quickly determine the current market and Sales Representative for the customer by merely browsing the Customer dimension
6	Include the attrition date and reason for attrition attributes in the Customer dimension	Provides the ability to quickly determine if a customer is no longer a customer by browsing the Customer dimension only
7	Attributes that are likely to change at a different rate than other attributes in the same dimension should be in a separate dimension	Minimize the number of updates
8	Create a separate *existence* dimension for any entity that can have a discontinuous existence	Provides the ability to track the periods in which the instance of the entity is valid (needed to support some temporal queries)
9	Create a separate *existence* dimension for any attribute whose historical values must be kept	Provides the ability to track accurate historical values, even during periods of inactivity
10	Create a relationship between the Time dimension and each *existence* dimension	Provides the ability to perform temporal queries efficiently using descriptive attributes of the Time dimension
11	*Existence* dimensions should be in a direct relationship with their respective original dimensions	
12	There should always be a CustomerExistence dimension	The ability to track and perform analyses on customer attrition
13	If some products are either seasonal or if it is necessary to determine when products were discontinued, then create a ProductExistence dimension	The ability to perform analyses for seasonal and discontinued products
14	There should be a Household dimension and an ExtendedHousehold dimension	Provides the ability to perform Household analyses
15	The organizational hierarchical structure can be contained in one *Market* dimension	Provides the ability to maintain a history of the organizational changes, and the ability to perform analyses according to the organizational structure

materialized views that are relevant to CRM, and explore CRM query optimization.

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Chapter 2.21

Developing a Global CRM Strategy

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ABSTRACT

While the managerial rationale for adopting customer relationship management (CRM) has been fairly well articulated in the literature, research on strategy development is scant. Moreover, reports of "CRM failures" in the popular business press have done little to inspire confidence. To date, what little research has been conducted in the area of CRM strategy development has been confined to a single country (often the U.S.). Global CRM strategy development issues have yet to be specifically addressed, particularly which elements of CRM strategy should be centralised/decentralised. The present study examines the complexities of global CRM strategy using the case of a leading financial services company. Interviews are conducted in 20 countries. Global Head Office and external IT consultant perspectives are also considered. Our findings confirm that a hybrid approach has wide practical appeal and that subsidiary orientation towards centralisation/decentralisation is moderated by firm/market size and sophistication.

INTRODUCTION

Recent advances in information technology (IT) have enhanced the possibilities for collecting customer data and generating information to support marketing decision making. CRM has been heralded by some as being the key to delivering superior business performance by focusing organisational efforts towards becoming more customer-centric and responsive (Davenport, Harris, & Kohli, 2001; Puschman & Rainer, 2001). However, others have cautioned that increasing information may actually *increase* the complexity of the decision-making process thereby adversely affecting decision-making performance (Van Bruggen, Smidts, & Wierenga, 2001).

Much of the extant academic literature on CRM has focused on identifying antecedents and consequences (e.g., Bull, 2003; Day & Van den Bulte 2002; Kotorov, 2003; Ryals & Knox, 2001). CRM has been variously conceptualised as (1) a process (e.g., Day & Van den Bulte, 2002; Galbreath & Rogers, 1999; Srivastava, Shervani, & Fahey, 1998); (2) a strategy (e.g., Croteau & Li, 2003; Verhoef & Donkers, 2001); (3) a philosophy (e.g., Fairhurst, 2001; Reichheld, 1996); (4) a capability (e.g., Peppers, Rogers, & Dorf, 1999) and (5) a technology (e.g., Shoemaker, 2001). Although there is clearly more to CRM than technology (Day & Van den Bulte, 2002; Reinartz, Krafft, & Hoyer, 2004), it is important to recognise that technology does play a central role in supporting the seamless integration of multiple customer touch points. IT also enables organisations to collect, store, develop, and disseminate knowledge throughout the organisation (Bose 2002; Crosby & Johnson, 2001). Customer knowledge is critical for successful customer relationship management (Crosby & Johnson, 2000; Davenport et al., 2001; Hirschowitz, 2001).

CRM Defined

The importance of technology in enabling CRM is exemplified by the attempts at defining the concept. CRM has been defined as the alignment of business strategies and processes to create customer loyalty and ultimately corporate profitability enabled by technology (Rigby, Reichheld, & Schefter, 2002). In a similar vain, Ryals (2002) defines it as the lifetime management of customer relationships using IT. E-CRM is defined as the application of customer relationship management processes utlising IT and relies on technology such as relational databases, data warehouses, data mining, computer telephony integration, Internet, and multi-channel communication platforms in order to get closer to customers (Chen & Chen, 2004; Fjermestad & Romano, 2003). In many respects e-CRM is a tautology in that without “e,” or technology, there would be no CRM. We therefore standardise on the term CRM throughout the paper.

As a business philosophy, CRM is inextricably linked to the marketing concept (Kotler, 1967) and market orientation, which stresses that firms must organise around, and be responsive to, the needs of customers (Kohli & Jaworski, 1990; Narver & Slater, 1990). From a capability perspective, CRM needs to be able to gather intelligence about current and prospective customers (Campbell, 2003; Crosby & Johnson, 2000; Davenport et al., 2001; Zablah, Bellenger, & Johnston, 2004) and apply that intelligence to shape its subsequent customer interactions. Furthermore, CRM processes need to acknowledge that relationships develop over time, have distinct phases, and are dynamic (Dwyer, Schurr, & Oh, 1987). Adopting this view highlights that CRM processes are best thought of as longitudinal phenomena. The interesting feature for firms is that they should interact and manage relationships with customers differently at each stage (Srivastava et al., 1998). Essentially, CRM involves the systematic and proactive management of relationships from initiation to termination across all channels (Reinartz et al., 2004). Another aspect of the relationship continuum is that not all relationships provide equivalent value to the firm. CRM requires firms to allocate resources to customer segments based on the value of the customer segment to the firm (Zablah et al., 2004; Zeithaml, Rust, & Lemon, 2001).

CRM Strategy

A high degree of CRM process implementation is characterised as where firms are able to adjust their customer interactions based on the lifecycle stages of their customers and their capacity to influence or shape the stages (i.e., extending relationships, Reinartz et al., 2004). Standardising CRM processes enables consistent execution to customers across all delivery channels. Successful CRM also requires organisational alignment (employee reward systems, organisational structure, training procedures) and investments in CRM technology. Interestingly, the level of technological sophistication of CRM technology makes no contribution to economic performance and supports the view that CRM is more than just software (Reinartz et al., 2004).

CRM can be conceptualised at three levels: (1) company wide, (2) functional, and (3) customer facing (Buttle, 2004). This study adopts the company-wide definition of CRM which views CRM as a core customer-centric business strategy focused on acquiring and retaining profitable customers (Buttle, 2004). This requires a customer-centric business culture, formal reward and recognition systems that promote employee behaviours that enhance customer satisfaction and the sharing of customer information and its conversion into useful knowledge.

Unfortunately, CRM's potential has, in many instances, failed to be realised. Successful implementation requires the adoption of a customer-centric business strategy and a redesign of functional activities, workflows, and processes (Galami, 2000; Nelson & Berg, 2000). Some organisations have begun focusing their business strategy around their customers and capturing, sharing, and applying customer knowledge to deliver superior service and customisation (Mitchell, 1998).

However, despite the rhetoric, empirical research on CRM strategy development is scarce. In particular, work on the vexing standardisation/localisation issue is lacking. In this increasingly globalised economy, it is surprising that researchers have overlooked cross-national differences and global CRM strategy issues. To address these gaps, the present study will seek to explore in depth the issues surrounding standardisation versus localisation of CRM strategy development. A case study of a leading financial services company is used to explore these issues. The paper reviews the localisation/centralisation literature, describes the study to be undertaken, and based on the findings draws a number of conclusions regarding global CRM strategy development and highlights areas worthy of future research.

GLOBAL CRM STRATEGY

In an increasingly competitive and complex market environment, multi-national enterprises (MNE's) are under constant pressure to re-assess the degree of autonomy they grant to their local subsidiaries. While headquarters are likely to have more expertise on strategic matters, local subsidiaries are likely to have more information on operational issues and be more responsive to dynamics impacting their specific market. Within a specific MNE context, centralisation refers to where decision making is vested largely with the global parent company (Cray, 1984). By contrast, decentralised organisations are defined as those where each subsidiary has a high degree of autonomy in making decisions on processes and products relevant to the needs of the local market (Edwards, Ahmad, & Moss, 2002).

There is some empirical evidence to suggest that although subsidiaries of global parent organisations may be given some autonomy in making operating decisions, strategic decision making is invariably controlled by the parent organisation (Bowman, Farley, & Schmittlein, 2000), which can be manifested through IT (Roche, 1996). Moreover, IT provides an efficient and effective decision support system to transfer information from the local subsidiary into the parent company's reporting models, increasing the capacity of headquarter management to engage in local company decision making (Clemmons & Simon, 2001; McDonald, 1996). Using a case study approach, Ciborra and Failla (2000) found that IBM failed in its vision for global CRM because of their fixation for standardisation and centralisation and the use of IT to enforce behaviours. Furthermore, they concluded that this variation in CRM adoption at the country level and unique regulatory requirements made the concept of "global CRM" tenuous at best, although they acknowledge that CRM is a "powerful weapon for centralisation" (Ciborra & Failla, 2000, p. 122).

This desire for greater parent company control is a function of perceived risk. That is, the greater the perceived level of risk, the greater the desire for active decision making (Garnier, 1982). The types of decisions likely to require parent company decision making include capital expenditure; acquisitions and divestments; and funding. A criticism of centralised decision making is that it is expensive and that local subsidiaries are unable to react quickly to changes in local market dynamics (Harris, 1992). There is some empirical evidence to suggest that organisations with decentralised decision making performed better than those organisations characterised as having centralised decision making with respect to marketing (Ozsomer & Prussia, 2000). Moreover, highly centralised organisations make less contribution to their host country in terms of investment, knowledge transfer, and management expertise than their decentralised counterparts (Fina & Rugman, 1996).

We have adopted a typology developed by Barlett and Ghoshal (1989) to classify the predisposition of organisations for a globalised/localised orientation. They describe organisations as: global, international, multi-national, and transnational. A global organisation is characterised as driven by the need for global efficiency, while having structures that are more centralised in their strategic and operational decisions. An international organisation is characterised as transferring and adapting the parent company's knowledge or expertise to foreign subsidiaries. The parent retains influence and control, but to a lesser extent than a classic global structure. A multi-national organisation manages its subsidiaries as though they were components of a portfolio of multi-national entities with headquarters exercising low control and low coordination. Finally, a transnational organisation seeks a balance between global integration and local responsiveness. This type of organisation has structures considered to be both centralised and decentralised simultaneously. Transnational firms have higher degrees of coordination with low control dispersed throughout the organisation. Using this typology, our focal firm can be characterised as a global organisation. That is, they employ structures that are more centralised in their strategic and operational decisions, and their products are homogenous throughout the world. Given a centralised structure, most of the decisions are made at headquarter level and imposed on subsidiaries.

Agency Theory

We use agency theory (Ross, 1973) as the theoretical foundation for describing the relationship between headquarters and country subsidiaries. Agency theory refers to the basic agency structure of a principal and agent who are engaged in cooperative behaviour, but having differing goals and attitudes to risk (Ross, 1973). In our research, the principal is headquarters and the agent is the subsidiary organisation. Goal differences, risk tolerance differences, and information asymmetry can create problems in agency relations (Eisenhardt, 1985). The first general problem is differences in the goals of principal and agents. Agents may act in their own self-interest at the expense of the principal. Secondly, principals and agents may have different tolerances towards risk. In the context of CRM strategy development, the principal is likely to have a lower risk tolerance than the agent. The third problem, asymmetric information arises when one party has more information than the other, or when one party prefers to keep some information private.

There are two types of agent behaviour that could be detrimental to the principal. The first, adverse selection might refer to a subsidiary's misrepresentation of its ability to undertake/implement CRM. The second moral hazard refers to the fact that the agent may not act as diligently as anticipated in carrying out the will of the principal. However, agency theory proposes that better information management systems can reduce the agency problem and provide the principal with greater control and is consistent with our earlier discussion on global CRM strategy development. Control may take the form of behaviour-based or outcome-based strategies. Both rely on the principal's ability to evaluate the performance of the agent, either on a behaviour-by-behaviour basis or at the end of the project based on its outcome (Eisenhardt, 1985).

From the principal's perspective, adopting an outcome-based control strategy is likely to be difficult given that the principal would need to wait until the long-term outcomes became known. Consequently, a behaviour-based control strategy may be preferred by the principal in CRM strategy development. The degree of knowledge that the principal (headquarters) has about the agent (wholly owned subsidiary) in terms of market characteristics, customer profile, and processes, enables headquarters to more effectively monitor and control a subsidiary's behaviour (Kirsch, 1996). This is likely to mitigate the risk of subsidiaries acting in their own self-interest at the expense of the entire organisation. Agency theory (Ross, 1973) is therefore useful in addressing our research questions: what aspects of CRM strategy should be centralised/localised? and what are some of the complexities of cross-national CRM strategy development? Another fundamental concept is the level of involvement between the principal and agent in implementation. For instance, if the agent is able to customise the CRM implementation to reflect their country's requirements, then the principal has less ability to control the behaviour of local country CRM managers compared to where the local subsidiary is required to implement a standardised CRM solution. However, the control dichotomy needs to be balanced to avoid implementation failure particularly where headquarters does not have an in-depth understanding of local market conditions. Furthermore, where a standardised implementation is imposed, it is important to consider the level of knowledge and dynamic learning mechanisms that will need to be created in the local subsidiary to address system failures.

We also examined the channel coordination literature (i.e., Frazier, 1999; Frazier & Rody, 1991; Hunt & Nevin. 1974), which describes the relationship between buyer and seller involving a distribution channel. However, given that this research seeks to examine the relationship between headquarters and its subsidiaries, agency theory offers a more robust theoretical foundation with respect to CRM strategy development. The channel coordination literature relates more to relationships characterised as involving a distribution channel, rather than describing the parent-subsidiary relationship.

METHOD

Data Collection

Understanding both substantive and methodological context permits the reader to put the research into context and thus derive deeper meaning from the findings (Johns, 2001). Data were derived using the case study method and utilising a multi-sample longitudinal research design (Yin, 1994). Case studies enable the development of deep insights into respondent beliefs and assist in theory development (Beverland, 2001). Bonoma (1985), Hirschman (1986), and Deshpande (1983) have all advocated for greater application of qualitative research methods in marketing. In order to avoid cueing subjects into a desired response, respondents were asked fairly general questions on the topic in order to elicit themes (Strauss & Corbin, 1992). Specifically, two "grand tour" questions (McCracken, 1988) were asked. The first related to issues surrounding local subsidiary decision-making empowerment in relation to CRM strategy. The second, on what CRM processes and systems should be centralisation versus decentralisation. Each participant was also sent a copy of the final transcript for comment. Any comments were noted and the results adjusted accordingly (Johnston, Leach, & Liu, 1999). The research questions were then e-mailed to sample 1 respondents with a statement thanking them for participating in the initial depth interviews and reiterating the purpose of the research. This was broadly described as seeking to gain an understanding of global CRM strategy development complexities with the aim of sharing the eventual findings across the whole group. In order to cross validate the results using a different group of respondents, we e-mailed the same two research questions to a second sample of respondents coupled with a statement describing the research. The objective was to assess the robustness of the initial sample findings with a separate sample of respondents (Deshpande, Farley, & Webster, 1993).

Two rounds of interviews were conducted with managers having a functional responsibility for CRM in their respective national subsidiary. Whether CRM respondents were responsible for CRM strategy or implementation was dependent on the level of the respondent within the organisation. Invariably, more senior respondents were responsible for strategy formulation. We had a mix of both strategic and operational CRM respondents (see Tables 1 and 2). The first sample consisted of CRM representatives from the following subsidiaries: Australia, Belgium, Germany, Italy, Netherlands, Spain, Switzerland, United Kingdom, and United States. To improve construct validity, interviews were also conducted with the internal strategy department at headquarters and with external consultants assisting in CRM strategy formulation. This provided a strategic level view of the vision for CRM from a Group/HQ perspective (Deshpande, 1983; Johnston et al., 1999). Details of first round respondents are presented in Table 1.

The first round of interviews was conducted by one of the authors over the telephone (Holbrook, Green, & Krosnick, 2003) and recorded/transcribed in order to assist in thematic analysis. The transcribed data was then edited and any additional data was integrated to develop a case summary. Details of second-round respondents are presented in Table 2. Australia, Germany, Netherlands, Spain, and Switzerland were repre-

Table 1. First round sample characteristics

Subsidiary	Person Interviewed	Function
1.	**Senior Consultant CRM Project**	**Strategic**
2.	**Customer Relations Manager**	**Strategic**
3.	**Marketing Manager**	**Operational**
4.	**Leader CRM**	**Strategic**
5.	**Customer Service Manager**	**Strategic**
6.	**CRM Manager**	**Operational**
7.	**Marketing Manager**	**Operational**
8.	**CRM Director**	**Strategic**
9.	**CRM Manager**	**Operational**
10.	**CRM Manager**	**Strategic**
11.	**Senior Consultant - XYZ Consulting**	**Strategic**

Table 2. Second round sample characteristics

Subsidiary	Person Interviewed	Function
1.	**Marketing Manager**	**Operational**
2.	**CRM Manager**	**Operational**
3.	**Customer Relations Manager**	**Strategic**
4.	**CRM Manager**	**Operational**
5.	**Marketing Manager**	**Operational**
6.	**Leader CRM**	**Strategic**
7.	**CRM & Corporate Sales Manager**	**Operational**
8.	**Manager CRM & Internet Marketing**	**Operational**
9.	**Marketing Manager**	**Operational**
10.	**Marketing Manager**	**Operational**
11.	**Marketing Manager**	**Operational**
12.	**CRM Director**	**Strategic**
13.	**CRM Programs Manager**	**Operational**
14.	**CRM Manager**	**Operational**
15.	**Manager Prospecting & New Media**	**Operational**

sented in both samples, although in this case an alternative respondent, having responsibility for CRM, was interviewed.

FINDINGS

In reporting our results, we quote actual statements made by respondents in order to improve the validity of the findings for the reader (Eisenhardt, 1989; Yin, 1994).

Perceived Complexities of Global CRM Strategy Development

The general consensus of both samples suggested that they are limited in their ability to make strategic decisions. "*[Subsidiaries] get a very strong framework from headquarters.*" Most respondents also anticipate that strategic decision-making is unlikely to become more devolved. Some respondents noted a distinction between strategic decision-making in terms of IT and operations: *"I must say that the CRM project on the IT side is very much directed by the project group at head office. On the other hand, nobody asks us if CRM processes are in place and actively managed"* and "*CRM initiatives particularly system related are being governed on a global or regional basis [and the subsidiary] probably does not have an overriding influence on it.''* An exception to this is country X, where the different stage of CRM development in that market has meant that "*[head office] kind of gave us the ability to operate outside of their purview.*"

Respondents in both samples noted cultural differences and maturity of markets as contributing to the complexity of global CRM strategy development. For instance, "*local cultural differences make it difficult to offer standardised CRM tools.*" Another respondent noted "*no one central system can accommodate all of the differences that exist.*" And another: "*what works great in one country may not work at all in another* *country.*" Another perceived complexity was the capacity to meet all the different subsidiary requirements. "*The number of countries and the differences in market size and maturity creates another layer of complexity.*" And "*you have to deal with a lot of market specifics—market-specific business processes and market-specific system adaptations.*" Process concerns were also articulated, "*…existing local IT systems and related business processes cause issues when trying to overlay a global IT system.*" Interestingly, hardly any respondents considered software-related issues as potential barriers to CRM strategy development, which may reflect their view that CRM is more than just software. However, one respondent noted, "*fractured information flows between head office and local subsidiaries results in misinformation regarding CRM developments.*" And another respondent (in the second sample) raised the issue of cross functionality: "*CRM can't be implemented easily because it is cross functional.*" Some respondents also noted that "*country-specific legislation also needs to be considered.*"

Standardised Across Markets or Tailored to Local Market Requirements?

On the question of whether CRM processes and systems should be centralised, or decentralised, a "hybrid" approach has practical merit. That is, embracing a centralised CRM IT system which can then be configured by subsidiaries to meet local market requirements. The perceived benefits of this approach are that it is cost and resource efficient. Nearly all agreed that there were considerable advantages to centralisation. For example, "*If you just let every country do what they wanted, it would be chaos. Everybody would come up with unique solutions, there would be double investments and duplication of effort, there would no cooperation and I think the organization would suffer.*" And "*centralise as much as possible and localise as little as possible.*" A small market perspective was that "*we feel that some sort of centralisation in one country can very much benefit smaller countries due to budget constraints impeding their ability to develop their own systems.*" The general consensus was that decentralisation would be inefficient in terms of resource utilisation, costs, and duplication of effort. On the other hand, they did recognise that complete centralisation would lead to a situation of inflexibility. "*If you do everything on a central basis, one size fits all, then you are going to end up with inertia of the organization—think global act local.*" There was some dissension on whether centralisation was more cost efficient than localisation. "*From a high level perspective [centralisation] might be cheaper, but down the road, one country will have a couple of hundred requirements, another country will also have another couple of hundred and the question is whether it is going to be worth it. The money that you and everyone is going to spend for changes will be [the] same as having a local solution.*" The answer seems to be somewhere in the middle. "*In my opinion, I think it makes sense to develop them centrally and to adapt to local requirements. Each market is different and has different cultures, has different issues and so to develop things centrally makes sense because of development costs. But each market has to adapt them locally.*" And, "*You may need to develop some tools that are able to have some consistency at its core, but which can then be configured to meet local needs, because its in the local market where you have got to survive.*" And "*a centralised CRM tool is cost efficient and easy to update if you want to further develop the tool. If it is decentralised, then each country may spend a lot of financial resources doing that. The negative thing is that it doesn't take into account the local needs of the market.*"

Another perspective viewed lack of market-specific information as a potential barrier to centralisation. *"My perspective is that markets know more what they need than the central department. I think the processes are not that different from country to country, but the key integration points are different for each market and are not well understood by headquarters. I think that when you try and bring a group approach to a specific problem its not going to work."* Another respondent noted the possibility for resistance, *"…what I can see, there is high resistance [to a centralised tool] from the markets because they want a lot of customisation which is not allowed and that causes a lot of problems."* Similarly, *"I think that CRM processes should be decentralised because of the respective market idiosyncrasies and it is important to set common objectives and standards and pursue them. In my opinion, centralisation is much more expensive [compared to localisation] because of the customisation costs."* One respondent noted that performance measurement also needs to be standardised in order to enable comparability. *"Success measurement KPIs need to be defined so that the performance of one market can be objectively compared against another market."*

One respondent suggested a set of guiding principles or framework could be utilised to assist in providing some direction, but ultimately subsidiaries would be responsible for decision making given their more intimate understanding of the market. *"I think there needs to be a strategic framework which is applicable for all subsidiaries all over the world and you can act within this framework to bring in your own experience, bring in your market-specific issues."* Another respondent noted that an alternative to the centralisation-decentralisation dichotomy is clustering markets based on similar characteristics and then applying a common approach. *"It might be a European solution for say all European countries, 'an Americas solution' for North and South America and so forth."*

Global Strategy

Local subsidiaries are often not empowered to make strategic decisions with respect to CRM. This may be a function of the perceived risk (Garnier, 1982). This finding is consistent with Bowman et al. (2000) who found that strategic decision making was controlled by the parent company. There also appears to be some dissension on whether the organisation has achieved a global strategy for CRM. *"Is there one [a global strategy]? To my mind we have only managed to derive some more or less binding rules for the subsidiaries, which tell them the 'do's', and 'don'ts' in treating their customers. A concise strategy focused on retention and acquisition to my mind does not yet exist."* In summing up, one respondent noted that, *"CRM is really about the business first and the business processes. The system should be designed to support this, not the other way round."* A number of large market respondents noted that there should be a global platform for knowledge management. *"We need to capture the key learnings from each market and leverage off these for the next country."* And *"lets stay connected and learn from each other."*

Cross-National Differences

In comparing differences between countries a clear pattern begins to emerge: two countries are demonstrably more advanced in terms of CRM implementation than the other 18, who are largely still in a passive "data collection" phase, not yet using customer data in their marketing strategies to anywhere near its full potential. The two advanced countries, by contrast, are well ahead of the curve—using advanced customer analytics for segmentation purposes to proactively manage customer relationships. The other interesting dynamic within this context is the fact that Head Office has largely allowed the advanced country "to get on with it" and granted them a high degree of autonomy. Among the other 18, there is another fairly obvious partition, between more advanced and less advanced. We say obvious because the split is fairly predictable and is driven by country size, stage of economic/social development, and market size. Basically, mature versus developing economies.

There also appears to be a feeling that the group strategy favours large markets and the needs of smaller subsidiaries in emerging markets are subordinated. *"There needs to be more attention paid to the smaller [market] solution and strengthening central support."* And *" from the point of view of small markets, you might think that decisions are sometimes based on the big market."*

DISCUSSION

Most respondents recognised the many advantages of standardisation. They could see the merit in having a universal strategic framework to guide the CRM process. They acknowledged that IT systems should be standardised to avoid resource duplication and any possible re-inventing of the wheel. This was particularly evident in smaller and/or less developed markets. However, a number of problems with standardisation were also acknowledged. These included inability to factor into account cultural differences/idiosyncrasies, country-specific legislation, and complexities arising from the inherently cross-functional nature of CRM. Thus, somewhat predictably, calls for a hybrid approach can de deduced from the data. However, based on the strength of arguments and also drawing on the literature, we conclude that local adaptation needs to be well justified and should be viewed more as the exception rather than the norm.

Theory-Building and Managerial Implications

This paper makes at least two significant contributions to the extant CRM literature. First, given the lack of empirical research in the area, it extends on earlier work on the complexities of global CRM strategy development (Ciborra & Failla, 2000; Massey, Montoya-Weiss, et al. 2001). Findings confirm that there is a lack of clarity regarding what the important antecedents are to global CRM success. The more mature markets in this study seem to have a better developed understanding of the importance of these dimensions and invest resources in enhancing their competencies in these areas. Second, we have shed some light on the perennial standardisation/adaptation question and have provide a preliminary framework of what elements may be amenable to centralisation and which to localisation. For global CRM managers and strategists, the findings suggest that a centralised approach has merit. Indeed, the majority of CRM functionality could well be centrally located, with the more customer-centric elements driven at the subsidiary level. The benefit of this approach is that it improves control and coordination while reducing transaction costs (Clemmons & Simon, 2001).

Limitations and Future Research

A number of limitations of this research are noted. First, the non-random selection of respondents introduced an element of judgement into the sampling process. Furthermore, for the majority of subsidiaries, a single informant may not accurately represent the entire view of the organisation. However, it was felt that the manager identified as responsible for CRM activities was the most qualified to respond to in-depth interview questions. Another limitation of this study is that it only involves a single organisation in a single industry and therefore the results may not be generalisable to other organisations or industries. The researchers attempted to mitigate the limitations of the sample by utilising two respondent samples (Deshpande et al., 1993). A problem also arises in attempting to find a suitable second informant in small subsidiaries, and some initial respondents may object to having a cross-validation process. Finally, stringent university "Ethics in Research Involving Humans" guidelines prevented us from identifying verbatim quotes with individual respondents because that would compromise respondent anonymity.

A number of directions for future research have emerged from this exploratory study. First, a study examining global CRM strategy development across industries would be useful to test the generalisability of these findings. In addition, further research is required to examine the relative importance of those global CRM factors we have identified and test whether there are some other factors which contribute to global CRM complexity, which have been overlooked in the current study. Also further work is required to quantify the cost-benefit of localisation versus centralisation. It is not clear whether the inflexibility that a centralised CRM tool mandates compensates for the anticipated cost benefits. It may be that the costs of local market customisation erode these cost benefits. An interesting stream for future research would be to attempt to develop a framework that provides organisations with some insights into the required sequencing of CRM activities consistent with stage of implementation in order to build a solid foundation for the development of further CRM capabilities. Finally, from a cross-cultural perspective, the applicability of a stage model to global CRM implementation is worth considering.

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Chapter 2.22

Building Complex Adaptive Systems:

On Engineering Self-Organizing Multi-Agent Systems

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ABSTRACT

Agent oriented software engineering (AOSE) proposes the design of distributed software systems as collections of autonomous and pro-active actors, so-called agents. Since software applications results from agent interplay in multi-agent systems (MASs), this design approach facilitates the construction of software applications that exhibit self-organizing and emergent dynamics. In this chapter, we examine the relation between self-organizing MASs (SO-MASs) and complex adaptive systems (CASs), highlighting the resulting challenges for engineering approaches. We argue that AOSE developers need to be aware of the possible causes of complex system dynamics, which result from underlying feedback loops. In this respect current approaches to develop SO-MASs are analyzed, leading to a novel classification scheme of typically applied computational techniques. To relieve development efforts and bridge the gap between top-down engineering and bottom-up emerging phenomena, we discuss how multi-level analysis, so-called mesoscopic modeling, can be used to comprehend MAS dynamics and guide agent design, respectively iterative redesign.

INTRODUCTION

AOSE (Weiß, 2002) is a prominent approach to the development of complicated distributed software systems. *Agents*, that is, autonomous and pro-active entities, are proposed as a basic design and development metaphor. Since highly dynamic and distributed application domains lend themselves to be understood as collections of collaborating actors, the agent metaphor provides appropriate design abstractions (Jennings, 2001). As the actual software applications result from agent interplay, they allow *decentralized* coordination mechanisms that promise the purposeful construction of systems that self-organize, that is, establish and maintain structures without external control, justifying intensive research activities (e.g., Kephart & Chess, 2003; Müller-Schloer, 2004). Awareness is rising that MAS implementations comprise the inherent potential to exhibit complex systems dynamics, for example, *criticality*, *phase transitions* (Parunak, Brueckner, & Savit, 2004) and *emergent* phenomena (Serugendo, Gleizes, & Karageorgos, 2006) have been observed.

The need to handle complex system dynamics in MASs is attracting increasing attention in AOSE research, as the rising phenomena complicate and challenge conventional top-down development efforts. So state Henderson-Sellers and Giorgini (2005):

> *...To alleviate this concern of an uncontrolled and uncontrollable agent system wreaking havoc, clearly emergent behavior has to be considered and planned for at the system level using top-down analysis and design techniques. This is still an area that is largely unknown in MAS methodologies… (p. 4)*

It has been found that these dynamics can be embedded implicitly in top-down designs, leading to unexpected synchronizations and oscillations that impair system performance of MASs, composed of agents that individually perform as intended (Mogul, 2005; Moore & Wright, 2003; Parunak, & VanderBok, 1997). Simulations are required to identify these phenomena and empiric practices dominate development approaches (e.g., De Wolf & Holvoet 2006; Edmonds, 2004).

In this chapter, sources for CAS phenomena in MASs are discussed. Particularly, we give an overview on current best practices for the development of self-organizing dynamics in MASs, leading to a novel classification of implementation approaches. While these practices have been classified phenomenological, insights in underlying mechanisms are required (Maes, 1994) to guide the utilization of emergent dynamics in software.

Current approaches to the construction of MASs can be distinguished between top-down development *methodologies* and bottom-up, *experimentation-based* prototyping procedures. Engineering procedures address the purpose-, cost- and time-oriented construction of applications and typically rely on iterative, top-down procedures that start from system requirements, which are agreed with stakeholders, and refine these to implementable system designs (cf. *Toward Development Methodologies* and *Summary* sub-sections). When engineering efforts target complex system dynamics, the design of applications that reliably exhibit the nonlinear system behaviors is inherently intricate (Edmonds, 2004), forcing elaborate simulation cycles conducted by experts. In order to mediate between both development paradigms a CAS inspired multi-level, *mesoscopic* modeling approach is presented and demonstrated that can be used to *redesign* MASs, enforcing the intended dynamics. Complex systems and complexity scientists as well as AOSE practitioners find a discussion of the particular challenges that MAS development efforts face established solutions.

This chapter is structured as follows. In the next section software-engineering approaches for agent-based systems are briefly introduced, followed by a discussion of relationships between MASs and CASs. Afterwards, engineering approaches to self-organizing dynamics in MASs are discussed. In the fifth section, these are classified and in the sixth section a multi-level modeling approach is presented, supporting iterative cycles of bottom-up analysis and top-down (re-)design. Finally, conclusions and prospects for future work are given.

AGENT-ORIENTED SOFTWARE ENGINEERING

AOSE proposes agents as a basic design and implementation metaphor for complicated distributed software systems. Agents are understood as autonomous and pro-active entities that are situated in an environment and collaborate with each other in so-called MASs, that is, sets of agents (Jennings, 2001). Different notions of agency exist that are supported by dedicated agent architectures, guiding agent implementation. These range from purely *reactive* mechanisms (e.g., Brooks, 1986), to *cognitive* models inspired by psychology and philosophy that address rational agent behaviors (e.g., Rao & Georgeff, 1991).

Agent-based application development is facilitated by dedicated programming languages and middleware platforms (recently reviewed by Bordini et al., 2006; Braubach, Pokahr, & Lamersdorf, 2006), directly supporting different theories of agency for application programmers. Agent platforms provide dedicated middleware platforms that offer specific services, for example, agent communication and coordination, to MAS developers utilize to construct MASs in general-purpose programming languages.

Three general software-engineering approaches to MASs can be distinguished (Müller, 2004), which comprise *agent-oriented, organizational*, and *emergentist* approaches. Agent-oriented approaches focus on the design of individual agents, typically biased towards certain agent architectures and organizational approaches that facilitate the specification of static organizational structures in the MAS. Corresponding methodologies guide MAS development from the initial examination of system requirements to the actual agent implementation. They commonly provide tailored development *processes* and modeling *notations*, supported by design *tools* (Henderson-Sellers & Giorgini, 2005; Sudeikat, Braubach, Pokahr, & Lamersdorf, 2004). These top-down approaches are opposed by bottom-up emergentist procedures that particularly focus on self-organizing dynamics. They distinguish carefully between *micro*-level agent implementations and *macroscopic* observable system-wide phenomena, providing heuristic design guidelines (Brueckner & Czap, 2006) and MAS analysis techniques (e.g., De Wolf, Holvoet, & Samaey, 2005).

SELF-ORGANIZATION: COMPLEX SYSTEM DYNAMICS IN MAS

Industrial as well as academic research initiatives intend to utilize self-organizing dynamics for the construction of robust and scalable applications. Both properties require purely *decentralized* coordination of entities, so that the absence of single points of failure (robustness) as well as the coordination of increasing numbers of entities (scalability) is ensured. The terms *autonomic computing* (Kephart & Chess, 2003) and *organic computing* (Müller-Schloer, 2004) have been coined to express visions of future adaptive IT systems that configure and maintain themselves according to high-level policies.

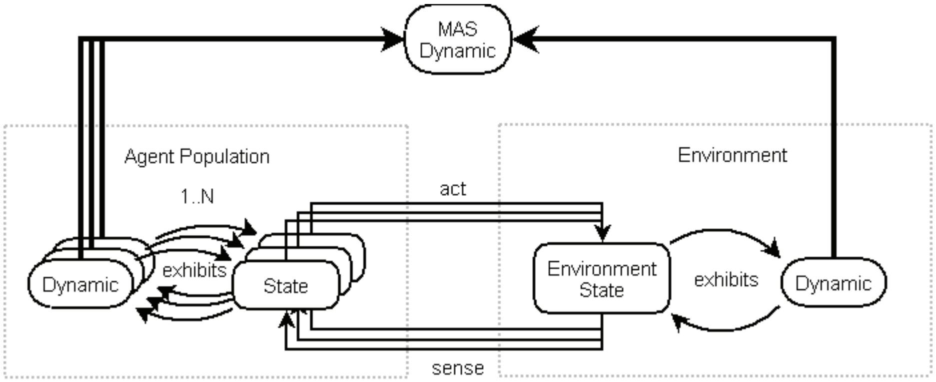
To enable these properties IT research targets the construction of adaptive processes that give rise to and maintain configurations without external control. This *self-organizing* behavior is distinct from *emergent* phenomena, that is, novel artifacts that rise from microscopic interactions (De Wolf & Holvoet, 2004). Since development efforts aim at these two complex system phenomena via *modular* and *hierarchical* structures of artificial *autonomous* entities, the resulting software systems have the potential to exhibit CAS dynamics, for example, *criticality* and *phase transitions* (Parunak et al., 2004). However, they are distinguishable from CASs observed in nature, as *self-organized criticality* and *edge of chaos* phenomena are typically absent.[2] These phenomena result from *critical* points—configurations where system properties change suddenly—that are approached and maintained by the system itself. In MASs, critical points can be identified but are commonly controlled via fixed, tunable parameters (Parunak et al., 2004).

CASs are typically defined in terms of sets of autonomous actors that interact (Bar-Yam, 2002), and computational tools have been proven valuable to give insights in their intricate dynamics (e.g., Rauch, 2002). The typically applied simulation tools need to be distinguished from general-purpose AOSE technologies (Drogoul, Vanbergue, & Meurisse, 2002). While simulation tools allow the interleaved execution of simple program models in observable environment models, AOSE provides tools to the decomposition of computational systems in truly distributed and autonomous actors.

Figure 1 presents a canonical view on MASs. A number of agents execute concurrently and interact (act/sense) with an environment that exhibits its own dynamic. Abstracting from the applied agent architectures, agents maintain execution states that are altered by environment perception and reasoning dynamics inside individuals, that is, stochastic processes in adaptive agents or reasoning processes in cognitive agent architectures. The exhibited microscopic dynamics give rise to macroscopic phenomena, that is, self-organization and emergence.

Bonabeau, Dorigo, and Theraulaz (1999) identified four basic principles for the design of *swarm* intelligent systems: (1) *multiple interactions* among the individuals, (2) *positive feedback,* (3) *negative feedback,* and an (4) *increase of behavior modification*. Multiple interactions as well as positive and negative feedback generate nonlinearities responsible for complex system behaviors. Furthermore, increase of behavior modification introduces, for the systems under consideration, a *slaving* principle proposed in the 1970s by Haken (2004). The presence of feedback loops enforces that results of agent actions continuously influence agent behavior, leading to collective adaptation. According to our canonical MAS model, self-organization results from two basic ingredients. First, agents sense their (local) environment; and secondly, they adjust their behaviors to adapt to perceptions. From the abstract view on MASs in Figure 1, it becomes apparent that MASs inherently allow for these two components. It depends on the application domain and implementation details if agent interdependencies result in feedback loops that steer the system. Top-down development approaches have to either prevent their occurrence by restricting agent behaviors or to anticipate their rise from MAS designs.

Figure 1. A canonical view on multi-agent systems. Agents sense and modify (act) their environment. In addition, agents and their environment exhibit their own dynamics, leading to macroscopic system dynamics.



When self-organizing properties are *intended* in MASs, system design forms a paradox in itself, that is, design requires developers to revise agent and environment implementations in a way that ensures the rise of the intended macroscopic artifacts (Sudeikat & Renz, 2006). Assuming that the constituent agents are properly implemented, that is, behave according to predefined rules, developers need to ensure that these rules actually lead to the intended dynamics. Due to nonlinearities and the complexity of the intended phenomena, it is a major challenge how to break the intended phenomena down into individual, microscopic agent models. Tools are needed to bridge the gap between the micro- and macro-scales of MAS implementations. In the following section, we examine current AOSE best practices to address this challenge.

ENGINEERING SELF-ORGANIZING MAS

After numerous successful applications of self-organization in MASs have been reported (Brueckner & Czap, 2006; Serugendo, Gleizes, & Karageorgos, 2006), there are notable efforts to compare and classify the utilized mechanisms. These provide MAS models that guide collective agent behavior adjustment. Adjustment design can be used to create adaptive system behaviors, for example, *phase transitions*, finally leading to self-organizing structures and emergents. Mechanisms have been categorized according to (1) the applied computational techniques (De Wolf & Holvoet, 2006; Mamei, Menezes, Tolksdorf, & Zambonelli, 2006; Serugendo et al., 2006), (2) the intended system properties (De Wolf & Holvoet, 2006a); and (3) their sources of inspiration (e.g., Hassas, Marzo-Serugendo, Karageorgos, & Castelfranchi, 2006; Mano, Bourjot, Lopardo, & Glize, 2006). Development processes support their application and formal tools have been proposed to analyze and anticipate MAS behaviors.

Template Architectures

Following Serugendo et al. (2006), five coordination mechanisms, based on *direct interactions, stigmergy, reinforcement, cooperation,* and *generic architectures* are currently utilized for the construction of self-organizing MASs. Mechanisms based on *direct interactions* rely on environments that allow agents to directly sense information of other individuals and environment objects. A prominent example is the adaptive configuration of structural and/or spatial aspects in MASs via *gradient-fields* or *co-fields* (Mamei, Zambonelli, & Leonardi, 2004). Spatial and contextual information is represented by computational fields originating from agents and/or environment objects. Fields are propagated by the environment, allowing agents to directly sense field gradients and infer information to act coherently, for example, to arrange themselves in spatial formations.

Stigmergy-based coordination is particularly inspired by biological systems where individual efforts stimulate corresponding actions of other agents (Grasse, 1959). Numerous insect species rely on so-called *pheromones*, chemical substances that denote specific insect behaviors, sensible to population members and gradually evaporating when released to the environment. When insects exhibit specific behaviors they distribute corresponding pheromones, therefore communicating their behavior. For example, when a termite builds a wall its building brick is distributing a dedicated pheromone that stimulates other termites to drop bricks nearby, leading to unique nest structures. Corresponding MAS implementations utilize *digital pheromones* (Parunak, 1997). Their evaporation provides a means of inter-agent communication and ensures that obsolete stimuli disappear gradually when their reinforcement stops.

Adaptive behavior of whole MASs can also be achieved by mechanisms that use *reinforcement* of individual adaptive behaviors. Corresponding agent implementations adapt agent behaviors based on individual stochastic processes (e.g., Weyns, Schelfthout, Holvoet, & Glorieux, 2004). Perceived environment states provided feedback on the success or failure of agent actions. This feedback is used to enforce the usage of behaviors that have been successfully applied, commonly supplemented with stochastic perturbations allowing agents to try less common behaviors.

Collective coherent MAS behaviors can also rise from agent *cooperation*. These mechanisms design agent implementations to agree on cooperative scenarios with other individuals. The sum of the local cooperative behaviors leads to the globally observed system functionality. Examples include the *organization self-design* approach from Ishida, Gasser, and Yokoo (1992) and the *adaptive multi-agent systems* (AMASs) theory (Gleizes, Camps, & Glize, (1999), which lead to the ADELFE development methodology (Bernon, Gleizes, Peyruqueou, & Picard, 2003). The methodology and corresponding tool support (Bernon, Camps, Gleizes, & Picard, 2003) guide agent design in terms of *cooperative* and particularly *noncooperative* scenarios. Agents are designed to perceive and resolve the latter ones in order to ensure that the system itself maintains the intended functionality.

Finally, *generic agent architectures* have been developed to allow modification of the MAS structure at run time. Agents can change the MAS structure directly, for example, in *holons* and *holarchies* (Koestler, 1967) or reason about and modify MAS *meta-models* at run-time (e.g., Dowling & Cahill, 2001), resulting in MAS architectures that can adjust themselves according to environmental influences.

Independent from the previous classification, De Wolf and Holvoet (2006) have examined and cataloged decentralized coordination mechanisms. They distinguish between *stigmergy, co-fields, market-based, tag-based,* and *token-based* coordination. *Stigmergy* (digital pheromones) and *co-field* (gradient fields) mechanisms correspond to the aforementioned outlined classification by Serugendo et al. (2006). *Market-based* coordination denotes agent collaboration in virtual markets where agents negotiate prices of resource access and/or service offers. This coordination scheme is established to control MAS resource allocation, since market dynamics adapt to demand and supply changes, typically leading to equilibrium states. *Tag-based* coordination is typically used for team formation and relies on tags attached to individuals. These can be viewed and modified by population members, indicating trust and reputation information. Based on this information, agents can decide team formations and role adoptions. Finally, *tokens* can be used to represent special conditions, roles, or permissions, for example, resource access. Agents need to possess the corresponding token to adopt roles or use resources and pass the token to other individuals. The rules for token distribution control MAS configuration and adaptation.

Toward Development Methodologies

The basic principles that enable self-organizing processes in *stigmergic* MASs are well understood and lead to heuristic development guidelines. Early design principles have been given by Parunak (1997), were expanded and revised by Parunak and Brueckner (2004), leading to a classification of basic principles given by Brueckner and Czap (2006), regarding the design of suitable *agent populations*, appropriate *agent interactions* that ensure information flows, leading to positive and negative feedback loops and the *emergence of desired function* via behavioral diversity inside agents and local fitness measures.

The coordination mechanisms described in the previous section provide means to implement MASs according to these guidelines. Due to the well understood dynamics, a trend towards their *reconstruction* in self-organizing MASs can be observed (discussed by Sudeikat & Renz, 2006). Development teams (1) identify a well understood coordination mechanism and (2) map its constituent parts to the actual application domain. Finally, the (3) behavior of prototype implementations is examined and parameters—controlling agent and/or environment properties—are adjusted. In this respect, the usage of coordination mechanisms as *design patterns*, that is, reusable design examples (Gamma, Helm, Johnson, & Vlissides, 1995), has been proposed by De Wolf and Holvoet (2006b). Initial guidelines on the selection of these patterns based on system requirements have been given (De Wolf & Holvoet, 2006a), in terms of a look-up table relating intended system properties to suitable coordination mechanisms. While this methodological stance reflects current development trends, it raises concerns similar to the application of traditional design patterns, that is, how to combine patterns properly, leading to quality architectures.

General-purpose methodologies usually do not consider the rise of emergent and self-organized structures (Henderson-Sellers & Giorgini, 2005). An exception is the ADELFE methodology that provides an extended version of the *rational unified process* (Kruchten, 2003), tailored to the design of adaptive MASs composed of cooperative agents. ADELFE provides tool support guiding the development process (Bernon, Camps, 2003) and a development life-cycle that stresses the identification of cooperation failures (noncooperative situations) and the equipment of agents with procedures to recover from these. Accordingly, MASs provide the intended, adequate functionality when all constituent agents provide their designated (sub-) functionalities, that is, *cooperate*. The inherent focus on cooperative mechanisms impairs support for other coordination schemes.

Since the inherent nonlinearities in self-organizing MAS dynamics impair formal specifications and subsequently render reductionist, top-down development approaches, impractical (Edmonds & Bryson, 2004), typical development procedures adopt an empirical stance and regard development as iterations of experiments. Therefore, Edmonds (2004) proposes a tailored combination of *engineering* and *adaptation* procedures for MAS development. While engineering procedures address the construction of systems by design and implementation activities, examine adaptation procedures the available (prototype) implementations and fine-tune system parameters. Edmonds (2004) argued that complicated dynamics require the adaptation phase to revise the *theory* developers have about the system behavior. The theory leads to testable hypotheses that can be checked by scientific experiments. Only when the theory is thoroughly validated developers can make assumptions about system reliability.

Another example for an experimental approach to MAS design has been given by De Wolf and Holvoet (2005). They adjusted the incremental and reductionist *unified process* (Jacobson, Booch, & Rumbaugh, 1999) in order to revise MAS implementations. In their approach architectural design concerns the selection of an appropriate coordination mechanism for the identified system requirements. Testing is adjusted to address macroscopic properties via system simulations.

Gershenson (2006) proposes a conceptual framework for the description of self-organizing systems. In concordance to ADELFE, his approach provides a measurement of the *satisfaction* of the system under consideration, in terms of a weighted sum of the goal satisfaction of individual agents. The weights have to be evaluated via experiment. The aim of corresponding design efforts is to construct systems that autonomously maximize agent satisfaction, leading to maximal system satisfaction. MAS designs rely on the introduction of so-called *mediators* (Heylighen, 2003) that arbitrate among individuals, therefore minimizing *interferences* and *frictions* (Gershenson, 2006). The conceptual framework facilitates the identification of suitable domain entities and strategies, supporting system designs that intend equilibrium states via mediating agents.

Formal Methods

Since development practices depend on experimentation procedures to analyze (nonlinear) system behaviors, formal computer science tools promise to speed up MAS simulations. Formal specifications can be used to simulate abstract models of agent implementations. Two usages can be distinguished. First, formal models can be derived from actual MAS implementations (e.g., described by Sudeikat & Renz, 2006). The derived models then allow predicting system behaviors that are expected to emerge under different parameter values and initial conditions. Secondly, abstract specifications of MAS designs can be used as *proof-of-concept* allowing validating that an initial design allows the rise of the intended dynamics.

Applied models utilize mathematics, particularly systems of *differential equations* and transition systems, that is, *process algebra* (Viroli & Omicini, 2005). Most work on formal specifications of self-organizing processes addresses *swarm robotic* systems, mathematical approaches for these systems were reviewed by Lerman, Martinoli, and Galstyan (2004) and formal specification languages were examined by Rouff, Hinchey, Truszkowski, and Rash (2006).

Mathematical treatment of complex, nonlinear system dynamics typically models the rate of change of macroscopic observables (see e.g., Haken, 2004). Temporal development of discrete systems is represented by difference equations, but typically continuous functions can be assumed, leading to sets of coupled and nonlinear, first-order differential equations. These are well established to describe self-organizing system dynamics in various disciplines (Haken, 2004), for example, chemical reaction systems or population dynamics of biological ecologies. Lerman and Galstyan (2001) established these equations to model homogenous MASs composed of reactive agents and presented a structured process to derive these equations from microscopic agent modes (Lerman & Galstyan, 2004). Assuming an underlying time-continuous Markov processes, MAS dynamics can be modeled by rate equations, describing in quantitative terms mean occupation numbers of individual agent states. Sudeikat and Renz (2006a) exemplified how similar, phenomenologic models can be derived for MASs composed of cognitive agent when an underlying stochastic process can be assumed to govern MAS dynamics.

Process algebra is a prominent formal tool to describe, model, and verify concurrent and reactive systems (Milner, 1989). Subjects are described as *transition systems*, that is, as sets of states, actions, and transition relations (S → S'), caused by actions. Stochastic extensions to this algebra have been given (e.g., by Priami, 1995) that annotate activity rates to channel definitions and make process activities subject to delays. These extensions transfer the underlying transition systems to Markov transition systems (Brinksma & Hermanns, 2001). Activity rates define how the probability of state transitions increases in time. Interpreter implementations are available for large-scale simulations (e.g., Phillips, 2006).

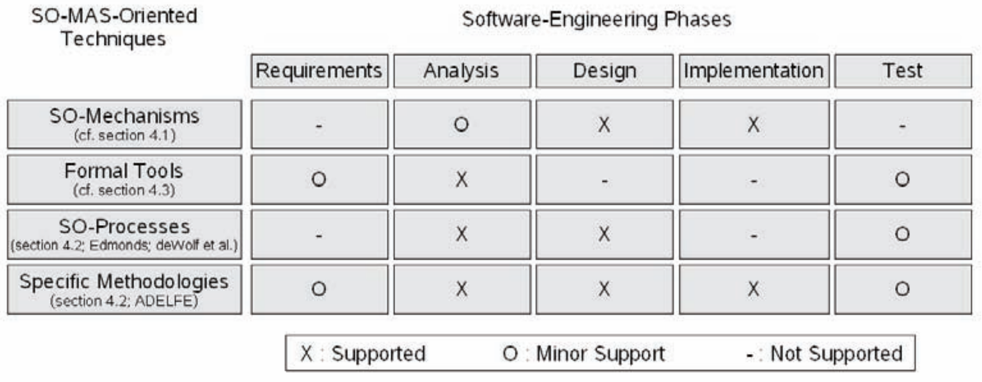
Rouff et al. (2006) examined conventional and stochastic process algebra as well as logic-based approaches, concluding that stochastic process algebras are suitable to model concurrent system dynamics while the latter formalisms are more suitable to verify agent internal reasoning. Stochastic algebras have been applied to model complex biological and chemical processes, for example, ant colonies (Sumpter, Blanchard, & Broomhead, 2001) and have been applied to self-organizing MAS dynamics (Gardelli, Viroli, & Omicini, 2005, 2006). Gardelli et al. (2006) utilized stochastic algebra specifications for quantitative, large scale simulations of abstract MAS designs. These allowed illustrating, that intended MAS designs enable the rise of intended system dynamics and facilitate the examination of system parameters and macroscopic behavioral regimes. Having examined these regimes in abstract MAS designs, developers face the challenge to enforce similar macroscopic system parameters in the MAS to-be. While the relation between stochastic algebras and MAS implementations has not been examined yet, Sudeikat and Renz (2006a) provided an initial tool support to derive process terms semi-automatically from annotated implementations.

Summary

Development efforts for self-organizing systems intend complex system dynamics which in turn complicate top-down development procedures. Therefore, current development efforts rely on template architectures and prototype/simulation approaches. While experience and heuristics guide the MAS design, methodologies support application development, for example, via enforcing the distinction between *engineering* and *adaption* (Edmonds, 2004), the promotion of a certain coordination scheme (Gershenson, 2006), or the identification of suitable template architectures (Serugendo et al., 2006). Open research questions concern how the applied coordination schemes influence each other and how they can be combined without interferences in real-world scenarios. In order to relieve simulation procedures, formal tools have been proposed. These promise computationally cheap simulations of large numbers of autonomous processes on a macroscopic scale. Therefore, they can be applied to both facilitate the analysis of available systems (Lerman & Galstyan, 2004) as well as to examine abstract MAS designs and their support for the intended dynamics (Gardelli et al., 2006). The abstract nature of these models facilitates examinations of distributed coordination mechanisms and self-organizing dynamics, but gives developers limited insight into the intended agent designs. Instead the derived models form a kind of requirements engineering for self-organizing MASs since the identified parameter ranges define properties that final agent designs have to bring by. For example, the simulation parameters for an intrusion detection system from Gardelli et al. (2006) comprise the probabilities that certain agent types interact. While simulations can ensure that a MAS composed of accordingly behaving agents will perform well, it is up to the developers to ensure consistent behavioral regimes in MAS implementations.

Software projects are commonly carried out in interactive sequences of development phases, comprising the analysis of system *requirements*, system *analysis*, *design*, *implementation*, and *testing* of the resulting software (Kruchten, 2003). System requirements express the intended functionality of the software system to-be. A detailed examination of the intended functionality guides system analysis, defining the system architecture, which is refined in the design phase until the implementation is enabled. In the last phase resulting implementations are tested. Figure 2 shows the support of these development phases by the here discussed techniques and procedures. The classified coordination mechanisms (SO-Mechanisms, cf. *Template Architectures* sub-section) reduce requirements and system analysis to the identification of an appropriate pattern, mapping this template architecture to the application domains guides MAS design and implementation. Formal tools (cf. *Formal Methods* sub-section) have been applied to simulate abstract MAS models and derive mathematical models from MAS implementations. This allows examining behavioral regimes of intended MAS designs (analysis) and implementations (test). The available methodic development approaches (SO-process, cf. *Toward Development Methodologies* sub-section) focus mainly on system analysis and design in simulation-based procedures, broadening test to simulation. The specific ADELFE methodologies is considered separately (cf. *Toward Development Methodologies* sub-section), since it provides a complete development cycle supported with notation and tools, but focusing on the *cooperation* coordination mechanism.

Figure 2. The relation between the discussed techniques for MAS development and general software engineering phases. Design and implementation relate mainly to established coordination mechanisms; requirements engineering and testing are merely unsupported.



SO-MAS-Oriented Techniques	Software-Engineering Phases				
	Requirements	Analysis	Design	Implementation	Test
SO-Mechanisms (cf. section 4.1)	-	O	X	X	-
Formal Tools (cf. section 4.3)	O	X	-	-	O
SO-Processes (section 4.2; Edmonds; deWolf et al.)	-	X	X	-	O
Specific Methodologies (section 4.2; ADELFE)	O	X	X	X	O

X : Supported O : Minor Support - : Not Supported

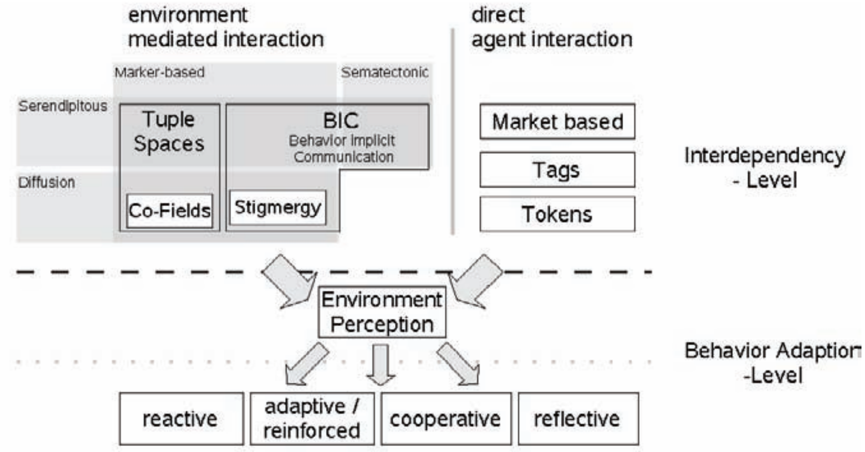
This examination highlights the lack of *requirements engineering* and *testing approaches* to self-organizing MASs. While simulation-based development procedures are currently revised, testing refers to the automated validation of specification that defines how the system under development should behave. It is a major challenge for general-purpose AOSE research to move from experimentation to testing procedures. This transition will be possibly supported by suitable means to describe and analyze the requirements for self-organizing systems.

A CAS-BASED CLASSIFICATION OF COORDINATION MECHANISMS

In the *Self-organization—Complex System Dynamics in MAS* section it has been found that complex system dynamics originate from entities that (inter-) act autonomously, but are correlated by positive and negative feedback from their environment. Agent reasoning, adjusting agent behaviors according to the available local information and the spread of this information in the MAS are two basic ingredients to self-organizing dynamics (cf. *Self-organization—Complex System Dynamics in MAS* section). The here discussed mechanisms are field tested and well understood, but their support for both of these ingredients has not been examined yet. Therefore, we differentiate in the following between interdependency- and behavior adaption-level mechanisms. While the former ones describe how information propagates to individuals from the environment and other agents, the latter ones provide blueprints for agent implementation, specifying how agents use the provided local information to select appropriate behaviors. Figure 3 displays this classification. It turns out to be that the identified coordination mechanisms form disjoint sets, supporting either feedback loops or behavior selection.

Interdependency-level mechanisms are distinguished between *direct* interactions of agents (right) and indirect interactions that are *mediated* by a (virtual) environment. The prominent stigmergy and co-field approaches are both examples for mediated interactions, since agents communicate implicitly via environment changes and virtual fields. The *environment* propagates information from anonymous individuals, and agents use these for behavior adjustment. Mamei et al. (2006) provide a fine-grained classification scheme of mediating mechanisms that inter alia concern the propagation of information and the introduction of dedicated representations. Infor-

Figure 3. Coordination mechanisms for self-organizing MAS. These provide techniques to implement agent interdependencies and selection between different agent internal behaviors.



mation propagation can either rely on *diffusion* or on agents that wander a shared data space where they encounter *serendipitously* novel information. Coordination mechanisms require the introduction of explicit data items (*marker-based*) or agents infer implicit information from the perceived environment (*sematectonic*). *Behavior implicit communications* (BICs), introduced by Omicini, Ricci, Viroli, Castelfranchi, and Tummolini (2004) relates to the fact that agents do not necessarily need to engage in communication to spread information. Sole observation of other agents' behavior can be used by individuals to infer their states, enabling coherent agent coordination, similarly enforced and degraded as in stigmergy systems. BICs describe both marker-based and sematectonic coordination and stigmergy can be regarded as specialization. Co-field implementations rely on specific *tuple spaces* (e.g., reviewed by Mamei et al., 2006), that is, a standard coordination model, based on tokens that explicitly represent the distributed information. As tuple spaces and BICs support serendipitous mechanisms, specific frameworks support the spatial diffusion of markers (e.g., digital pheromones and tuples) in virtual environments. Diffusing tuples are used to construct co-fields (Mamei, Zambonelli & Leonardi, 2004) while stigmergy denotes mediated communications between individuals via the modification of either serendipitous or diffusing environment elements. Evaporating digital pheromones are a prominent example (Brueckner & Czap, 2006). It is to note that sematectonic data spaces contradict diffusing approaches.

Direct agent interactions take place between distinguishable agents, either exchanging messages/tokens or modifying tags. Message exchange enables negotiations for *market-based* coordination and transmitted *tokens* represent permissions to play certain roles, for example, access resources. *Tag*-based coordination also provides a direct interaction approach, since their modification requires direct interaction with a known individual (cf. *Template Architectures* sub-section).

Individual *behavior adaption* is controlled by the employed agent architectures, ranging from purely *reactive* mechanisms to, *adaptive, cooperative,* and *reflective* architectures. Reactive agent models respond directly, knee-jerk to sensor perceptions, possibly deciding between behaviors categorized in priorities (Brooks, 1986; cf. *Agent-oriented Software Engineering* section).

Adaptive, cooperative, and reflective agent models correspond respectively to *reinforcement*, *cooperative* mechanisms and *generic* architectures, as identified by Serugendo et al. (2006) which support run time (re-)configuration (cf. *Template Architectures* sub-section). The term *reflective* is introduced to replace the term *generic*, characterizing the general feature of these systems that they explicitly enable MAS reconfiguration to be triggered by individual agents.

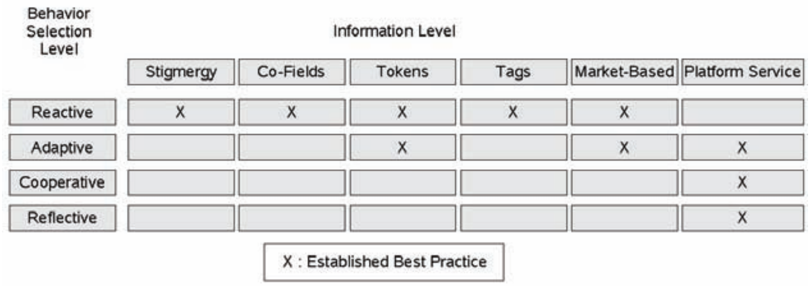
In principle, all combinations of interdependency and behavior adaption mechanisms are conceivable, however only specific combinations of agent architectures and interaction schemes are utilized. Figure 4 presents employed best practices. In this matrix the previously discussed interdependency-level mechanisms are supplemented with *platform* (communication) *services*, since some agent architectures do not require dedicated information propagation techniques, but can be implemented using generic message services.

The literature review revealed a trend that these practices focus either on environmental dynamics, steering simple reactive agent models or on more sophisticated agent designs (adaptive, cooperative, and reflective), revised to emerge collective, adaptive system behaviors (cf. Figure 5). Exceptions are token- and market-based coordination that applies adaptive agent implementations as well. This observation indicates that the combination of coordination mechanisms in MAS applications is unexplored and agrees to the previously described focus of methodologies and heuristics on specific mechanisms.

CAS-INSPIRED MAS ANALYSIS: TOWARDS MULTI-LEVEL MODELING OF MASS

Complex system dynamics are inherently nonlinear and it has been argued that their complexity impairs top-down design procedures (Edmonds, 2004). Therefore, intended system dynamics are typically anticipated, utilizing the established coordination mechanisms (cf. *Template Architectures* to *Formal Methods* sub-sections). In the following, a CAS-inspired, multi-level modeling approach to MASs is presented, showing how self-organizing processes can be explained by examining coarse-grained agent contributions to macroscopic phenomena. When constructing self-organizing MASs, developers typically have to understand and catalogue exhibited agent behaviors, forming ontologies of agent contributions to system-wide phenomena. So-called *mesoscopic* modeling, introduced by Renz and Sudeikat (2005a, 2006), aims to aid these efforts. This analysis view does not replace but supplement

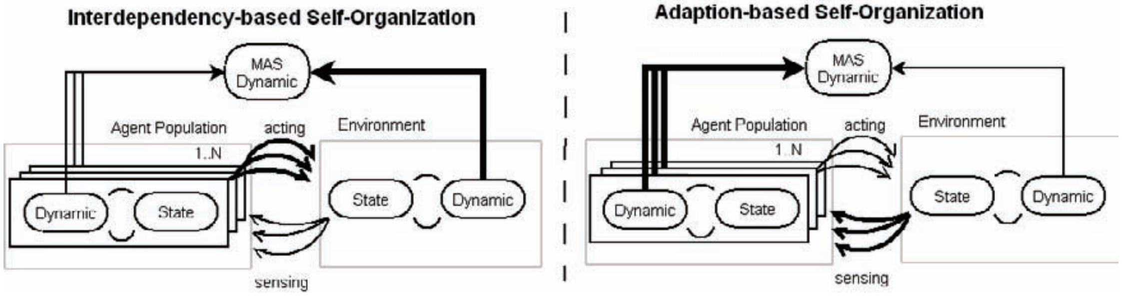
Figure 4. Established combinations of interdependency and behavior adaption mechanisms. Sophisticated information propagation schemes rely on simple agents, while complex agent models utilize generic platform message services.



Behavior Selection Level	Information Level					
	Stigmergy	Co-Fields	Tokens	Tags	Market-Based	Platform Service
Reactive	X	X	X	X	X	
Adaptive			X		X	X
Cooperative						X
Reflective						X

X : Established Best Practice

Figure 5. The distinction between interdependency-based (left) and adaption-based self-organizing architectures. Interdependency-based coordination focus on environment dynamics to coordinate rather simple agents. Adaption-based mechanisms control system dynamics via collective adaption of individuals.



the available software engineering methodologies and toolsets (cf. *Engineering Self-organizing MAS* section).

Mesoscopic Modeling

Multi-level descriptions are appropriate tools to study CASs. Taking inspiration from established efforts to understand CAS behaviors (e.g., Haken, 2004), we propose intermediate—mesoscopic—description levels to mediate between top-down and bottom-up development. This modeling notion allows relating system behaviors to individual agent behaviors, facilitating bottom-up analysis of prototype implementations and their topdown (re-)design (cf. *Applying Mesoscopic Models—MAS Redesign Support* sub-section).

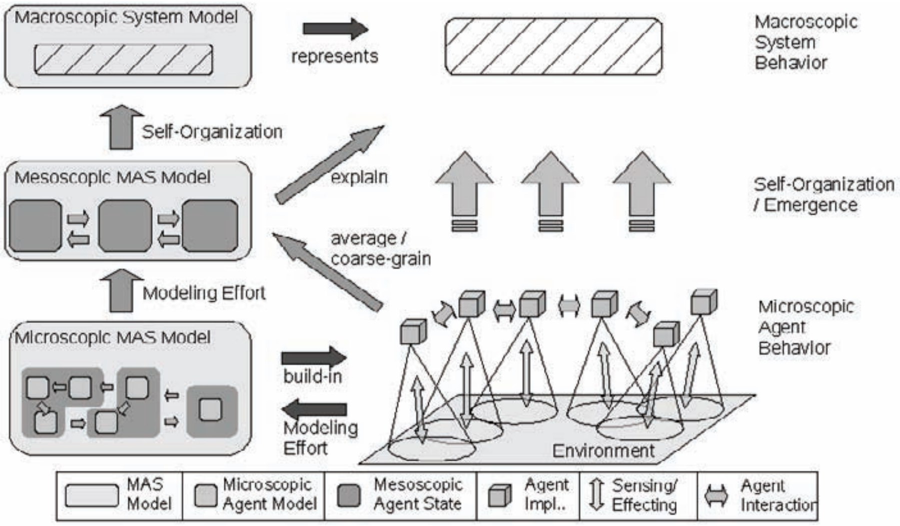
M*acroscopic* models describe the systems behavior space. Points in this space denote MAS configurations, in terms of behaviors observable in the sense of functional system requirements. Trajectories in this space represent system reconfigurations and their corresponding dynamics. Since designers intend specific macroscopic phenomena when conceptualizing MASs, it is necessary to foresee the principally possible system configurations. This helps to distinguish *intended* structures and/or emergents from *unintended* ones and the possible transitions between them. Since developers typically can not anticipate the complete MAS behavior space at design time, this model is subject to incremental revision and requirements engineering activities (Sudeikat & Renz, 2007).

The purpose of a *microscopic* modeling level is to provide sufficient details to guide agent implementation. Resulting models describe the available behaviors and the selection process that underlies agent adjustment, typically biased towards the applied agent architecture.

Transitions between qualitatively different macroscopic configurations can be explained by mesoscopic models (Renz & Sudeikat, 2005a, 2006) that introduce intermediate artifacts, abstracting from microscopic agent behaviors (cf. Figure 6). Abstraction is done by merging multiple microscopic agent behaviors and replacing them by a few abstract states, so-called *hidden* agent states, which are not directly observable in the behavior of the individual agents but average out short time fluctuations of the microscopic agent actions. This approach is inspired by similar modeling methods developed in physics to describe phase transitions in equilibrium as well as in far-from-equilibrium systems, see for example, Haken (2004).

Appropriate abstraction is a considerable modeling effort, requiring classifying and merging agent states that contribute to macroscopic dynamics in similar ways. The introduced mesoscopic

Figure 6. The relation of MAS implementations (right) and mesoscopic modeling (following Sudeikat & Renz, 2006)



states resemble *roles* agents play in respect to the exhibited macroscopic system dynamics. The resulting models are distinct from macroscopic models since they still include the underlying mechanisms causing the short-time behavior of the self-organization process (Renz & Sudeikat, 2006). It has been found that these models are useful to mathematically describe these processes that result from distributed coordination mechanisms in MASs. When appropriate agent states have been identified, system reconfiguration can be expressed by rate equations (Sudeikat & Renz, 2006a) and process algebra (Sudeikat & Renz, 2006b), requiring estimation or measurement of relevant transition rates for typical environmental conditions.

Figure 6 relates the three description levels to each other (left) and the MAS implementation they model (right). Microscopic agent (inter-) actions (bottom) give rise to macroscopic MAS configurations (top). Mesoscopic descriptions capture averaged agent behaviors. These exhibited behaviors explain how agents contribute to rising structures.

Applying Mesoscopic Models: MAS Redesign Support

In bottom-up development procedures MAS prototype implementations are tuned by simulation. This typically focuses on parameter adjustment (cf. *Toward Development Methodologies* subsection), a non-trivial task that requires extensive simulation (De Wolf et al., 2005). Procedures for the purposeful adjustment of prototypes and mechanisms have yet found minor attention (e.g., by Gershenson, 2006) but could relieve developers from costly simulation cycles. In addition these procedures provide vocabulary and tools to bridge the gap between bottom-up and top-down engineering. Sudeikat and Renz (2006) showed how the identification of agent contributions to the observable macroscopic structures (mesoscopic roles) can guide MAS redesign, that is, the purposeful modification of agent and environment implementations to enforce intended macroscopic structures. Here, two redesigns are exemplified, namely, reimplementation of adaptive minority game players and collectively clustering ants.

Case Study I: Minority Games

The so-called *minority game* (MG) (Challet & Zhang, 1997) is a socio-economically inspired setting to examine inductive reasoning in populations of adaptive agents. In a round-based game, an odd number of agents have to make repeatedly binary decisions (1 or 0) and agents in the *minority* group get rewarded. In order to increase their reward, agents need to conform to the next minority decision, while their only source of information is a limited memory of the past round results.

Renz and Sudeikat (2005, 2005a) redesigned a stochastic adaptive agent population, where agents adjust their probability to alternate their previous selection. Successful agents increase their likelihood to change, while unsuccessful agents tend to stick to their previous selection. It turned out that these agents—in specific parameter regimes—can play *optimal* and *fair*, that is, enter a behavioral regime where population reward is maximized and agents get awarded in turn.

A mesoscopic model classifies three behavioral regimes, namely, supplier *loyal*, *alternating*, and *undecided* agents. Optimal behavior occurs when agents synchronize into two distinct alternating groups. In this case the agent with the smallest alternation probability adopts a so-called *emergent role* (Renz & Sudeikat, 2006). Its selection determines which group will win and loose respectively, since the alternating groups are equal sized. This role was named *Schwarzer Peter* (get the short straw in German speaking countries) and solely arises from game dynamics. Since *Schwarzer Peter* agents force other individuals to loose, eventually this role will be adopted by other (less successful) agents.

Besides a mathematical treatment, the mesoscopic model guided agent *reimplementation*. The continuously changing strategies of the stochastic MG were replaced by deterministic transitions between three agent states, representing the mesoscopic behaviors. By means of self-organization, deterministic state transitions lead to similar, optimal behavior in a controlled and predictable way (Renz & Sudeikat, 2005a, 2006).

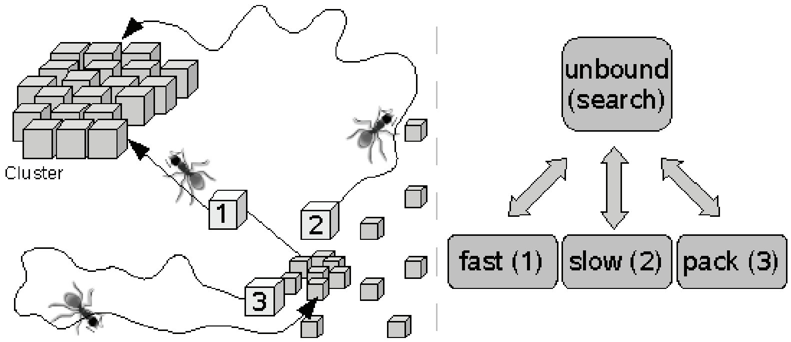
Case Study II: Collective (Ant) Sorting

Ants achieve global structures of grouped items (eggs, larvae, etc.) by continuously transporting items to similar ones nearby (Parunak, 1997). These *brood-sorting* mechanisms are well studied and have been applied to sort and cluster large scale data in open environments with streams of incoming items (Parunak, Weinstein, Chiusano, & Brueckner, 2005). A naive implementation comprises reactive agents that walk an environment (torus) in Brownian motion, inhabited by a number of randomly distributed items. Agents execute a searching behavior either to find items to pick up (when unbound) or to drop at another item (when bound to an item).

Figure 7 denotes the mesoscopic system description. Ants contribute to cluster formations in three distinct ways. They move items from the grid to a cluster after (1) a comparatively short walk, (2) they carry a comparatively long walk, or (3) they pick up items and release them on the same cluster. The length of a walk is related to the environment size and item density. From the mesoscopic system description (Figure 7), it was inferred that the short walk behavior (1) is to be amplified to enhance clustering efficiency. This increase is achieved by two redesigns, focusing on agent movement and the inhabited environment.

A first redesign replaced the Brownian motion with a stiffened random walk behavior. When agents have gained a high velocity, the average deviation to their current heading is reduced. Therefore, the trajectories of individual agents stiffen over time, resulting in a mean velocity increase. The second redesign increases agent's probability to drop items. It is enforced that items are dropped on top of encountered items. Released items adopt the heading of the encountered item and move (fall) till they reach an empty grid cell.

Figure 7. The transportation behaviors of sorting ants (left). Agent movement can be (1) comparatively direct (2), indirect, or (3) may also let agents pick up and drop items at the same cluster. These behaviors correspond to mesoscopic transportation velocities (right; from Sudeikat & Renz, 2006).



What results are *elongated structures* of aligned items. The elongated shape increases the cluster surface, therefore increasing the probability to be encountered by stiffened walking agents. The obtained improvement has been quantified by Sudeikat and Renz (2006).

Mesoscopic models provide a novel vocabulary that depends on the application domain and allows us to reason about MAS behaviors. Their application poses a non-trivial modeling effort, but the resulting system abstraction can be formally specified, allowing developers to anticipate the effects of changes. Mesoscopic models describe how agents contribute to the globally observable structures. Mesoscopic states describe roles agents play in relation to the system structure, for example, fast and slow moving agents are *roles* agent play in relation to the global transport behavior toward a cluster. Therefore, the derivation of mesoscopic models relies inherently on the identification of contributions to global artifacts and different views on the same MAS are possible. Based on these models are two redesign strategies principally possible. (1) The MG case study exemplifies how intended system behavior can be controlled and adjusted by resembling the identified mesoscopic states directly in agent implementations. The wanted, emergent system behavior observed in the stochastic MG can now be obtained by self-organization in the mesoscopic model (Renz & Sudeikat, 2006). (2) In the case of collective (ant) sorting (Sudeikat & Renz, 2006) an increase in sorting efficiency was achieved solely by identifying an agent behavior to be amplified and corresponding adjustment of reactive agent models and environment objects representing the mesoscopic states explicitly. During these redesign efforts the mesoscopic models do only change when analysts gain novel insights in the agent contributions to structures. The estimation of transition rates between identified roles, that is, mesoscopic states, relies on environmental changes.

CONCLUSION

In this chapter we justified that AOSE research has to address the possible rise of emergent and self-organized phenomena in MASs. Design efforts may introduce them unintended, or revise agent and environment interactions to ensure their rise. In addition, we argued that the development of MASs—particularly ones with self-organizing properties—can be regarded as the challenge to construct CASs, leading to the question how both research areas can endorse each other. While MASs, that is, agent-based modeling, is an established tool for CAS research, corresponding analysis techniques only play a minor role in AOSE research.

Established techniques and methodologies to design and implement self-organizing MASs have been reviewed and classified according to their focus on collective *agent behavior adjustment* or *agent interdependency propagation*. Both are suitable to design self-organizing MASs and are currently applied rather independently from each other. In order to mediate between top-down development approaches and bottom-up experimentation procedures, mesoscopic modeling—a CAS-inspired multi-level analysis approach—has been discussed and it has been exemplified how the gained insights in system dynamics can be used to redesign agent implementations, enforcing the rise of intended structures. While simulations of the final implementations are necessary, representations of mesoscopic models allow the anticipation of (re-)design results. We expect the proposed modeling approach, together with the novel classification of MAS designs to stimulate the analysis of MAS implementations, allowing developers to examine and compare underlying mechanisms. In order to combine design heuristics and simulation procedures and top-down engineering practices, tools, and models for the examination of self-organizing MASs are necessary. The typically applied computational techniques to the construction of self-organizing MASs are catalogued and have been classified in this chapter (cf. *A CAS-based Classification of Coordination Mechanisms* section). Commonly agreed taxonomies of self-organizing phenomena and their causes are essential to revise prediction techniques and (semi-) automated analysis tools in order to move from MAS *simulation* to *testing* MASs for intended phenomena. This transition is crucial for purposeful engineering practices.

We expect the rising awareness that self-organization is a generic, inherent feature of MAS implementations (cf. *Self-organization—Complex System Dynamics in MAS* section) and that it will affect general-purpose AOSE practices. Tool support for MAS *analysis* by simulation and *construction* by adjusting template architectures will become more and more crucial. Since mesoscopic modeling facilitates the anticipation of system behaviors, it is a topic of future research how these can be introduced in structured development processes.

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[2] See the SOS FAQ v.2.99 http://www.calresco.org/sos/sosfaq.html for references and a readable introduction

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Chapter 2.23

Challenges in Developing a Knowledge Management Strategy:

A Case Study of the Air Force Materiel Command

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ABSTRACT

It is widely acknowledged that knowledge management (KM) strategy is a desired precursor to developing specific KM initiatives. Strategy development is often difficult due a variety of influences and constraints. Using KM influences as a foundation, this case study describes issues involved in developing a KM strategy for the Air Force Material Command, including issues to be considered for future strategy development such as leadership support and understanding, conflicts with IT organizations, funding, technology usage and configuration, and outsourcing.

INTRODUCTION

Enablers, barriers, and influences of KM have been grouped into three broad categories: internal managerial influences, internal resource influences, and external environmental influences

(Holsapple & Joshi, 2000, 2002). Managerial influences "emanate from the organizational participants responsible for administering the management of knowledge" (Holsapple & Joshi, 2000, p. 239); resource influences include human, financial, knowledge, and material resources that make KM a reality (p. 241); and environmental influences affect what "knowledge resources should or can be acquired in the course of KM, as well as what knowledge manipulation skills (e.g., human or technical) are available" (p. 242).

KM strategy is also generally regarded as essential to implementation and should be guided by organizational strategy (Zack, 1999). Earl (2001) provides a taxonomy of strategic starting points, seven "schools of knowledge management" and key attributes of each. Yet despite such insight, little is known about KM strategy within the military (Bower, 2001; Plant, 2000). Difficulties stem from the unique context in which KM must be implemented including culture, organization, and operating environment. Because of these unique attributes, an investigation of military KM may prove telling theoretically and practically.

CASE BACKGROUND

Headquartered in Dayton, Ohio, Air Force Material Command (AFMC) employs 85,000 military and civilian employees worldwide. AFMC has "cradle-to-grave" oversight for all aircraft, missiles, and munitions. The Directorate of Requirements (DR) is home to AFMC's Knowledge Management program.

In the early 1990s, AFMC/DR developed a repository of acquisitions regulations, process descriptions, and other miscellaneous information. The repository soon expanded into the Defense Acquisition Deskbook program and was managed by an interservice Joint Program Office. AFMC/DR continued updating Air Force (AF) documents within Deskbook; however, this did not require DR's entire budget. As a result, it was decided the excess funding was to be used for the development of an additional KM application that helped to document and disseminate overarching AF lessons learned.

AFMC/DR was also developing Web-based training for acquisitions personnel due to impending talent drains as more civilian personnel retired. To improve AFMC's preparedness, Deputy Director Robert Mulcahy became a KM champion. He consolidated deskbook, lessons learned, and web-based training into one KM system in order to provide better capture and dissemination of critical workforce knowledge.

Mulcahy assigned Randy Adkins to lead the consolidated AF knowledge management (AFKM) program. Initially, the AFKM program centered on the use of commercial KM processes and technologies for solving specific customer problems. Soon, however, the now-consolidated KM system grew beyond its original three components; by 2000, two new modules were added: the AFMC Help Center and Community of Practice (CoP) workspaces." The Help Center provided search capabilities for information across AFMC web sites; the CoP workspaces fostered information exchange, collaboration, and problem solving. The AFKM Hub/home page was a portal-like entrance into the entire system.

RESEARCH METHOD

AFMC was one of the first AF organizations to embrace KM; the AFKM team also faced significant challenges determining future directions for their efforts. It was therefore likely key issues impacting KM strategy development might be identified in this context. Additional case research was also needed to bridge the gap between KM theory and practical advice (Jennix, 2005, p. vii). Given these factors, an exploratory case study methodology was used.

Holsapple and Joshi's (2000, 2002) KM influences framework provided three foundational constructs for “analytic generalization” (Yin, 1994, p. 31); these factors—managerial, resource, and environmental—could be examined as potential barriers to KM strategy development. Considerations for design quality were made in accordance with Kidder and Judd (1986) and Yin (1994); however, internal validity was not addressed due to the study’s exploratory nature.

Data included interviews, field notes, and physical traces. Open-ended interviews were taped and transcribed, then reviewed and approved by respondents. Twelve individuals were interviewed providing a cross-section of organizational leadership, the AFKM team, and AFKM customers. Transcripts were first searched and categorized according to a priori KM influence (and emergent) categories and themes. Resultant data was combined with field notes (capturing impressions about the interviews and observations of individual/organization dynamics) and physical traces (e.g., documents, Web sites, organizational charts, budget records, advertising media, etc.) to form a robust understanding of the case.

FINDINGS

The AFKM effort exhibited many of Holsapple and Joshi’s (2000, 2002) influence factors; however, the military environment provided some unique constraints that further exacerbated the negative influences. On the whole, this study revealed a variety of latent and emergent issues that should be considered for any KM strategy development; key issues are discussed below.

Leadership Support and Understanding

Mulcahy had been a staunch supporter for KM efforts. David Franke replaced Mulcahy in 2000, and a new Director of Requirements was also appointed. Both were open to KM concepts and the AFKM program, but neither was as educated or enthused about KM as Mulcahy. Adkins indicated that Franke didn’t see KM as needing emphasis above other AFMC programs, thereby increasing the difficulty of securing exposure and backing necessary to compete for scarce resources. Furthermore, few other individuals had much of an idea of what KM was about. Although it was easy to communicate the importance of individual applications (e.g., lessons learned, document repositories, corporate yellow pages), it was more difficult to explain comprehensive KM concepts. Adkins realized “learning about KM” took time, but the ignorance of those upon whom he relied for support threatened the program’s survival before it had a chance to prove itself on a large scale.

Conflict with the IT Organization

Dealing with AFMC’s information technology (IT) organization was a continual challenge because it perceived its role as providing technology solutions for the customer, as did AFMC/DR. Additionally, a conflict arose when the IT organization mandated LiveLink® as AFMC’s only authorized collaboration tool. LiveLink® directly conflicted with CoP development and was generally more sophisticated than was needed by the average customer. While Adkins’ team had a wealth of KM knowledge and system development expertise, the IT organization was the authorized policy maker, and continued conflicts risked AFKM being changed, dismantled, or absorbed.

Funding

A $600,00 budget cut loomed that would eliminate six personnel impacting AFKM systems development workload distribution. Furthermore, many AFKM customer-specific applications had been developed without charge. Without such assistance, some customers would never get their

KM efforts off the ground and AFKM's support practices would have to be re-evaluated

System Usage Concerns

Despite rave customer reviews about AFKM systems, Adkins was disturbed by low usage rates. Access metrics showed usage generally rising, and yet it was a small portion of what it could be. Publicity capmpaigns did little overall; it was clear the AFKM system tools were still in their infancy and the low usage statistics didn't help the team adequately justify the benefits or budget.

Technological Challenges

The AFKM team became so efficient at developing technology solutions that they could develop a "CoP in a box" with a few minor customizations in only a few days. Instead of providing content (i.e., deskbook, lessons learned), the team now provided software frameworks, in which customers added information and knowledge. However, a new AF portal was decreed the de-facto access point for all AF information and knowledge. This raised the question of how to design future applications. Adkins' team was heavily involved in the technology of CoPs, but the community-based capabilities of the AF portal might change everything.

Outsourcing KM

With so many issues impacting AFKM; Adkins needed a strategic vision and implementation roadmap to guide future development. Adkins' foremost concern was the development of a strategic vision and plan. He needed documents that would provide starting points for decision-making and describe how to proceed to the envisioned business environment.

Unfortunately, AeroCorp's recommendations captured the complexities of AFMC's environment, and yet were so broad and involved it was difficult to determine a starting point. AeroCorp also had difficulty developing concise methodologies or "blueprints" that addressed the enormity of what AFMC needed to do to evolve into a true knowledge-sharing organization. In particular, AeroCorp applied integrated definition (IDEF) modeling to KM. IDEF modeling was developed for systems engineering and often depicts "as-is" enterprise processes and information requirements; it did not serve as a user-friendly methodology for fully explaining or depicting strategic KM needs.

After seeing the initial draft of the IDEF model, it was clear the process was "over-engineered." After a year of waiting, the promised roadmap was too unfamiliar and complicated for Adkins and others to practically implement. Faced with an impending budget cut, AeroCorp would likely not have an opportunity to make necessary changes. At this point, Adkins had no good answers.

LESSONS LEARNED

Adkins understood he needed a strategic vision to guide AFKM's direction and decision-making. When outsourcing KM strategy met with limited success, he rescoped and refocused the team on a few key areas under their immediate control. From 2002 forward, the AFKM team:

1. promoted CoPs as a key technique for KM across the AF,
2. provided enterprise Web search capabilities across AFMC and selected AF sites,
3. used a process approach for delivering CoP capability.

The team's strategy became one of building momentum by providing rapid KM services ("CoPs in a box") and following up with training and implementation support; leadership could observe successes at the grassroots level. Since the change in strategy, AFKM has enjoyed remarkable success. The AFKM Web site, now called AF Knowledge Now, continues to expand its capabilities and customer base. In 2004, Adkins secured key support from the AF Chief Information Officer; Adkins' team was dubbed the AF Center of Excellence for Knowledge Management, and AF Knowledge Now was integrated into the AF portal.

IMPLICATIONS AND CONCLUSION

This study highlighted some real-world examples of such barriers and several issues to be considered for strategy development: many of the same factors that act as barriers to implementation may also impede KM strategy development. This study highlighted some real-world examples, such as barriers and several issues to be considered for strategy development:

- KM is hard to define and communicate to others.
- KM initiatives must be championed and supported at the highest levels of any organization.
- KM strategy development is not easy, yet it is critical to the success of any KM initiative.
- Outsourcing KM can be very risky.
- Focusing on specific KM efforts is important for countering negative KM influences.

Despite rising awareness of KM and its benefits, we are reminded that such issues may well play out in any organization, military or otherwise, and should be accounted for preemptively during KM strategy development to improve the chances of improving long-term organizational performance.

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ENDNOTE

[1] The views expressed in this case study are those of the authors and do not necessarily reflect the official policy or position of the Air Force, the Department of Defense, or the U.S. Government.

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Chapter 2.24

A Multi-Agent System for Optimal Supply Chain Management

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ABSTRACT

Supply chain management recently has been developing into a dynamic environment that has to accept the changes in the formation of the supply chain. In other words, the supply chain is not static but varies dynamically according to the environmental changes. Therefore, under this dynamic supply chain environment, the priority is given not to the management of the existing supply chain but to the selection of new suppliers and outsourcing companies in order to organize an optimal supply chain. The objective of this research is to develop a multi-agent system that enables the effective formation and management of an optimal supply chain. The multi agent system for optimal supply chain management developed in this research is a multi agent system based on the scheduling algorithm, a cooperative scheduling methodology, which enables the formation of an optimal supply chain and its management. By means of active communications among internal agents, a multi-agent system for optimal supply chain management makes it possible to quickly respond to the production environment changes such as the machine failure or outage of outsourcing companies and the delivery delay of suppliers.

This research has tried to suggest a new direction and new approach to the optimal supply chain management by means of a multi-agent system in dynamic supply chain environment

INTRODUCTION

Many companies have tried to introduce SCM (supply chain management) in an effort to enhance competitiveness amid severe competition caused by market globalization. Now, the participating companies in the supply chain are not fixed but rather are dynamically being changed in response to the environmental changes. Under such a dynamic SCM, it is very important to determine with whom to cooperate in order to solve these problems coming from environmental changes. Instead of seeking to optimize the existing supply chains, this study has focused on optimizing the supply chain itself. The optimization of an existing supply chain can be efficient to a fixed supply chain, but it is difficult for a dynamic supply chain to respond flexibly under the environment that its member is always changing. When a company joins an existing optimal supply chain, or when a company, which is currently joining a supply chain, has to transfer to another supply chain, they have to change their systems or processes in order to join in the new supply chain. However, this is not an easy job. The optimization of a supply chain is not made only once. Rather, it is to be made continually in response to diverse environmental changes. That is, it needs to be made on a real-time basis.

By the way, the supply chain, which consists of a lot of companies, is likely to meet with various complex problems for entire optimization, and these problems bring a significant influence on making the optimal supply chain. For example, machine failure of one participating company affects not only its related member companies but also the whole supply chain that the company belongs to. Therefore, this problem must be coordinated or adjusted not as a problem of one company, but as a problem of whole supply chain. To this end, each member of the supply chain has to cooperate and exchange information between members on a real-time basis. A multi-agent system can provide a useful tool for this purpose. Many preceding studies have emphasized that the multi-agent system is the best way in solving many complicated problems under diverse environmental changes (Bussmann, 1999; Choi, Kim, Park, & Park, 2004; Fox, Barbuceanu, & Teigen, 2000; Julka, Karimi, & Srinivasan, 2002; Shen & Norrie, 1998; Shen, Norrie, & Kremer, 1999). Also, this is an efficient way of exchanging and sharing information without integration of its applications among companies. That is to say, it enables relevant companies to move smoothly to another supply chain without changing their systems and processes. Accordingly, only by the transfer of the agent alone, which represents the relevant company, cooperation, and information exchange among members within the supply chain can this be made possible.

In this study, we developed an integrated scheduling method in order to organize and manage an optimal supply chain and a multi-agent system in order to solve the various problems occurring on a real-time basis in the optimal supply chain. The integrated scheduling method enables the scheduling for the entire supply chain in cooperation with related members in a supply chain, thus it is possible for a manufacturing company to make scheduling by taking into consideration the production environments of outsourcing companies and the delivery status of suppliers. And the multi-agent system shares the information on production environment and supply capacity of both outsourcing companies and suppliers, making it possible to respond to the dynamic environmental changes such as a delay in supplying parts or raw materials, power stoppage, or machine failure of the outsourcing companies for an optimal supply chain management.

BACKGROUND

A multi-agent system has been considered the best way to solve complicated problems under the diverse environmental changes (Shen et al., 1999). In fact, it is not easy for manufacturing companies to be flexible for dynamic changes. A number of researchers have attempted to apply agent technology to manufacturing enterprise integration, supply chain management, manufacturing planning, scheduling, and control (Bussmann, 1999; Maturana & Norrie, 1996; Parunak, 1987; Parunak, Baker, & Clark, 1997). This trend is well described in Shen et al.'s studies on agent-based production system (1999). Shen et al. developed in their studies many production-related agents with diverse functions and configurations. Their studies mainly focused on making new a manufacturing system using an agent technology for automation and efficiency in the process planning and scheduling. Also, the AARIA (Autonomous Agents for Rock Island Arsenal) project of Intelligent Automation company (Baker, Parunak, & Erol, 1997), ABCDE (Agent-Based Concurrent Design Environment) system developed by KSI (Knowledge Science Institute) of University of Calgary (Balasubramanian & Norrie, 1995), a virtual manufacturing agent made by LIPS institute of the University of Texas at Austin (Chuter, Ramaswamy, & Baber, 1995) and MASCOT (Multi-Agent Supply Chain cOordination Tool) agent of Intelligent Coordination and Logistics team of Carnegie-Mellon University (Norman, David, Dag, & Allen, 1999) are representative studies that have used a multi-agent system for development of intelligent manufacturing system.

While making intensive studies on the intelligent manufacturing system by means of an agent system, the scope of this research has been extended to the study on a multi-agent system for supply chain management. Shen et al. (1999) emphasized that there are a lot of complexities and changes in the manufacturing environment under supply chain, and that the agent system can be the best way for effective supply chain management. Also, they said that a multi-agent system can be the best method to integrate the activities of suppliers, customers, and business partners with internal activities of a company (Shen & Norrie, 1998). Meanwhile, more active research has been done on the agent-based supply chain models. Wu, Cobzaru, Ulieru, and Norrie (2000) suggested a new method that one participating member is connected via a Web system to the agents of its related business partners in the manufacturing, distribution, and service field. When an event happens, each agent cooperates to organize a virtual cluster to solve a specified problem. Julka et al. (2002) suggested an SCM model based on an agent while emphasizing the importance of a more flexible and efficient system. Shen et al. (1999) divided production management into five divisions such as design, process planning, scheduling, marketing, and coordination. And then they established a mediator agent for each division and a mediator agent for each mediator agent. Through this mediator-based multi-agent system, they suggested the possibility that if the scope of manufacturing activities within a factory is extended to its suppliers or business partners, an effective SCM could be established. MetaMorph II system suggested by ISG has a mediator-based multi agent structure, suggesting a supply chain network model where the agents for suppliers, business partners, and customers are connected to the mediator of the system via Internet (Shen et al., 1999).

Most existing research has tried to solve the complex and difficult problems, which cannot be solved by individual application programs, by means of mutual cooperation among agents. That is to say, the existing studies have focused on solving various problems occurring within a supply chain by way of communicating among agents. But this study has tried to organize an optimal supply chain by means of communicating among agents, while focusing on maintaining and managing the optimal supply chains. The existing studies and this study are similar in the sense that both have made use of a multi-agent system, but differences between them are in where and how the multi-agent system has been used. Also, it can be said that the studies on the optimization of supply chain by means of a multi-agent system have not yet been made much.

A METHOD FOR OPTIMAL SUPPLY CHAIN MANAGEMENT

Organization of Optimal Supply Chain

This study focuses on the following problems: How to organize an optimal supply chain under the dynamic supply chain environment? When environmental changes have occurred to the optimal supply chain, how to respond to it? As an object of our research, this study chose a molding company among many make-to-order manufacturers. When a molding company tries to select a supplier and an outsourcing company, such factors as delivery date, cost, and productivity are to taken into consideration. In particular, owing to its industrial characteristics, the due date is the most important factor. A molding company is a typical make-to-order manufacturer, and so if it fails to meet the due date required by a customer, it is impossible for the company to sell its product. Also, as most products of the molding companies are standardized, their price and quality are almost the same, thus showing no much difference. Because of this, instead of the price and quality, the delivery date becomes a critical factor in choosing a supplier or an outsourcing company.

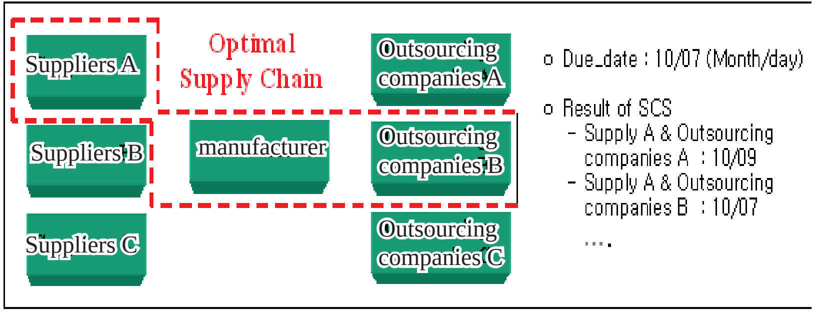
When there are many outsourcing companies and suppliers, as illustrated in Figure 1, this study has selected the supplier and outsourcing company that can meet the due date demanded by customers in order to organize an optimal supply chain.

If an outsourcing company participating in the optimal supply chain is unable to perform operation due to its machine failure, or a supplier fails to provide the specified parts on the due date, the manufacturer has to reorganize the supply chain. Like this, when environmental changes occur, it is absolutely necessary to automatically obtain, exchange, or share information in order to speedily respond to the sudden environmental changes.

An Integrated and Dynamic Scheduling Method for Optimal Supply Chain Management

This research uses genetic algorithm to establish integrated and dynamic scheduling. This algorithm integrates process planning and scheduling in order to consider alternative machines of outsourcing companies and operation sequences, and also can perform rescheduling in response to the changes in the production environment. Traditionally, process planning and scheduling were

Figure 1. Optimal supply chain



achieved sequentially. However, the integration of process planning and scheduling brings not only best effective use of production resources but also practical process planning without frequent changes. Choi, Kim, Park, and Park (2004) have proved that this integration of process planning and scheduling is far superior to the sequential process of planning and scheduling in the aspect of completion time of jobs.

We used a genetic algorithm with flexible representation structure for the integrated and dynamic scheduling method. Genetic algorithm enables integrated scheduling, considering alternative machines of outsourcing companies and operation sequences. Also, it enables rescheduling when changes have been made to the suppliers, outsourcing companies, and producer. In order to design genetic algorithm, first of all, the attribute of the problem should be analyzed, and then the presentation proper to the problem, performance measure, genetic operator, and genetic parameter should be decided. The following is genetic algorithm for the establishment of integrated scheduling considering alternative machines and operation sequence under the dynamic situation.

Representation

To achieve integrated production plan through genetic algorithm considering alternative machines and operation sequences, first of all, the problem should be represented in chromosome. The representation should be made in the way that all the processing sequence, alternative operation sequences, and alternative machines could be decided. First, to represent processing sequence, the pattern to repeat the number of the job as many as the number of operation is used. One gene means one operation, and in the represented order it will be allocated to the machines. For example, the problem of three jobs and three machines is represented in sequence as shown in Figure 2. The threefold repeated number in the first row is the number of the job, and the reason that each job number has been repeated three times is that each job has three operations. The first repeat of the job number means the first operation of the job, and the second repeat means the second job operation. If the job number continues to represent the number of job operation, this chromosome will always maintain its feasibility. The second row is the random numbers that will be used to decide alternative operation sequence. As each job is done in the one-operation sequence, each job produces the same random number within the number of maximum alternative operation sequence. For example, as job 2 in Table 1 has three alternative operation sequences, the random figure has to be produced within three. The third row has the random numbers to decide the alternative machine, producing them within the number of maximum alternative machines. In Table 1, the second operation of job 1 is to be done in the M2 but also can be done in the M1 and M3. In this case, the number of machines that can handle the second operation of job 1 is 3. As there are no more alternative machines than this in Table 1, the random figures for all alternative machines will be produced within three. The index in the last row means the repeat number of job numbers, namely showing the ordinal operation of each job.

Selection Method

The seed selection is used as a way of selection (Park, Choi, & Kim, 2001). Seed selection, as a way of individual selection that is used in the propagation of cattle and the preservation of the individual, has been introduced to the evolution of genetic algorithm. If the random value of the individual, which belongs to the father among parents, comes within the figure of probability (0.9), the best individual will be selected from within superior individuals from ranking population. But, if not, the individual will be randomly selected from among the entire group. The mother will be selected randomly among the entire group, but in this case, first two individuals will be selected randomly, and then the better individual based on the value of probability will be selected. These will be used as parents, and then returned to the individual groups, so that they will be used again later.

Genetic Operator

Crossover operator should maintain and evolve the good order relationship of chromosome. The crossover operator used in this research has a process as follows:

① Produce a random section
② Insert all the genes inside the random section into parent 2
③ All genes with the same index as the genes in the random section will be deleted in parent 2
④ It will be corrected according to the alternative operations sequence of the initial job number to make alternative operation sequence coincide to the same job number
⑤ These processes will be performed alternating parent 1 and parent 2

The position of insertion is just before the gene where the random section has started. If in parent 1 the random section starts in the fourth place, then the position of insertion will be before the fourth gene in parent 2. This crossover operator produces two children. After two offspring are evaluated, the better one will be sent as a next generation. The mutation operator gives a change to the chromosome, thus maintaining diversity within the group. This research uses the mutation operator based on the neighborhood searching method (Park et al., 2001).

Table 1. Alternative machines and alternative operation sequences of each job

Job 1	Operation sequence 1 (alternative machine)	M1	M2	M3
		(M3)	(M1)	
			(M3)	
	Operation sequence 2 (alternative machine)	M1	M3	M2
		(M3)		(M1)
				(M3)
Job 2	Operation sequence 1 (alternative machine)	M1	M2	M3
		(M3)		(M1)
				(M2)
	Operation sequence 2 (alternative machine)	M1	M3	M2
		(M3)	(M1)	
			(M2)	
	Operation sequence 2 (alternative machine)	M3	M1	M2
		(M1)	(M3)	
		(M2)		
Job 3	Operation sequence 1 (alternative machine)	M1	M3	M2
		(M3)	(M1)	
			(M2)	
	Operation sequence 2 (alternative machine)	M1	M2	M3
		(M3)		(M1)
				(M2)

Figure 2. Chromosome representation

3	2	2	2	3	1	1	1	3
2	3	3	3	2	1	1	1	2
3	2	2	1	1	2	1	1	2

(1 1 2 3 2 1 2 3 3) …
(Index)

Objective Function and Replacement

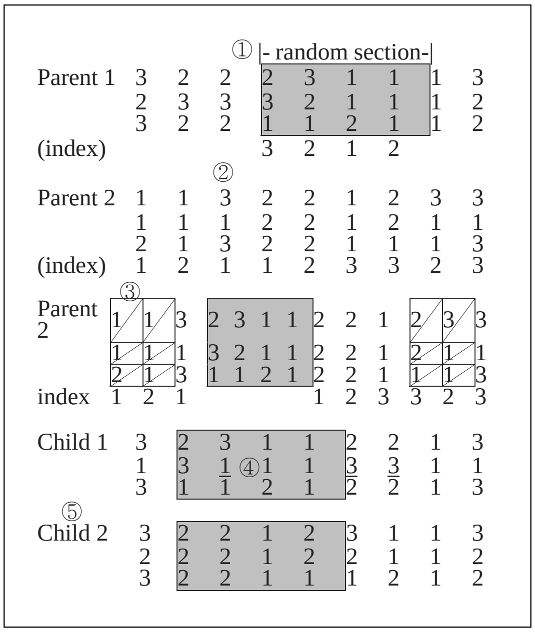
The minimum makespan in the scheduling often means the highest efficiency of a machine. When a chromosome is represented as a permutation type, the makespan is produced by the process that assigns operations to the machines according to sequence of gene from left to right, while maintaining the technological order of jobs and considering its alternative operation sequence and alternative machine. The process is shown in Figure 3. The next generation will be formed by the selection among the current generation and with the help of genetic operator. The new individuals will be produced as many as the number of initial population and form the next generation. By using elitism, bad individuals will be replaced with good individuals. Also, because of crossover rate and mutation rate, some individuals will be moved to the next generation without getting through the genetic operator.

Genetic Algorithm for Dynamic Scheduling

The genetic algorithm suggested in this paper reflects the dynamic changes in the suppliers and outsourcing companies along with the production changes of the producer. When the changes of production environment have happened in suppliers or outsourcing companies—the acceptance of new orders, machine failure, outage, and the absence of the worker in duty—all these changes will be reflected in the rescheduling. For example, when a machine cannot be operated for 10 hours because of its failure, or a supplier cannot keep the lead-time, thus delaying 10 hours, the integrated scheduling will reflect the usable time of each machine and the possible starting time of each job. Figure 4 shows the process of rescheduling when a new order has been accepted at the time of t1.

In the process of rescheduling, the remaining jobs and the new jobs to be done by the new orders will be considered in the new production planning. It also considers the starting time of jobs and the usable time of machines. The starting time of jobs can be changed by the delay of supply or the operation delay of its prior process. The usable time of machines, as shown in the black shade of Figure 4, can be changed by when the machine has already been allotted to other job, machine failure, and the absence of the worker on duty. All these dynamic changes will be reflected in the rescheduling (Park, 1999). In the rescheduling process, the chromosome is to be modified, and a new objective function is to be produced in response to the environmental changes. Based on this rescheduling, a new supplier or an outsourcing company is to be selected, and the information of rescheduling is to be transmitted through the multi-agent system. In order to solve several problems simultaneously, the genetic algorithm in this study has been represented in a chromosome and has been designed for better evolution, so that it can more effectively solve the complex problems of integrated scheduling. Like this, the strong point of genetic algorithm lies in its approach based on the problem-centered chromosome design. Also, thanks to its flexible representation, speedy performance, and excellent performance capability, the genetic algorithm makes it possible to reflect in the rescheduling all the information about suppliers and outsourcing companies, which comes from the multi-agent system on a real-time basis. In this respect, the genetic algorithm is considered to be best suited to the dynamic supply chain management.

Figure 3. The example of crossover



A MULTI-AGENT SYSTEM FOR OPTIMAL SUPPLY CHAIN MANAGEMENT

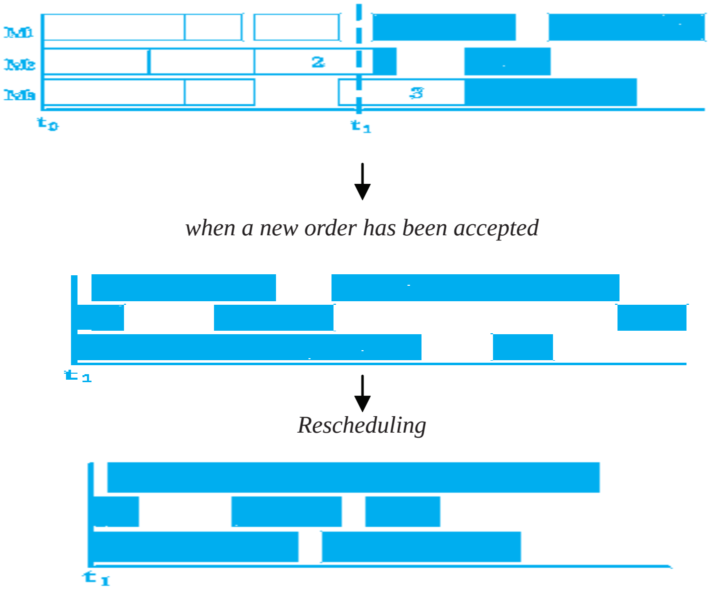
The Whole Structure of a Multi-Agent System

The key factor in the development of a multi-agent system is how the roles should be assigned to each agent. In the multi-agent system, one agent doesn't perform all functions. Rather, each agent has an individual function, and so they mutually communicate with each other to jointly solve complicated matters. Because of this reason, how to classify each agent is a key factor to designing a multi-agent system. For the development of a multi-agent system, all the activities from a customer's order to manufacturing were reviewed, and then these activities were assigned to each agent. Each agent is given a specified function so as not to have many functions.

As illustrated in Figure 5, the multi-agent system can be divided in two subsystems: virtual manufacturing system and SCM system. The virtual manufacturing system is composed of an inventory analysis agent, manufacturability analysis agent, process planning agent, and scheduling agent. This system makes a decision on whether it will be able to manufacture or not, makes scheduling in consideration of the production environments of both suppliers and outsourcing companies, and makes a decision on the necessity of parts or materials through inventory analysis. This activity is directly related to the selection of suppliers. The SCM system consists of an outsourcing management agent, supplier management agent, outsourcing company communication agent, supplier communication agent, and registry server agent. This system organizes and manages the optimal supply chain based on the integrated scheduling that is the result of virtual manufacturing.

Based on the exact scheduling, the virtual manufacturing system makes a decision on whether it can manufacture within the due date. The SCM system's main function is to respond to the manu-

Figure 4. Example of dynamic scheduling



facturing environment changes occurring in the optimal supply chain. To this end, the mediator of the manufacturing company has to exchange information on a real-time basis with both the supplier's and outsourcing company's agent. The multi-agent system has a mediator-centered structure. All the agents are connected to the mediator, which takes control of each agent, and also are responsible for smooth information exchange with suppliers and outsourcing companies.

Function of Each Agent

All agents own their basic function to communicate with each other, and each one has diverse kinds of engines according to his role.

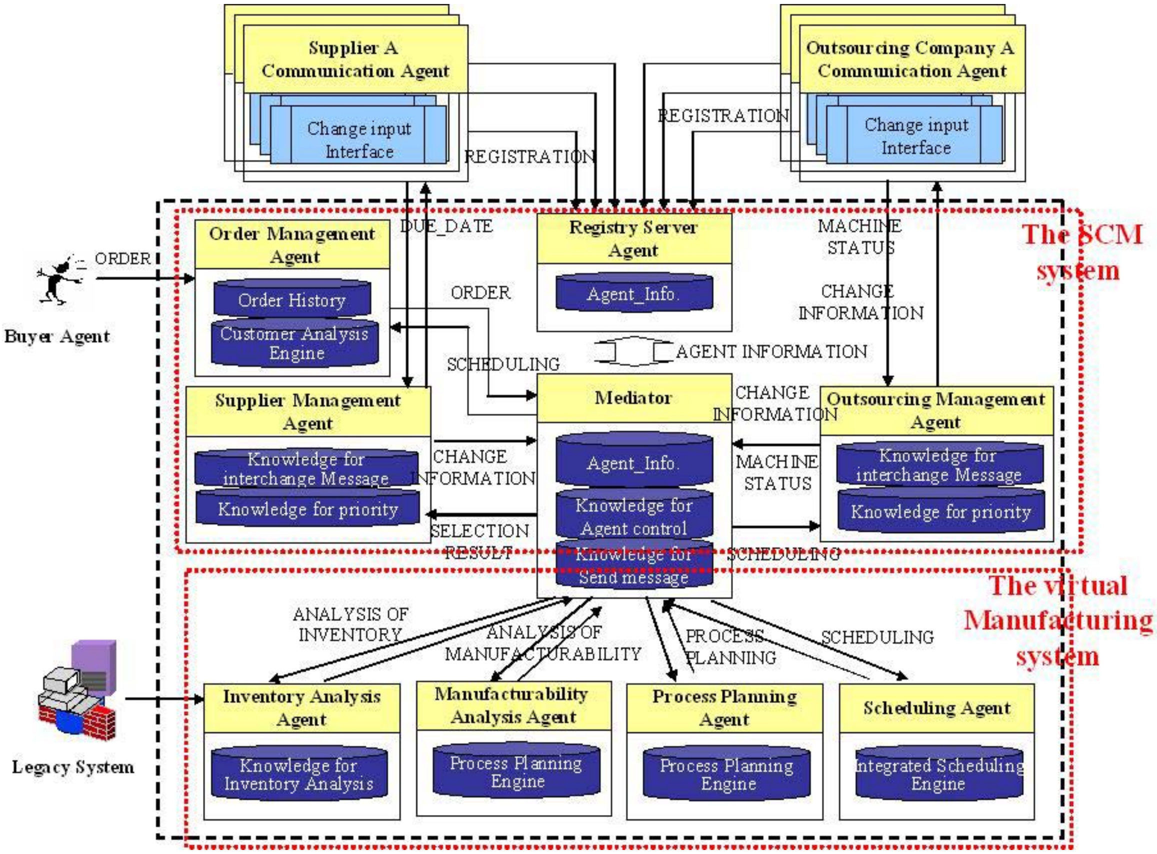
Mediator

The mediator plays the role of controlling and coordinating the message exchange among agents within the system. The agent in charge of controlling and coordination is necessary in order to perform harmoniously the various jobs of many agents, to remove the bottlenecks occurring within the system, and to prevent the collision between each agent. For this purpose, the mediator has a knowledge base for agent coordination and message exchange as well as information on each agent.

For example, when the SMA (supplier management agent) received from the SCA (supplier communication agent) the information on production environment change, that is, "The material delivery from the supplier is delayed," the mediator is to send this information speedily to the SA (scheduling agent) so that it may make rescheduling according to the production environment changes. The roles of mediator are as follows:

- Message transmission between internal agents
- Function control of internal agents
- Function of filtering the messages
- Knowledge of mediator's behaviors
- Knowledge of internal agents

Figure 5. Structure of multi-agent system of an optimal supply chain



The mediator is in charge of controlling and coordinating each agent, and has diverse knowledge base to help the message exchanges between agents, which are illustrated in Table 2.

As illustrated, the knowledge is expressed in the form of rules. Case 1 shows that when OMA (order management agent) receives an order, the mediator is to send the message asking the MAA (manufacturing analysis agent) to make a decision whether it can be produced or not. See Case 1.

Case 2 shows that when it receives the message that it can produce the ordered product from MAA, the mediator is to send PPA (process planning agent) the message asking for scheduling. See Case 2.

Diverse messages from internal agents converge to the mediator. The mediator is to perform the function of operating its system smoothly, so that it can remove bottlenecks and prevent collisions between each agent. This study adopted the FIFO (first in first out) method in handling the messages. If messages from the agents come to the message queue, those messages will be handled in sequence.

Registry Server Agent

Buyer agent, outsourcing company agent, and supplier agent are to be registered in the registry server agent (RSA). Registered agents are to obtain position information from RSA so as to be able to communicate to his or her partner agent. The agents registered in the RSA can be candidates for the participating member of the

Table 2. The knowledge in the mediator

Knowledge of agent role	Knowledge of subagent composition Knowledge of subagent role
Knowledge of message exchange	Knowledge of job handling procedures Knowledge of how to handle the contents of message
Knowledge of problem solution	Knowledge of how to handle message in case of no answer Knowledge of how to express in time of trouble

optimal supply chain. In principle, the optimal supply chain needs to be organized through communication with the agents of all the suppliers and outsourcing companies. But in reality, for mutual communication among agents, each agent has to obtain information about his or her partner agent. For this reason, only the agents who can communicate via RSA can be candidates for the optimal supply chain organization.

The outsourcing companies and suppliers have to register the information on their agent's position and basic data of their companies. The basic data of the companies includes their name and role. Their role is whether they are outsourcing companies or suppliers. Outsourcing company and supplier have a different role. Because of this, they have to register additional information besides basic data. That is, the outsourcing company has to provide information on machines and facilities, and the supplier has to include information on the parts and materials that it can provide. In particular, in case of an outsourcing company, as an outsourcing company executes some parts of an ordered product, information on its production facilities such as a mill or a drill has to be registered.

Order Management Agent (OrderMA)

An order management agent receives orders and confirms them. It keeps order information and analyzes and classifies buyers through data mining and statistic analysis.

Case 1.

```
[ case 1 ]
 rule name  Accept Order
if   contents_name = order
then send product_width and product_length and product_height and raw_material and part_width and part_length and part_height to ManufacturabilityAnalysisAgent
```

Case 2.

```
[ case 2 ]
 rule name  Accept ManufacturabilityAnalysisResult
if   contents_name = ManufacturabilityAnalysisResult and
 ManufacturabilityAnalysisResult = yes
then send use_for and model_name and number_of_part and process_time and product_width and product_length and product_height and raw_material and part_width and part_length and part_height to Process Planning Agent.
```

Supplier Management Agent

A supplier management agent provides the information on the environmental changes in the suppliers to the inside system and also transmits the information on supply schedule to the suppliers. This agent also keeps the suppliers' priority on the basis of their capability and confidence. This data will be used at the time of selecting suppliers when they all can keep the same due date.

Outsourcing Management Agent (OMA)

An outsourcing management agent provides the information on the machine situation of outsourcing companies for the sake of scheduling, and also, based on the scheduling, it makes a decision on the necessity of outsourcing. The criteria for the decision-making are whether the outsourcing company can keep the due date or not. When the producer cannot keep the due date for itself, this agent sends the message containing the necessity of outsourcing. The following is the agent's action knowledge represented in the form of IF-THEN, saying, "If the due date based on the production planning is not satisfactory, inform the mediator of the necessity of outsourcing." Here, Last_time is the finishing time of the last operation in the production planning.

```
IF  Last_time > due_date
Then send  yes_message  to  Mediator
```

This agent has the priority information on outsourcing companies, and this information will be used for selecting outsourcing companies.

Inventory Analysis Agent (IAA)

An inventory analysis agent analyzes the inventory level and makes a decision on the purchase of materials. The information on the inventory level is to be secured from the inside of the system. The inventory analysis agent makes a decision based on the purchase necessity analysis knowledge.

Manufacturability Analysis Agent (MAA)

Based on the information on products and parts, MAA checks up the constraints related to the manufacturing process in order to make a decision on its manufacturability. Constraints usually come from the size and weight. In case the size of an ordered product is too large or the weight is too heavy, the small manufacturer cannot produce it. For example, if the size and weight surpass the capacity of the cranes of the manufacturer, it cannot execute the order. The judgment on manufacturability can be made by the knowledge base. This knowledge base includes information on various kinds of size and weight as well as the cases making it impossible to execute an order. The knowledge in Box 1 shows how the judgment on manufacturability can be expressed in JESS, that is, a language of java-based rule expression.

Process Planning Agent (PPA)

A process planning agent performs the role of process planning. This paper used CBR (case-based reasoning) based on a process planning engine. The reason is that if the products of order-based producers are similar, the same process will be used (Kolodner, 1993). Choi, Kim, and Park (2002) have proved the availability of this methodology by applying it to molding industry.

Scheduling Agent

A scheduling agent performs the role of scheduling based on a genetic algorithm-based engine, considering alternative machines and operation sequence. This agent plays the critical role in the multi-agent system, and based on this scheduling, the supplier and outsourcing company will be selected.

Box 1.

"The mold size of cavity plate is a>600, b>270, c>400, it is impossible to execute the order."

```
 (constraint_rule_002
        (size_a     ?a)
        (size_b     ?b)
        (size_c     ?c)
  =>
  (if (&& (>=?a600) (>=?b270) (>=?c400)))
   then (assert (manufacturability  no)))
```

Supplier and Outsourcing Company Communication Agent

A supplier and outsourcing company communication agent performs the role of communications between multi-agent system and suppliers and outsourcing companies. For the establishment of scheduling, the supplier communication agent provides the possible due date of raw materials, and the outsourcing company communication agent provides the information on the machine situation. These two agents provide multi-agent systems with the information on the production environment changes through user interface.

The Process of the Multi-Agent System

The process of the multi-agent system is composed of the followings: the process of scheduling for self-production, the process of scheduling for selecting outsourcing company, the process of scheduling for selecting supplier, and the process for rescheduling in case the production environments of suppliers and outsourcing companies have been changed. If necessary, based on the rescheduling, the supplier and outsourcing company should be reselected.

The Process of Scheduling for Self-Production

Figure 6 shows the case that a producer can make for order-based products at his own factory without the help of suppliers and outsourcing companies. The producer establishes the scheduling for accepted orders, and provides the result to the buyer agent.

The Process of Scheduling for Selecting Outsourcing Company

Figure 7 shows the case that if a producer cannot meet the required due date by self-production, he has to select an outsourcing company.

The outsourcing management agent analyzes the necessity of outsourcing based on the scheduling, and if necessary, it asks for the information on the machine situation of outsourcing companies. Based on this information on machine situation, the scheduling agent establishes rescheduling. Based on this rescheduling and outsourcing company priority, the outsourcing management agent selects an outsourcing company.

The Process of Scheduling for Selecting Supplier

Figure 8 shows how to select the supplier in case that the producer doesn't have enough inventory

Figure 6.The process of scheduling for self-production

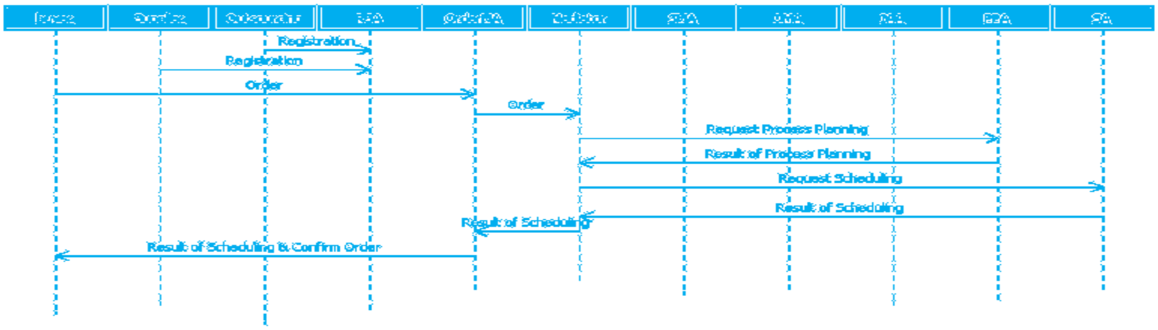


Figure 7. The process of scheduling for selecting outsourcing company

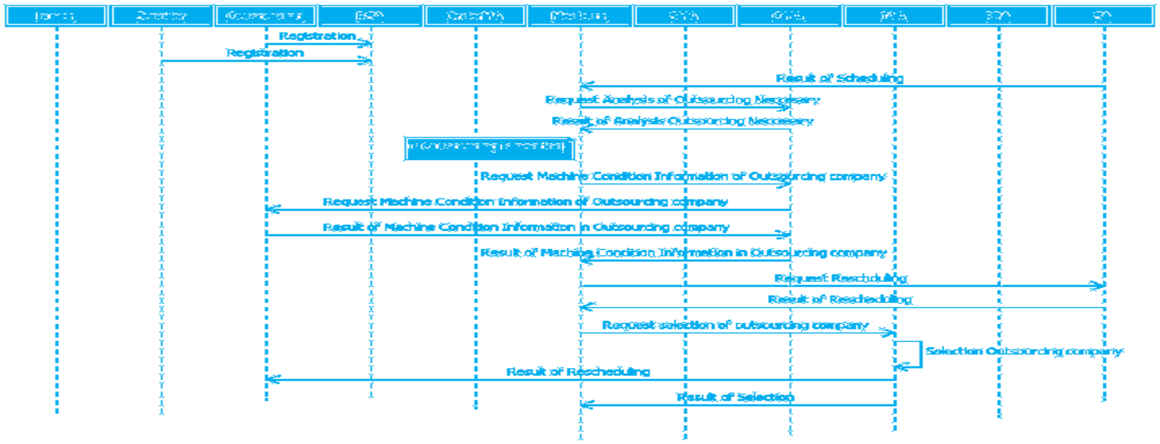
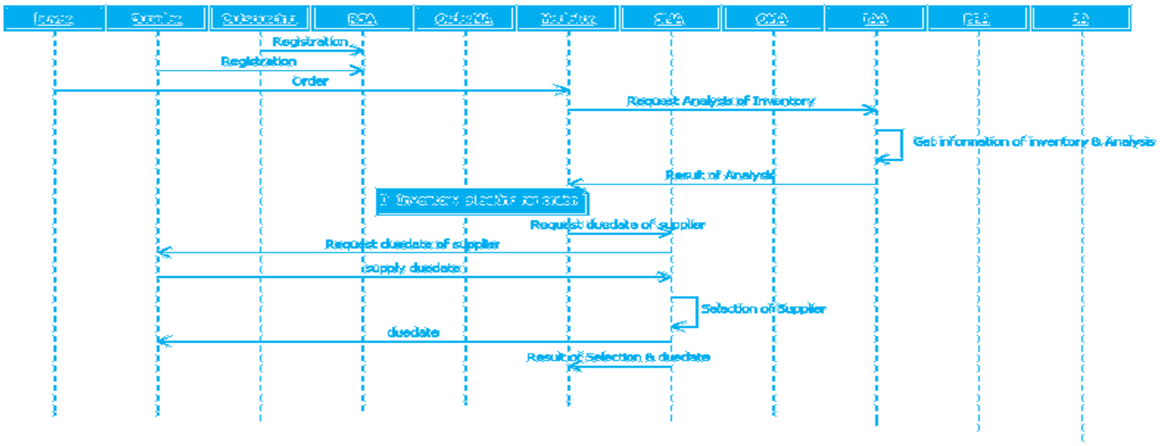


Figure 8. The process of scheduling for selecting supplier



of raw materials. The inventory analysis agent analyzes the inventory of the inside system and required raw materials for orders. If it thinks the supplier should be selected, the supplier management agent will ask the suppliers for a possible due date, and based on this information, it will select a supplier.

The Process of Rescheduling for Production Environment Changes

Figure 9 shows how to respond to the changes in the production environment. When there are changes in the production environments of outsourcing companies, the outsourcing communication agent provides this information to the outsourcing management agent. And based on this changed production environment, the scheduling agent achieves rescheduling, and the outsourcing management agent analyzes this rescheduling. However, if this rescheduling cannot meet the required due date, other outsourcing company should be selected.

To testify to the availability of the above processes of the multi agent system, this research adopts a molding company as a case study.

CASE STUDY OF MULTI-AGENT SYSTEM

Case Definition

In order to test the validity and practicality of the multi-agent system developed by this study, we made a prototype and applied it to real field cases. We visited the small "J molding company," the domain of this study, and reviewed and analyzed the facilities of the factory and its field situation. J molding company has such machines as a large mill, medium and small mill, drill, and lathe to perform milling, drilling, grinding, and electric discharge machining. Meanwhile, due to the constraint of facility of this company, there are some molds that cannot be manufactured. That is, the cranes of this company cannot handle the mold exceeding the weight of five tons. But there are no other difficulties in the resources, like manpower or machines, and in technologies. The knowledge base of MMA defines the constraints and uses them in judging manufacturability. The J molding company was maintaining a close relationship with its outsourcing companies and suppliers while outsourcing some part of milling and electric discharge machining.

Figure 9. The process of rescheduling for production environment changes

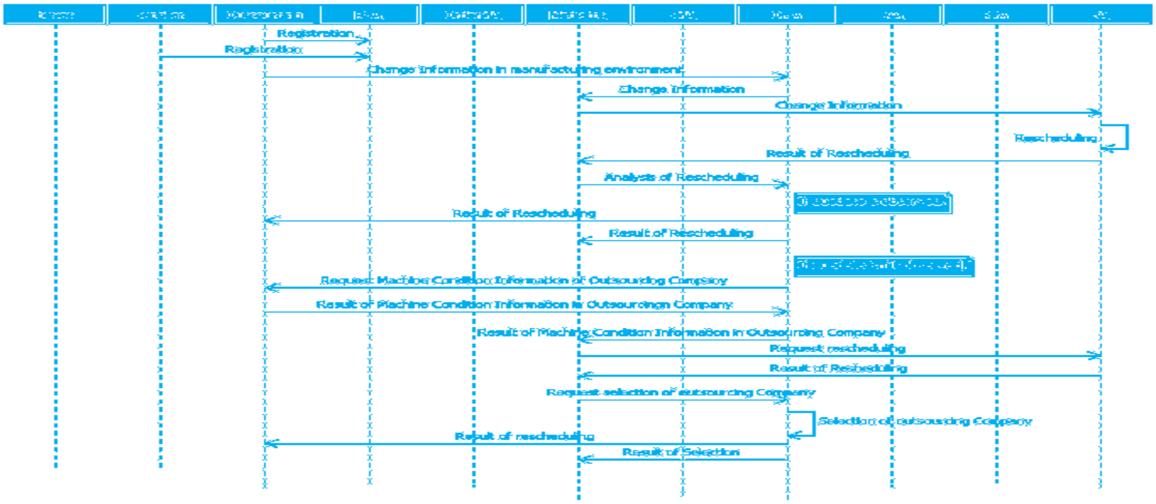
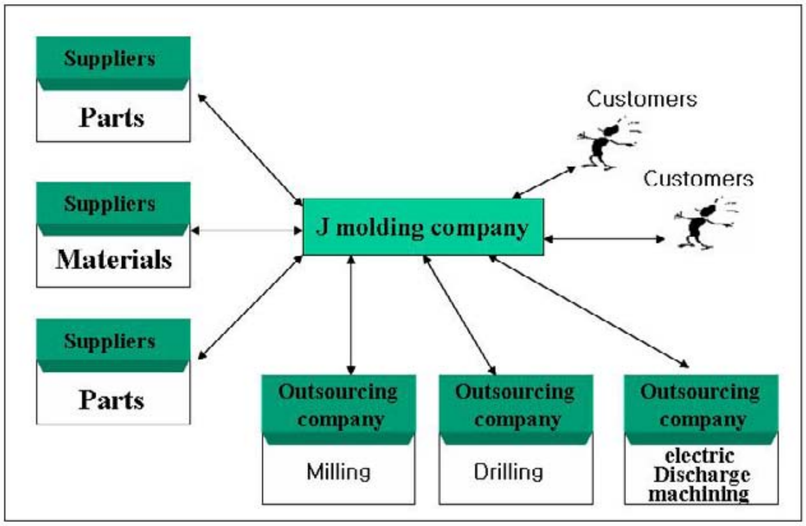


Figure 10. Supply chain of J molding company



As illustrated in Figure 10, J molding company has a supply chain consisting of material suppliers, outsourcing companies, and customers. Also, in order to meet the due date of the order, it tries to organize an optimal supply chain. The company keeps a good business relationship with three outsourcing companies and three suppliers. This case study is for the mold production of a "cake box."

Case Study

The case study has two stages: The first stage is how to organize an optimal supply chain according to the procedures as illustrated in Figure 11. The second stage is how to respond to the environmental changes such as a machine failure or power stoppage after organizing an optimal supply chain.

As illustrated in Figure 11, the organization of an optimal supply chain needs two steps: The first step is to perform virtual manufacturing for an ordered product. The second step is to select an optimal supplier and outsourcing company according to the result of virtual manufacturing.

Step 1. Virtual manufacturing
If the mediator receives from OMA a message that a client order "cake box" within six days from order date, it sends necessary information to the MAA so as to make judgment on manufacturability.

If the mediator receives a "yes" message from MAA, it sends order-related information to the PPA and SA so that both agents may prepare for process planning and scheduling respectively.

The mediator sends scheduling information from SA to the OMA to make a decision on whether there it is necessary to outsource.

"Makespan 61" is the result of scheduling for an ordered "cake box" mold. This means that if the factory operates eight hours per day, it takes eight days. In this case, as the customer's due date request is within six days from his or her order date, J molding company cannot satisfy the customer's due date. Accordingly, the OMA sends the message of outsourcing necessity to the mediator.

Step 2. The organization of an optimal supply chain
In order to select an optimal outsourcing company that can meet the due date, the mediator asks OMA

Figure 11. Procedure for organizing an optimal supply chain

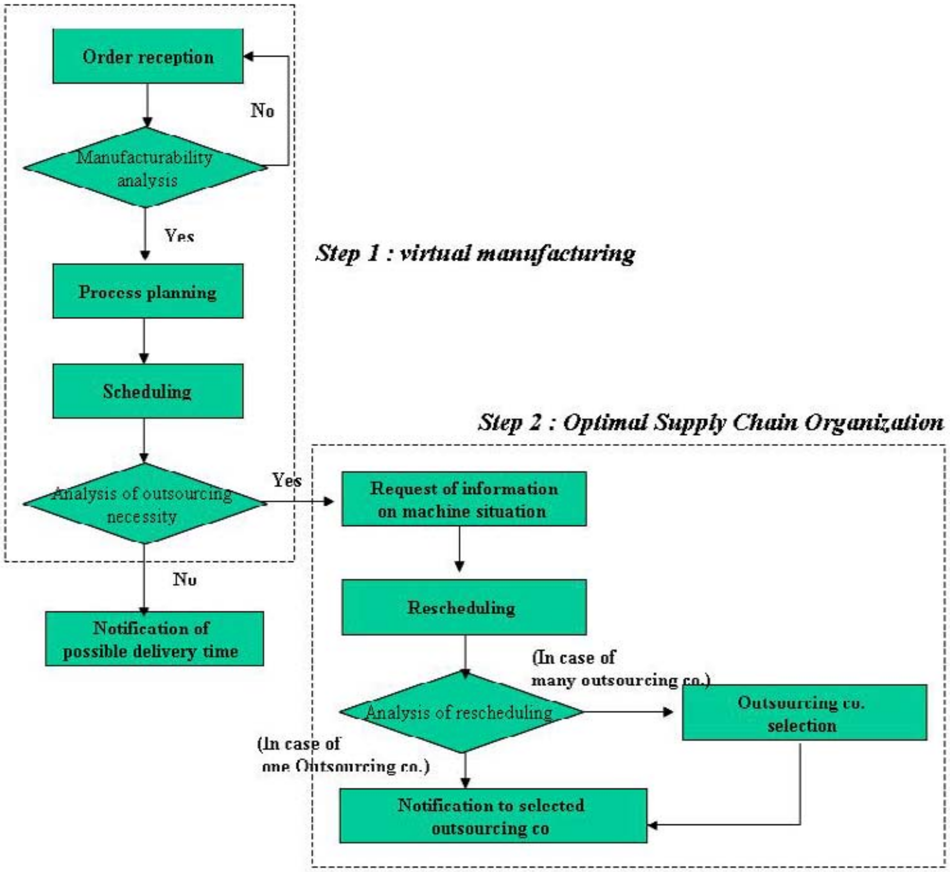
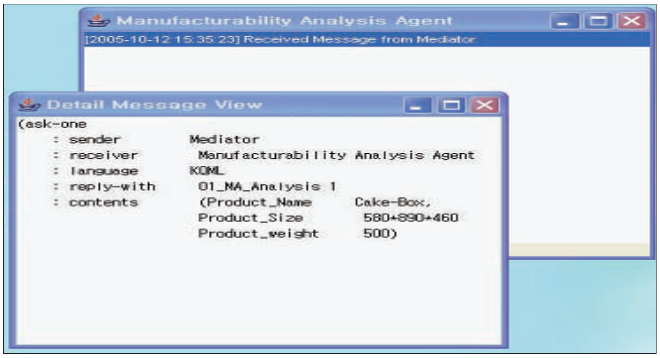


Figure 12. Manufacturability analysis-related message interface



```
[2005-10-12 15:35:23] Received Message from Mediator
```

```
(ask-one
    : sender        Mediator
    : receiver       Manufacturability Analysis Agent
    : language      KQML
    : reply-with     01_MA_Analysis 1
    : contents       (Product_Name      Cake-Box,
                     Product_Size        580*890*460
                     Product_weight      500)
```

for the information on the machine situation of outsourcing companies registered in the RSA.

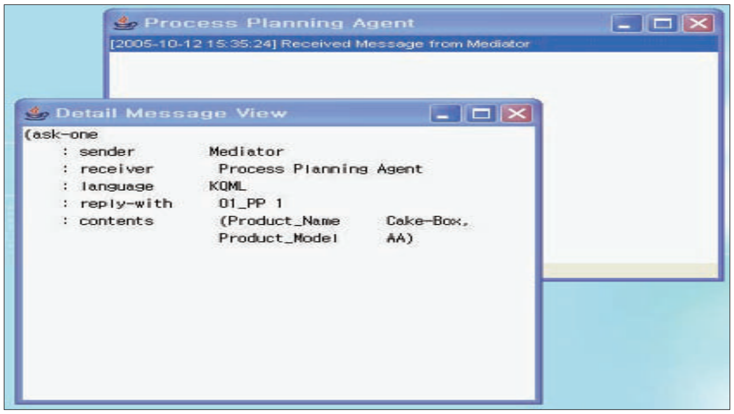
OMA asks the OCCA (outsourcing company communication agent) of each outsourcing company for the information on machine situation, which includes the machine schedule. If the machine is now in operation, that machine cannot be used for another order until the current operation is over. When the mediator receives the following information on machine schedule from outsourcing companies, it sends this information to the SA so that it may prepare for rescheduling.

- A outsourcing company: two units of mill are now not in operation. (AM 1 0, AM 2 0)
- B outsourcing company: one unit of mill can be used after six hours. (BM 6)
- C outsourcing company: one unit of mill can be used after three hours, and another one unit is now not in operation. (CM 3, CM 0)

As illustrated in Figure 17, rescheduling was made by considering outsourcing companies' machine situation. As a result of rescheduling, in case of A and C outsourcing companies, possible due date is October 18, 2005, thus satisfying customer's request. But B outsourcing company's possible due date is October 20, consequently not meeting the requested due date. This means that A and C can be a participating member of the optimal supply chain. Therefore, the mediator asks OMA to choose one company between these two outsourcing companies. Based on the priority information, OMA chooses A outsourcing company, and then notifies the mediator and OCCA of it.

By selecting A outsourcing company, the optimal supply chain for a "cake box" mold was organized. In this case study, the case of selecting a supplier was excluded, but the supplier also can be selected in the same way as the above-mentioned outsourcing company. Meanwhile, the optimal supply chain is not fixed, rather it can be changed in response to the changes of a manufacturing

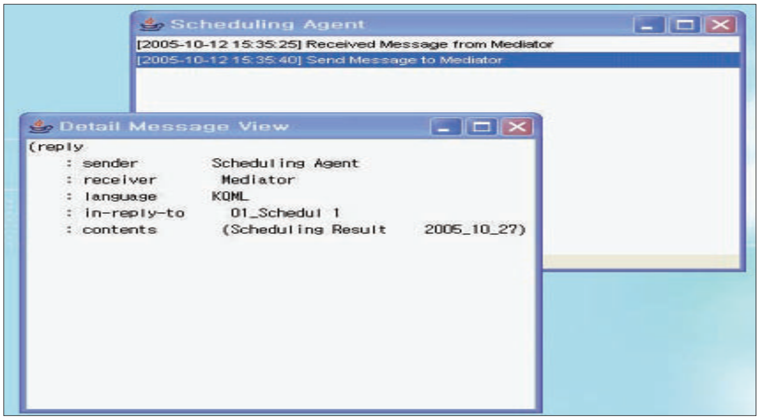
Figure 13. Process planning-related message interface



```
[2005-10-12 15:35:24] Received Message from Mediator
```

```
(ask-one
     : sender        Mediator
     : receiver       Process Planning Agent
     : language      KQML
     : reply-with     01_PP 1
     : contents       (Product_Name      Cake-Box,
                      Product_Model      AA)
```

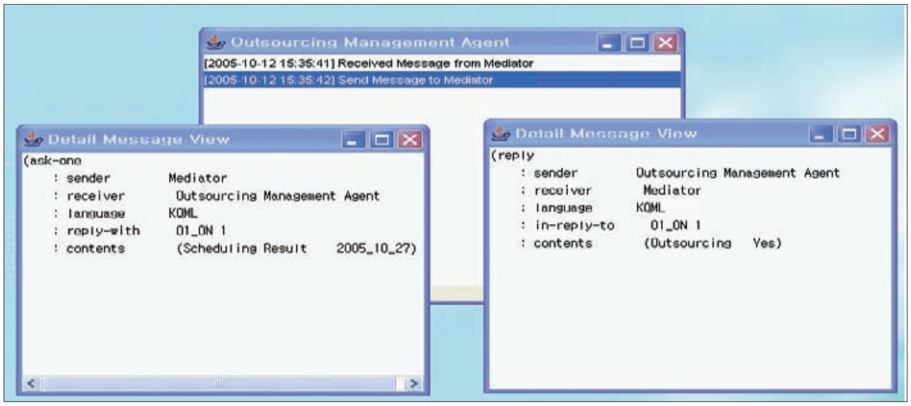
Figure 14. Scheduling-related message interface



```
[2005-10-12 15:35:25] Received Message from Mediator
[2005-10-12 15:35:40] Send Message to Mediator
```

```
(reply
     : sender        Scheduling Agent
     : receiver       Mediator
     : language      KQML
     : in-reply-to      01_Schedul 1
     : contents       (Scheduling Result     2005_10_27)
```

Figure 15. Outsourcing necessity-related message interface



```
[2005-10-12 15:35:41] Received Message from Mediator
[2005-10-12 15:35:42] Send Message to Mediator
```

```
(ask-one
    : sender        Mediator
    : receiver       Outsourcing Management Agent
    : language      KQML
    : reply-with     01_ON 1
    : contents       (Scheduling Result     2005_10_27)
```

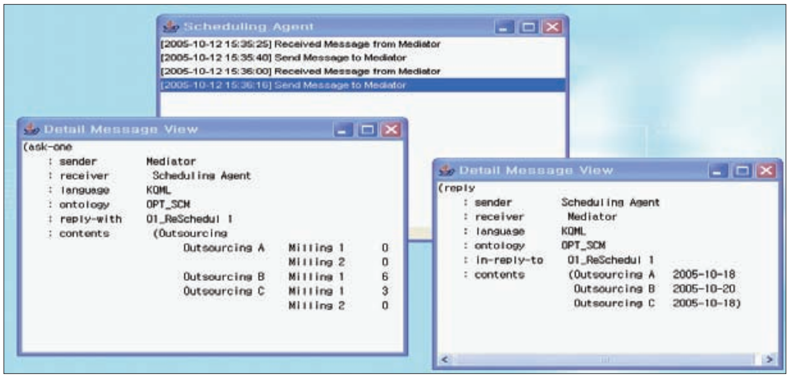
```
(reply
    : sender        Outsourcing Management Agent
    : receiver      Mediator
    : language      KQML
    : in-reply-to    01_ON 1
    : contents       (Outsourcing    Yes)
```

Figure 16. Message interface asking for information on the machine situation of outsourcing companies

```
[2005-10-12 15:35:44] Received Message from Outsourcing Management Agent
[2005-10-12 15:35:45] Send Message to Outsourcing Management Agent
```

```
(ask-one
    : sender        Outsourcing Management Agent
    : receiver      Outsourcing Company Communication Agent
    : language      KQML
    : ontology      OPT_SCM
    : reply-with     01_Sel_Outsourcing 1
    : contents       (Machine_Present_State     ?)
```

Figure 17. Rescheduling-related message interface in consideration of outsourcing companies' situation



```
[2005-10-12 15:35:25] Received Message from Mediator
[2005-10-12 15:35:40] Send Message to Mediator
[2005-10-12 15:36:00] Received Message from Mediator
[2005-10-12 15:36:16] Send Message to Mediator
```

```
(ask-one
    : sender        Mediator
    : receiver       Scheduling Agent
    : language      KQML
    : ontology      OPT_SCM
    : reply-with    01_ReSchedul 1
    : contents       (Outsourcing
                         Outsourcing A    Milling 1      0
                                          Milling 2      0
                         Outsourcing B    Milling 1      6
                         Outsourcing C    Milling 1      3
                                          Milling 2      0
```

```
(reply
    : sender        Scheduling Agent
    : receiver       Mediator
    : language      KQML
    : ontology      OPT_SCM
    : in-reply-to    01_ReSchedul 1
    : contents       (Outsourcing A   2005-10-18
                      Outsourcing B   2005-10-20
                      Outsourcing C   2005-10-18)
```

environment. But even if such environmental changes take place repeatedly, an optimal supply chain can be organized in the same way as the first organization of an optimal supply chain. As illustrated in Figure 19, this study performed the tests for two kinds of environmental changes. The first environmental change is: A outsourcing company, which is chosen as a member of the optimal supply chain, is unable to work because of milling machine failure. The second one is: A supplier becomes unable to provide the parts within the requested date. Figure 19 shows the process to solve the environmental changes.

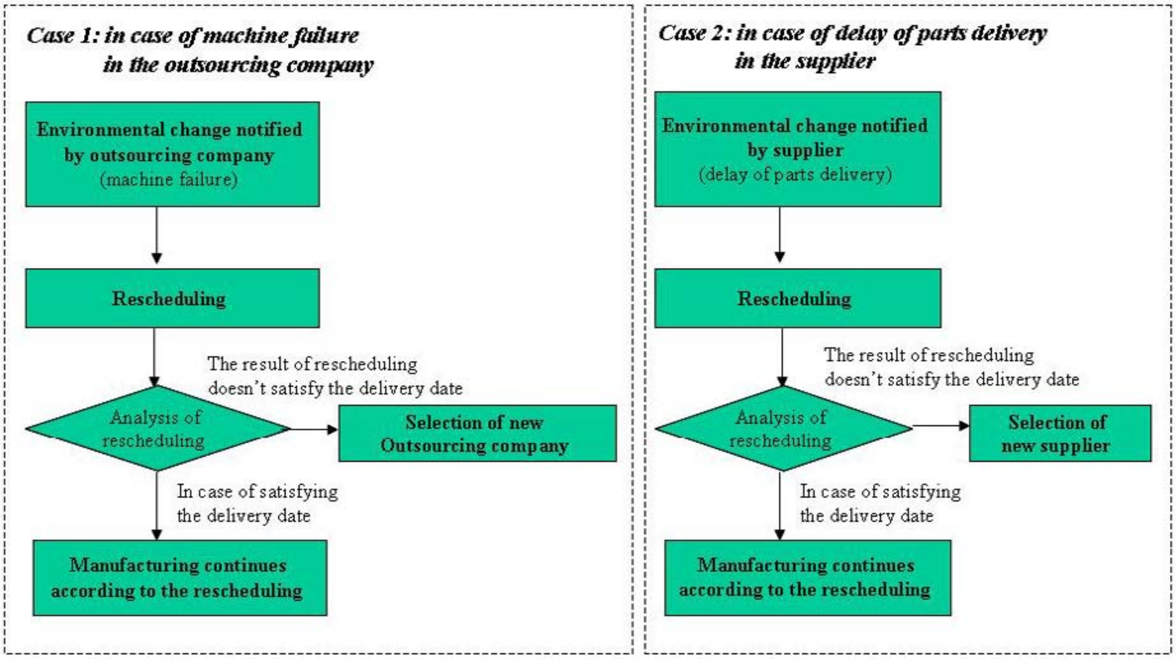
The above two environmental changes can affect J molding company in the following two ways: one is that the delay of work doesn't directly affect the due date requested by the customer, and the other is that it affects the due date. In the

Figure 18. Message interface related to the notification of the result of outsourcing company selection

```
[2005-10-12 15:35:41] Received Message from Mediator
[2005-10-12 15:35:42] Send Message to Mediator
[2005-10-12 15:36:17] Received Message from Mediator
[2005-10-12 15:36:18] Send Message to Mediator
[2005-10-12 15:36:18] Send Message to Outsourcing Company Communication...
```

```
(tell
    : sender        Outsourcing Management Agent
    : receiver       Outsourcing Company Communication Agent
    : language      KQML
    : ontology      OPT_SCM
    : in-reply-to    01_Sel_Outsourcing 1
    : contents       (Order 1   Yes)
```

Figure 19. The test procedures of optimal SCM cases



first case, the company's manufacturing activity will be continued according to the rescheduling, but in the second case, it has to reselect a new outsourcing company or supplier.

As shown in the above tests, the optimal supply chain can be reorganized in response to the dynamic changes in the manufacturing environment, so that the manufacturing company may smoothly maintain and manage its optimal supply chain.

Review of Case Study

In order to test the validity and practicality of the developed multi-agent system, this study produced a prototype performing key functions and applied it to the field for case study. Unfortunately, the multi-agent system has not yet commercialized because of many difficulties in realizing its knowledge base. Likewise, the multi agent system's prototype made by this study is not enough to be commercialized, and so we couldn't measure the performance and effect by means of application. Instead, as a way to test its validity and practicality, we had interviews with the experts in charge of scheduling at the make-to-order manufacturing companies, including the J molding company and 15 software developers related to agent development. The experts in charge at the make-to-order manufacturing companies testified to the validity of the multi-agent system, and those software developers evaluated the systemic performance of the multi-agent system. Evaluation was performed on a five-point scale on the next major items.

- *Experts in charge at the make-to-order manufacturers*
    - Is the scheduling of this system correct and accurate?
    - Is it reasonable that the optimal supply chain consisting of suppliers and outsourcing companies focused on due date for supply chain organization?
    - Does the work process for calculating the possible due date reflect well the reality?
    - Does this system smoothly react to the environmental change occurring in the supply chain?
- *Software developers*
    - Is communications among agents smoothly performing?
    - Is the role of each individual agent well assigned? And is the multi-agent structure appropriate?
    - Is the handling speed of the system satisfactory?
    - Is the agent development method reasonable?
    - Is there any serious mistake in the system?

As a result of evaluation, the experts in charge at the make-to-order manufacturers gave a score of 3.8 on the overage, and software developers gave a score of 4.2. The experts in charge gave a relatively higher score to the capability to react to the environmental changes and well-reflected work process, but a somewhat low score to the accuracy of scheduling. This seems to come from the fact that the current algorithm is not fully enough, because of the complex scheduling of the molding industry. However, they put a high value on the automation of scheduling and the possibility of job handling without human intervention and believed that commercialization of the multi-agent system will be able to bring cost reduction and productivity improvement. They also added that many efforts were being made to maintain a solid relationship with outsourcing companies and suppliers that satisfy the due date. These efforts mean that the core point of satisfaction of due date in the organization of optimal supply chain has validity. The agent software developers, who gave a higher score, seem to value the current high level of agent development. The evaluation team as a whole rated the validity and practicality of the multi-agent system very high. In particular, they have paid attention to the new approach to SCM.

FUTURE TRENDS

Owing to the characteristics of the domain of this research, we organized an optimal supply chain based on the satisfaction of due date. From now on, however, further research on the optimal supply chain, which has two different objectives, or considers two key factors simultaneously, will be made. Many companies consider the problem of price to be very important as well as due date. For example, when we consider the two factors of price and due date simultaneously, as the due date is the same but the price is different like Figure 20, it is easy to select its business partner. But as shown on the right side of Figure 20, if the price and due date are respectively different, it is not easy to evaluate them because the two have different worth. Therefore, the method to evaluate due date and price simultaneously has to be developed.

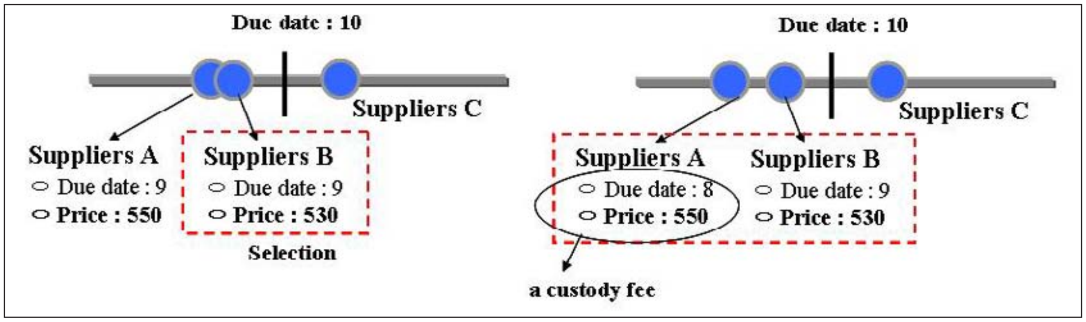
Furthermore, as due date and price have a trade-off relationship, negotiation is possible. That is, the following negotiation can be made: Instead of lowering the price, the due date can be lengthened, or if an earlier due date is required, the price will be higher. In these cases, a new negotiation protocol as well as a new negotiation method needs to be developed.

CONCLUSION

Owing to the increasing importance of quick response to the rapid changes of business environments, the supply chain also needs dynamic changes according to its environmental changes. In the dynamic supply chain environment, it is a key factor to decide who to cooperate with for effective manufacturing. This study developed a system to efficiently select an optimal business partner under the dynamic supply chain environment. To this end, this study developed an algorithm for both scheduling and rescheduling, which is to be made by taking into consideration the manufacturing environments of both suppliers and outsourcing companies. Also, by using a multi-agent system, this study made it possible to organize and manage an optimal supply chain on a real-time basis in response to the dynamic changes in the supply chain environment.

Like this, instead of trying to optimize an existing, fixed supply chain, we have tried to organize a new supply chain that can dynamically respond to the environmental changes, so that it can bring diverse effects such as cost saving, productivity enhancement, and speedy job handling. These

Figure 20. Evaluation of due date and price



effects are well presented in the results of our case study.

Finally, we expect that this multi-agent system will be usefully applied to the complex supply chain environment and also have expectations that the agents realized in the wrapper method through a new development framework will be used in diverse fields.

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Chapter 2.25

Integration of Global Supply Chain Management with Small to Mid-Size Suppliers

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ABSTRACT

The purpose of this chapter is to develop a conceptual insight and an integrated framework to global supply chain management through strategic aspects of business philosophy as it pertains to the small- to mid-sized supplier. Primary consideration is given to characteristics of the integrated supply chain and the necessity of adaptation in managing the supply chain in order to attain competitive advantage. A review of the current literature and an analysis of the supply chain in changing global markets emphasize the relative importance of strategically managing the supply chain process given the limited resources of the small- to mid-sized firm. It is argued that managing the supply chain through the development of market specific strategies allows the small to mid-sized firm to be anticipatory as opposed to being reactive in its strategic planning, which can greatly benefit customer satisfaction levels and thus enhance the performance of the firm.

INTRODUCTION

Supply chain management (SCM) as a strategy for competitive advantage has gained prominence in both large and small organizations. An understanding of the supply chain management concept from the perspective of suppliers and, in particular, small and medium enterprises (SMEs) is crucial to the study of vertical integration of global SCM. This understanding will better formulate internal business strategies of suppliers by supporting both the objectives of the supply chain and their own businesses. About 80% of the supply chain members are SMEs, and a major impact and savings may well be found with the SMEs within the supply chain (Smeltzer, 2002). By taking advantage of their position and criticality in the supply chain, SMEs can add value and contribute to the vertical integration essential in the supply chain. This creates advantages not just for themselves, but also for other members within their supply chain.

By some definitions, a supply chain is a network of facilities that performs the functions of procurement of material, transformation of material to intermediate and finished products, and distribution of finished products to customers (Lee & Billington, 1995). The supply opportunity analysis technique (SOAT) moves away from a reactive to a proactive mode by taking (determining) the suppliers' perspective (Bhattacharya, Coleman, & Brace, 1995). When customers demand customized products, products often become increasingly complex. In addition, the development and manufacturing of such products demand even greater resources that need to be shared by the supply chain members. In addition, the development and manufacturing of such products by the original equipment manufacturing (OEM) partners require supply chain members to increasingly share available resources as virtual partners (Rota, Thierry, & Bel, 2002). To the suppliers, these virtual partnerships can provide both opportunities of growth and threats of becoming obsolete from the supply chain. A supplier is usually involved with multiple customers and therefore in several supply chains. The supplier receives both firm orders and forecast orders. To be successful, the supplier needs to negotiate these firm orders and the forecast orders with its suppliers. To deliver customized products with short delivery times and high due-date observance, to plan for the supplier's own raw material requirements, it is important for the customer to effectively share information (Rota et al., 2002).

The transformation from reactive to proactive procurement parallels a transformation in relationships between suppliers and buyers. Suppliers have developed partnerships with customer firms. This partnership has turned into collaborative relationships or strategic alliances (Burt, Dobler, & Starling, 2003). The rising cost of product development, globalization, and shorter product lead times have been cited as important reasons for supplier collaboration (Bruce, Fiona, & Dominic, 1995; Helper, 1991; Lamming, 1993). The involvement by partners has a positive impact on strategic purchasing, and strategic purchasing has a positive impact on a firm's financial performance (Masella & Rangone, 2000). Even though there are many benefits from this collaborative or alliance network between suppliers and customers, there are obstacles. Trust plays a critical role in such collaborative or alliance relationships between suppliers and customers (Burt et al., 2003). However, such collaborations and alliances enable information flow across the supply chain.

To answer questions such as why a supplier was not treated according to its capabilities or why did engineering think it had capabilities when it did not, the characteristics of the suppler has to be clearly articulated (Nellore, 2001). Developing visions for suppliers can help OEMs to create clear expectations and thus better the core capabilities of the buyer and supplier firms (Nellore, 2001). OEMs also increase supplier involvement in product development and the share of inbound just-in-time (JIT) deliveries. However, while suppliers increase their outsourcing and globalization of production and product development activities, OEMs do not (von Corswant & Fredriksson, 2002). By outsourcing certain activities to specialized suppliers, companies can focus on those products and activities that they are distinctively good at (Venkatesan, 1992). This specialization, enabling a reduction of the capital base, implies improved return on invested capital (Quinn & Hilmer, 1994) and the possibility to benefit from economies of scale. However, outsourcing means that important activities are placed outside the boundaries of the firm (Richardson, 1972). In addition, coordination of these activities demands vast resources, and many companies therefore strive to reduce their supply bases (Cousins, 1999). A cooperative strategy between OEMs and suppliers is needed to ensure efficient coordination of these activities. Information flow enables such cooperative strategies.

A significant portion of product nonconformance costs can be directly attributed to variation in supplier processes. To mitigate the effects of variation in the near term it may be tactically prudent to assess tolerances to influential supplier processes. Such tolerance allocation strategies tend to be adversarial in nature, since the cost associated with a nonconforming product is principally borne by suppliers via scrap and repair costs, not to mention costs associated with safety stock increases, and so on. However, a more appropriate long-term strategy for reducing nonconformance costs is to consider ways to achieve a reduction of variation in supplier processes (Plante, 2000). Variance reduction of a supplier's processes requires knowledge of what influences the process variation so that appropriate improvement action can be undertaken in an informed manner. Gaining such knowledge requires that organizations invest in and commit to continuous learning (Plante, 2000). Companies such as Raytheon finds that 50% to 70% of its product costs are represented by outside purchases, with a majority of the material dollars spent on a few key parts provided by a few key suppliers. To address this conundrum, the Raytheon Six Sigma with Suppliers process was created, providing a set of tools and resources to help reduce supplier costs. The Raytheon Six Sigma with suppliers process has six steps (visualize, commit, prioritize, characterize, improve, and achieve), including an intense two-day workshop, which requires a heavy involvement and commitment by the supplier. Information flow between suppliers and customers can enable acquisition and use of this process knowledge to reduce supplier costs.

Measures related to quality, cost, delivery, and flexibility have been used to evaluate how well the suppliers are performing. Companies track supplier performance over time to detect problems early. It is imperative for even small businesses to establish performance measures (Knechtges & Watts, 2000). Performance cannot be measured solely by past or current levels of sales and profitability but should also include quantitative indicators of how the firm will do in the future. A recent study showed that in a supply chain, the supplier management practices adopted by first-tier suppliers affected second-tier suppliers' performance. Second-tier suppliers' performance consequently influenced both first-tier suppliers' quality and delivery performance (Park & Hartley, 2002). As performances of suppliers are evaluated regularly and frequently, these problems can be mitigated easily and at an earlier stage. The implementation of a successful supplier performance measurement system not only clarifies supplier understanding of performance expectations, consequences for poor performance, and rewards for performance excellence, but it also provides documentation of actual supplier performance. Supplier performance metrics can be used for a wide range of continuous improvement efforts. For example, they can be the basis for a establishing a proactive supplier development process, or making critical decisions when rationalizing the supply base, or even for determining how to distribute costs over several suppliers to better manage risk. Information flow of performance plays a critical part for maintaining supplier relationships. Supplier process, performance, strategy, and relationships can be made effective and efficient using information technology. Given the symbiotic relationship existing between supplier and customer, all participants of the global supply chain need to be educated and trained to facilitate IT adoption (Kirby & Turner, 1993).

In the next section, we present the characteristics, opportunities and challenges for SME companies and suppliers in general. Based on that discussion, we illustrate a conceptual framework consisting of five dimensions for suppliers in the third section. The remaining sections expand these five dimensions. The final section presents a summary and conclusions of the five dimensions.

Small- to Medium-Sized Companies: Their Characteristics, Opportunities, and Challenges

Small and medium enterprises (SMEs) have played a significant role in the global supply chain management in various countries and in the landscape of global business competition (Chapman, Ettkin, & Helms, 2000). As reported by the U.S. Small Business Administration (USSBA, 1999), SMEs are an integral part of the renewal process that pervades and defines market and economies. New and small firms play a critical role in experimental and innovation that leads to technological changes and productivity growth. With the emergence of the new technologies, new products, new services, new markets, and new management concepts, the pattern of competitive advantage for companies—particularly for small- to medium-sized organizations—has changed and has subsequently led to new opportunities and new challenges. There is no universally accepted definition of a small and medium enterprise (SME). In the literature, the definition of SME varies based on the number of employees, ownership of the shares capital investment, or financial turnover, among others (Reed, 1998; Taylor & Adair, 1994).

In order to better understand the strategic roles of SMEs in the global business, it is important to recognize their inherent characteristics. SMEs are often independently owned and operated and closely controlled by the owners/managers who are the principal investors and decision makers having entrepreneurial behavior. The attitude and expression of values (cultural and personal) of owners can play a significant role in the adoption of new technology and strategy development (Stansfield & Grant, 2003). The decision maker, often an entrepreneur or small network of associates, formulates attitudes based on perception of its environment. The entrepreneur's attitudes influence his/her own behavior, such as decision making, and thereby have a direct impact on the SME's capability. They also influence an employee's attitudes and behaviors and thus affect the internal environment through the organizational culture factor, and further indirectly affect the SME's capability through that mechanism.

SMEs are also characterized by an absence of standardization and formal working relationships, having a flat organizational structure. Thus, they have a more organic organizational structure when compared to a more bureaucratic structure in large firms (Ghobadian & Gallear, 1996). These characteristics make SMEs more flexible to environmental changes (Levy, 1998; Storey & Gressy, 1995) as well as incurring lower overhead expenses and thus are perceived more innovative. Consequently, they have the potential of playing a significant role in global competition. In particular, SMEs who possess/exhibit entrepreneurial behavior can use the new information technologies as the strategic tools to generate new products and services, and as driving force behind new processes, new forms of business organization, new scope for consumers, and new market opportunities and supply chain management.

The characteristics of an SME can determine the strategic opportunities and challenges available to these companies, particularly in the area of supply chain management. The entrepreneurial behavior of SMEs differentiates them from larger companies in supply chain management, particularly in a cross-cultural dimension and global market. While SMEs' managers are more sales oriented, they do not have a well-developed overall strategic plan. According to Dodge and Robbins (1992), 64% of SMEs that failed did not have a business plan. SME managers tend to rely on their tacit knowledge rather than systematic techniques in supply chain management planning activities, such as vendor selection (Park & Krishnan, 2001). The competitiveness of an SME is defined by its flexibility to environmental changes and dependent on its owner/manager (OECD, 1993), since the adoption of a strategic planning approach is affected by its ownership structure (O'Regan & Ghobadian, 2002). However, they may have limited resources required for efficient supply chain management and find themselves encountering more barriers due to increased competition at national and international levels, particularly when they do not have the resources to meet the demands of their trading partners in the supply chain. SMEs that are subsidiaries of larger organizations may be able to access resources from their parent organizations (O'Regan & Ghobadian, 2002) and be able to overcome these challenges of limited resources. However, they are typically responsible for their local strategies and limited flexibility in their national and international strategies. Furthermore, as managers of SMEs are usually holding multiple roles as entrepreneur, and owner/manager, the management focus tends to be operational rather than strategic. However, in order to take advantage of supply chain management as a means for competitive advantage and succeed, these companies need to take a strategic approach of supply chain management. In particular, SMEs are challenged to balance their short-term operational focus with long-term strategies and technological innovations. This in turn requires greater financial and technical resources. The lack of resources required for effectiveness and efficiency is another major challenge for SMEs in adopting appropriate strategies for their supply chain management, particularly in their quest for global competition.

Small to medium suppliers are less resourceful and often play niche roles within the supply chain as a commodity supplier, collaboration specialist, technology specialist, and problem-solving supplier (Kaufman, Wood, & Theyel, 2000) as shown in Table 1. The supplier topology divides along two dimensions: technology and collaboration. By dividing these dimensions into high and low categories, Kaufman et al. (2000) create four distinct supplier strategies. The top left quadrant

Table 1. Strategic supplier typology

	Low Collaboration	High Collaboration
Low Technology	**Commodity Supplier** • Spot market supplier • Low cost, low price priorities • Little or no differentiation	**Collaboration Specialist** • Detailed control parts supplier • Uses a closed network in each industry • Can be in many industries to maintain customer product information
High Collaboration	**Technology Specialist** • Proprietary parts supplier • Innovation in product technology used to produce high barriers to entry • First mover advantages • Uses design capabilities for competitive advantage	**Problem-solving Supplier** • Black box supplier • High differentiation • Cost less important • Small runs, high process and labor flexibility

defines suppliers who use standard technologies and relate to customers through standard market contracts. These suppliers compete on the basis of low cost. These suppliers can be replaced since switching costs are low. These commodity suppliers design and sell parts to their customers as specified by their customers. The top right quadrant describes collaboration specialists. These suppliers use standard technologies that meet customer specifications and delivery schedules. However, these firms develop enhanced collaborative techniques to fulfill current and to anticipate future customer needs. These suppliers use vendor managed inventory (VMI) strategy. The collaboration essentially requires accurate and timely information. They reduce the customers' internal monitoring or administrative costs.

The suppliers in the lower right quadrant are the problem-solver suppliers. They help their customers to avoid costly investments in specific resources. They employ both advanced technologies and collaborative methods in promoting innovative design and manufacture of supplied parts. The bottom left quadrant defines the technology specialists. They supply proprietary parts using advanced technologies. However, they have weak relationships with customers and the customers benefit from acquiring high technology parts without having to invest in resources. These different suppliers can also be classified as subcontractors who are connected to their customers through supply networks and play coordinating roles between both domestic and foreign players (Andersen & Christensen, 2005).

The common theme in this four dimensional topology is information technology (IT). Information technology is perceived as a critical enabler for efficient exchange of information between the SMEs and the members of supply chain management, and to improve organizational performance and enhance competitive advantage. However, due to resource constraints, SMEs place lower priority on IT investments. Thus, SMEs differ from large companies in their supply chain management practices and technology. Large companies have a greater scope of operation and thus are more likely to be involved in diverse markets. They can spread costly new systems over large units of production, and have internal technical development and maintenance capabilities (Smeltzer, 2001). SME managers and, in particular, small business entrepreneurs, tend to lack or not value many of the basic skills needed to adopt and implement networked processes. They are not operationally inclined or concerned with issues of managing their supply base methodically. They are keen to sell more. Larger firms have invested time and money in implementing their enterprise resource planning (ERP) and e-commerce strategies, including e-procurement and online selling, integrating with these firms can be frustrating. SMEs must develop the business planning skills to identify, select, and implement the supporting technology. Particularly, SMEs must adopt an integrated system such as ERP, e-commerce, and e-procurement systems to support their supply chain management and be able to "pull through" from downstream customers.

In the context of Porter's framework of competitive advantage strategies, and given the characteristics, opportunities, and challenges facing SMEs, the competitive success of these companies may not critically depend on price leadership or differentiation strategies but on how they are unique and critical to their trading partners (Quayle, 2002). In this context, SMEs could focus on meeting ultimate customers' needs, strive to supply quality products/services, and add value to meet the demands of their supply chains. Thus, it is essential that SMEs can link their business strategies to that of the supply chain. The organic organizational structure of SMEs should enable them to develop strategic alliances with their trading partners in the supply chain so that they are able to leverage the skills and expertise of supply chain partners to gain strategic advantage for the whole chain.

Conceptual Framework

Forrester (1958) viewed a supply chain as part of industrial dynamics, alternatively known as system dynamics and management system dynamics; it is broadly defined as the application of feedback thinking and control engineering concepts to the study of economic, business, and organizational systems. System dynamics is concerned with problem solving in living systems that bring together machines, people, and organizations. It links together the system theory and the control theory so that we are able to generate added insight into system dynamic behavior and, particularly, into the underlying causal relationships in the context of global performance of the system and internal control. In this context, supply chain is defined as a system of business enterprises that link together to satisfy customer demands and to provide value to the end customer in terms of product and services. We can discern a distinct generic procedure as part of the production/operation process in a supply chain that is called an echelon. In their most basic form, materials/goods flow from one echelon to the next until they reach the end customer. In reality, however, supply chains do not exist in isolation, but form part of a network of supply chains satisfying different demands.

Figure 1. Integration framework for supplier network

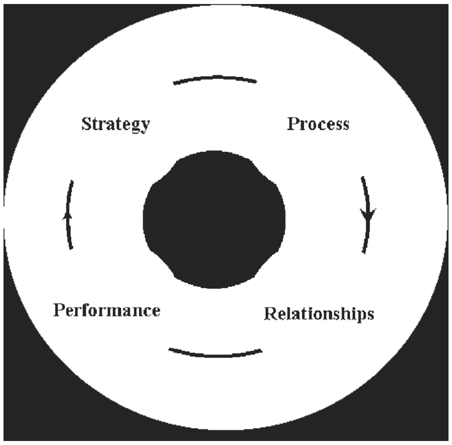


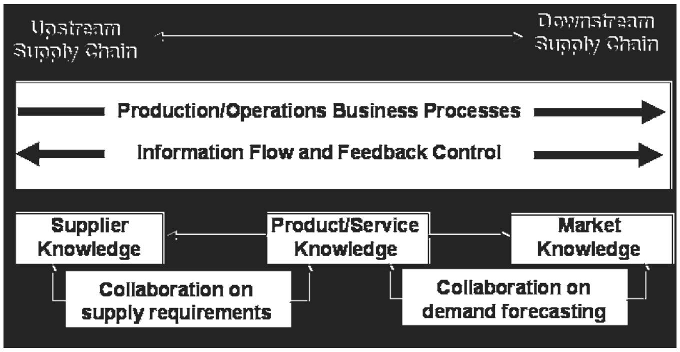
Figure 1 describes a framework for suppliers in the global integrated supply chain. The four major dimensions of the framework include strategy, process, partnership, and performance. These dimensions are enabled by the fifth dimension, global information flow. The ultimate goal in supply chain management is to create value for the end customers and the firms in the supply chain network. To accomplish this, firms in the supply chain network must integrate all their supply chain process activities both internally and with other firms in the network. This integrated supply chain process needs a supply chain strategy. The strategic fit requires the firm to achieve a balance between its responsiveness and its efficiency in its supply chain that best meets the requirements of its competitive strategy. The supply chain performance of the firm with respect to its supply chain strategy is in terms of its responsiveness and efficiency (Chopra & Meindl, 2004). Furthermore, to create value for the supply chain network, it is critical that suppliers and customers develop strong relationships and partnerships based on a strategic perspective. Good supplier relationships are a key ingredient necessary for developing an integrated supply chain network (Wisner, Leong, & Tan, 2005). Good supplier and customer relationships and a great supply chain strategy are not enough to create value in an efficient, integrated supply chain process. The supportive role of information technology is essential along with the use of information technology to measure the supply chain performance. This provides the firm with the ability to make decisions about supply chain improvements. It is generally accepted in the literature that today's forward thinking managers use an integrated approach to managing their business by using quantitative and technological tools to bring together multiple facets of the business including, but not limited to, procurement, inventory management, manufacturing, logistics, distribution, and sales. It has been argued that the next century's paradigm for addressing challenges from increasingly demanding customers and global competition will rely on the effective use of information sharing and inventory control to streamline operations and coordinate activities throughout the supply chain. The conceptual integrated framework of the supply chain network brings collaboration and information sharing to fruition. The collaboration and information sharing results in reduced supply chain costs, greater flexibility to respond to market changes, less safety stock, higher quality, reduced time to market, and better utilization of resources (Wisner et al., 2005).

Integrated Process

According to the Global Supply Chain Forum, supply chain management is defined as the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders (Croxton, Garcia-Dastugue, & Lambert, 2001). This definition identifies eight key processes as the core of supply chain management. The eight processes include: (1) customer relationship management, (2) customer service management, (3) demand management, (4) order fulfillment management, (5) manufacturing flow management, (6) supplier relationship management, (7) product development and commercialization, and (8) returns management. These processes transcend the length of the supply chain cutting through firms and functional silos alike. These processes also provide a framework for various aspects of strategic and tactical issues present in the supply chain processes. The integration of such processes would allow successful management of the supply chain for the suppliers as well.

Figure 2 shows a relatively simple and generic supply chain that links a company with its suppliers upstream and its distributors and customers downstream. Upstream supply chain includes the organization's first-tier suppliers and their suppliers. Such a relationship can be extended in several tiers all the way to the origin of material. Downstream supply chain includes all the processes involved in delivering the product or service to the final customers. Thus, there are physical flows in the form of raw materials, work-in-process inventories, and finished products/services, between supply chain echelons, from suppliers/vendors to manufacturers to distributors and retailers, and to consumers. Supply chain also includes the movement of information and money, and the procedures that support the movement of a product/service. Managing these physical and informational flows effectively and efficiently requires an integration approach that promotes organizational relationship and fosters the sharing of strategic and technological efforts (Sabbaghi & Sabbaghi, 2004).

Figure 2. Integrated supply chain process



An effective supply chain management has required an integrated approach and collaboration among the various tiers of suppliers and retailers, and has led to information sharing relations. In 1995, a pilot project between Wal-Mart, Warner-Lambert, Benchmarking Partners, SAP, and Manugistics led to the concept of collaborative planning, forecasting and replenishment (CPFR) (Cooke, 1998). Skoett-Larsen, Thernoe, and Anderson (2003) have defined three levels of CPFR: (1) basic CPFR collaboration that only involves few business processes and a limited integration with trading partners, (2) developed CPFR collaboration that is characterized by increased integration in several collaboration areas, and (3) advanced CPFR collaboration that deals with synchronization of dialogue between the parties in addition to data exchange. While in basic CPFR, the supply chain partners will usually choose a few key processes relevant to precisely their form of collaboration with customers and suppliers, in developed CPFR the parties start to coordinate data and information exchange by making agreements about the type of information sharing and exchanges. In advanced CPFR, the collaboration will be expanded to coordinate processes within forecasting, replenishment, and planning. The planning processes may in turn be decomposed into collaboration on production planning, product development, transport planning, and market activities.

CPFR is a set of norms and procedures created by the Voluntary Inter-industry Commerce Standards (VICS) Association to drive companies toward common business planning procedures and to search for efficiency in the supply chain while establishing standards to facilitate the physical and informational flow. The CPER model is part of the integration mechanism among these processes and a valuable technological innovation tool to support the implementation of various types of transactions among the supply chain companies. These norms would provide the foundations for companies in the supply chain to collaborate in sharing data and information, in forecasting and ordering, in better production and distribution, and to achieve a global optimum of cost and services. Successful collaboration and implementation of CPFR norms would enhance the partnership in a supply chain. This would lead to lower costs, improved product or service quality, better customer service, quicker project results, reduced cycle time/lead time, and improved value to customers. Furthermore, managing business processes requires both internal and external knowledge about the company's operations and its strategies, as the development of effective behavior standards influences operational processes among the partners in the supply chain. Thus, given the constant need for innovation in organizational processes and corresponding information technology, CPFR can be viewed as a tool for competitive advantage in the supply chain.

The effective competitiveness of supply chain between supplier and customer partly depends on the effectiveness and efficiency of the flow of order and information between various parties in the supply chain. Participating organizations need to adopt an appropriate business model and culture that facilitate inter-organizational integration, sharing of skills and knowledge, and enable change in response to market forces. The challenge at the front end, before the order, is to have relationships with suppliers over time using as much electronic technology as possible to be able to source product availability in real time, to meet the customers' requirements. At the back end, the challenge is to understand and identify the best way to integrate with all their suppliers. This requires system standardization that allows suppliers to easily connect into their IT systems to improve not only their data communication facilities but also improve their business processes and facilitate collaboration between partners. This can be supported by the use of an integrated enterprise-wide information system such as enterprise resource planning (ERP) system. Enterprises, particularly SMEs within a supply chain, must then be evaluated as to added value in this process provided to customers and by their working relationships and partnerships to improve their performance and competitiveness. Where material and component suppliers are regarded as partners in the activity of satisfying customers, the adversarial approach to supplier auditing is not appropriate. All aspects of the supplier's business process, from receiving and reviewing an order, through manufacture to delivery, needs to be reviewed by the auditor to ensure that they meet minimum acceptable standards and to identify opportunities to improve. The auditor acts as an independent observer in reviewing the SCM system. This method aims to identify opportunities for improvement in the customer-supplier relationship that will improve quality, delivery, and service (Saunders, 1994).

In a move to remain competitive, many OEMs have resorted to outsourcing a large amount of design and manufacturing work. In so doing, they have repositioned themselves as customer-focused market players instead of design and manufacturing experts. This repositioning has consequently led to an increased reliance on the Tier 1 suppliers. With increased reliance comes increased pressure. Because of these new market changes, today's suppliers are facing a significant shift in responsibilities: while their share of the design and development responsibilities has increased, there is a concomitant expectation that costs will decrease. Furthermore, suppliers have multiple OEMs and consequently need to respond to multiple process integration. There is an increased focus on suppliers becoming leaner, as well as a push for heightened investment in rigorous processes that focus on innovation in close collaboration with OEM customers. A significant factor contributing to the length of product development is the time and process required in responding to design changes. Communicating design changes in language relevant to or understood by both the manufacturer and supplier is difficult, time consuming, and expensive. Evaluating the impact of change, reaching agreement on options, and implementing the change can take months due to the back and forth communication between all parties involved in the project. This complex communication process involves exchanging and remastering design information in a variety of formats during product design, analysis, and change. This can be improved by using a collaboration tool that shares design intelligence between these departments, dramatically shortening the time to communicate change, evaluate tradeoffs, and make decisions. Engineering supply chain collaboration also results in early problem detection, saving time and money for all involved, and making it easy to tie and integrate processes from various OEMs and respond to them individually.

SMEs need to identify a number of factors that can impede external process integration along the supply chain, causing information distortion, longer cycle times, stock-outs, and the bullwhip effect, resulting in higher overall costs and reduced customer service capabilities (Wisner et al., 2005). Failing to see the big picture and acting only in regard to a single department within the firm or a single tier in the supply chain can create quality, cost delivery timing, and other service problems. To overcome this silo mentality, firms must strive to align their supply chain processes and strategy to the overall vision of the supply chain network. The inability to easily share information from all the members of the supply chain is a common process integration problem. Using information technology, one of the dimensions discussed in this chapter, can solve this problem. Successful process integration between the members of the supply chain requires trust. Trust and commitment may be improved by collaborating on a small scale, better communication, and going for a win-win situation. Lack of process knowledge within the firm and among partners can lead to the downfall of supply chain activities. Educating and training the employees can improve their process knowledge. Finally, reducing the length of supply chain, making demand data available to suppliers, improving order batching efficiency, reducing price fluctuations, and eliminating short gaming can improve the supply chain integrated process (Wisner et al., 2005).

Integrated Strategy

The integration of business processes in supply chain management from suppliers would add value first to original equipment manufacturers (OEM) and finally to their customers. This integrated strategic process is enhanced through the use of logistics management. According to the Council of Logistics Management (Cooper, Lambers, & Pagh, 1997), logistics management is defined as the process of planning, implementing, and controlling the efficient, cost-effective, flow and storage of raw materials, in-process inventory, finished goods, and related information flow from point-of-origin to point-of-consumption for the purpose of conforming to customer requirements.

The scope of the supply chain management expands further upstream to the source of supply and downstream to the point of consumption, involving the integrated strategic process. The need for integration of information systems, planning, and control activities exceeds the level of integration necessary in the management of logistics alone (Cooper et al., 1997).

Although not all efforts toward integration are successful, companies are increasingly using an integrated, strategic approach not only to manage the supply chain, but as a general philosophy in managing the business due to the perceived benefits of improved performance (Tan, 2001). In fact, one study completed in 1998 supports a positive impact to performance by correlating supplier performance and firm performance (Tan, Kannan, & Handfield, 1998). The study summarizes literature available to that point. The study also concludes that a company's customer relations and purchasing practices—as major components of supply chain management strategy—have a positive impact on the effectiveness of supply chain management as a whole. Furthermore, through empirical analysis, the same study lays a foundation for the premise that additional practices of concurrent engineering, customer focus, strategic alliances, and quality-driven production improve the strategic management of the supply chain management function as a whole (Tan et al., 1998).

However, in slight contrast to these findings, companies should be further interested in the firm's overall performance and their ability to attain competitive advantage, as opposed to merely positively impacting the supply chain management strategic process. Since the concept of supply chain management as a strategic tool for business planning is relatively new, there is less clear data on the effect of "overall" performance of the corporation given a successful supply chain management strategy. A statistical study on the impact of purchasing and supply chain management of activities relating to corporate success was published in 2002 (Ellram, Zsidisin, Siferd, & Stanly, 2002) that attempted to answer many of the questions concerning overall firm performance by stratifying companies into three categories using a number of different financial and benchmarking criteria. The results determined that above-average firms showed no increased use of supply chain management processes when compared to average and below-average firms and that below-average firms had higher perceptions of actually practicing this strategic process. The reasons for this are partially explained by realizing that firms with average and below-average performance levels may be facing market pressures and declining profitability and must seek ways to improve performance and lower costs. In other words, above-average performing firms may not seek the advantages of strategically managing the supply chain given the relative success of the corporation despite additional opportunities to increase the firm's performance.

These results heavily support many of the underlying principles developed later in this analysis when looking closer at the scarce resources available to the small firm and any attempts at using supply chain management as a replacement for corporate strategy, as some of the supply chain management literature suggests. Although many companies are moving toward such strategies due to the far-reaching effects of overall customer satisfaction, supply chain management should not be confused with, and cannot make up for, broader corporate strategy and the need for managing effective strategic processes in areas such as marketing, financing, and distribution, just to name a few (Ellram et al., 2002).

Small- to medium-sized firms are confronted with the issue of scarce resources to a greater extent than are larger corporations. In fact, often in such companies, it is the same individual(s) developing the strategic initiative, which means focusing too heavily on any one strategic area, inclusive of supply chain management, may actually lead the company to greater risk. Product and technology life cycles have shortened significantly and competitive product introductions make life cycle demand difficult to predict. At the same time, the vulnerability of supply chains to disturbance or disruption has increased, not only to the effect of external events such as wars, strikes or terrorist attacks, but also to the impact of changes in business strategy. Many companies have experienced a change in their supply chain risk profile as a result of changes in their business models, for example, the adoption of "lean" practices, the move to outsourcing, and a general tendency to reduce the size of the supplier base. A research study (Christopher & Lee, 2004) suggests that one key element in any strategy designed to mitigate supply chain risk is improved "end-to-end" visibility. It is argued that supply chain "confidence" will increase in proportion to the quality of supply chain information. Rather, it is the balance of strategic planning and execution within these organizations that is the common denominator among successful firms of small- to mid-size. Consequently, it is the successful management of the supply chain for any firm in context of its overall business strategy that can provide it with a competitive advantage, but doing so with a poor business strategy or a weak marketing plan is not likely to provide the firm an advantage in the marketplace.

It is clear that the uncertainty of global market conditions leave companies on the edge with respect to their strategic thought process in all aspects of strategic planning; yet it is the responsibility and opportunity of the enterprise to interpret, comprehend, and even predict circumstances relevant to the global market that determines its effectiveness. Global supply chain management provides a key element to understanding these conditions of uncertainty and is one of the primary reasons that the strategy is being so well accepted across organizations of all types and sizes. However, some unique problems and opportunities arise for smaller companies who are able to redefine, adapt, and redesign the supply chain. Managing each defining component of the supply chain is difficult for the small to mid-sized entity due to scarce resources. However, given the knowledge base and the in-depth understanding of the supply chain processes by limited individuals in the smaller firm, it seems reasonable to change and make necessary adjustments to the supply chain management processes.

For the smaller corporation, supply chain performance is based on the flexibility of the management strategy practiced by the entity to reduce the level of risk provided by factors of global market uncertainty. A company's performance in the marketplace has been specifically linked to flexibilities involving volume, product launch, and target markets (Vickery, Calantone, & Droge, 1999). This empirical study looks at the furniture trade and is extremely relevant given the trend toward overseas production and a declining U.S. market for producers. It reveals that companies able to adapt to changing market conditions performed more favorably in terms of financial measures and marketability by exhibiting performance in areas of volume flexibility and product launch flexibility over all others. Volume flexibility is the ability to increase or decrease aggregate production of a good or service, and launch flexibility refers to the ability to introduce new products, as well as variations of existing products, involving the entire supply chain. Both provide excellent examples of ways small companies should be able to pursue competitive advantages, given their ability to control these processes initiating with the need to do so. In other words, they do not require direction from other "functional" departments, but rather respond to immediate needs of the market as opposed to reacting too late. Clearly, flexibility can be used as a strategic tool for the smaller enterprise.

Partnerships

Partnerships are business relationships based on mutual trust and openness as companies share risks and rewards leading to such an advantage (Muskin, 2000). The ability of a firm to extend beyond traditional corporate boundaries by working with partners will increase efficiencies and success.

Traditionally, in the market economy, products and services are produced to meet the forecasted demand. Firms in a supply chain are tightly integrated and focused on high-volume, maximum utilization of working capital, and cost efficiency in their supply of products/services. The optimum competitive decision is often accepted as achieving economies of scale and/or economies of scope. Productive processes are arranged so as to optimize the utilization of production and distribution capacity. In this economy, sharing technology and expertise with customers or suppliers was considered risky and thus unacceptable. There has been much emphasis on in-sourcing and vertical integration in supply chain strategies and little emphasis on outsourcing and cooperative and strategic buyer-supplier partnership (Sabbaghi & Sabbaghi, 2004). For example, in the computer industry, companies such as IBM or Digital Equipment Corporation tended to provide most of the key elements of their own computer systems, from operating system and application software to the peripherals and electronic hardware, rather than sourcing bundles of subsystem modules acquired from third parties. Products and computer systems typically exhibited closed, integral architectures, and there was little or no interchangeability across different companies' systems, keeping existing customers hostage. Each company maintained technological competencies across many elements in the chain and emphasized the value of its overall systems-and-service package, determined to stave off competitors who might offer better performance on one or another piece of the package.

The supply chain strategy in the market economy has been designed to "push" products to the customer based on forecasted demand. It focuses on supporting a tightly integrated enterprise geared toward mass production of goods at the lowest possible price. The production processes across the supply chain are synchronized for efficient utilization of all resources. Information technology, however, acts as an enabler for operational optimization across the supply chain by offering better forecasts that are customer driven in addition to robustly synchronizing the sourcing, production, and processes across the supply chain to achieve optimal performance, even if the forecasts are not perfect. For example, in car manufacturing, cars are traditionally manufactured to match forecasted demand that lacks much customer input.

However, in the new information economy, also called the Internet economy or the Web economy, the focus is exclusively on customer needs. To this end, the firms collaborate in a network of trading partners, each specializing in one or more core competencies (be it shipping, manufacturing, marketing, billing, order entry, or procurement services) and divesting itself of non-core activities beyond those associated with sourcing, manufacturing, or distributing products/services. In this network economy, information technologies, digital networking, and communication infrastructures provide a global platform over which people and organizations interact, communicate, collaborate, and search for information. The Internet has created more sophisticated customers who demand innovative, personalized products/services delivered at their convenience. It has also expanded the very definition of the word "customer," so that it now includes employees, distributors, suppliers, business partners, and shareholders. As a result of these changes, a company's competitive position in this Internet economy depends on its ability to deliver customized, relevant, highly responsive service to every participant in these networks of economic relationships. This new economy has led to the rapid emergence of business networks and new business models within and outside the firm to satisfy the strategic need for competitive flexibility. In this new economy, the supply chain is geared toward the customer "pulling" products customized to their specific needs, and the firm's resources are organized to meet the unpredictable demand patterns of the customer. Therefore, the benefits of supply chain management integration promote organizational relationships that in turn foster the sharing of information technology and strategic efforts.

Partnership in supply chain management, in this network economy, has led to the development of various cooperative arrangements among various supplier and retailers. Jagdev and Thoben (2001) identify three types of collaboration and partnership between independent companies:

1. supply chain type of collaboration based on long-term collaboration where the participating companies in the supply chain must operate synchronously to meet customer demands;
2. extended enterprise type of collaboration, most integrated form of collaboration, where the information and decision systems and respective production processes are integrated; and
3. virtual enterprise type of collaboration, as a short-term collaboration where the participating companies, without system integration, are loosely related to bundle their competencies to meet customer demand.

The type of partnership would determine the effective strategies that SMEs may consider and the perceived value added in the supply chain. For example, in vendor-managed inventory system, the responsibility of stock management is handed over to the supplier (Hvolby & Trienekens, 2002). This would make it possible for the supplier to adjust production and distribution planning to changes in consumer demand. In this system, SMEs as the suppliers would be able to access the retailer's information systems to view stock levels and future requirements. On the other hand, advanced planning systems (APSs) make it possible to include suppliers and customer relations in the planning procedure to optimize the whole supply chain on a real-time basis (Kennerly & Neely, 2001). They would support collaborative planning among several partners in a network by shared access to information about known and expected material requirements and resources (Hvolby & Trienekens, 2002).

Quantity flexibility (QF) contract is an arrangement between supplier and retailer that responds effectively to the demand fluctuations over time and divides the risk of excess capacity. A retailer in this model is committed to purchasing a percentage of its forecasted demand. However, the supplier is committed to delivering more than the forecast. For example, if they agree to a 25% of QF contract, the retailer is committed to purchase 75% of the forecast while the supplier is committed to delivering up to 125% of the forecast should the retailer need more than forecast. If demand turns out to be low, the supplier is protected by the lower limit, whereas if demand turns out to be high, the retailer can take advantage of that upside by knowing that the supplier has some additional capacity. Thus, both supplier and retailer can be better off in a QF contract.

As another type of arrangement, revenue-sharing contracts between suppliers and retailers, for example, in the video rental industry, would allow retailers to increase their stock of newly released movies, thereby substantially improving the availability of popular movies. Under a typical revenue-sharing contract, a supplier charges a retailer a wholesale price per unit plus a percentage of the revenue the retailer generates from the unit. This revenue-sharing model has been practiced for quite some time in the distribution of films to theaters, where the studio charges the theater a small up-front fee and then takes a certain fraction of the box-office revenues. Cachon and Lariviere (2005) examined the revenue-sharing contract model in supply chain management where the partnership between supplier and retailer would improve the performance of any supply chain toward a global optimization. They have cited Blockbuster, a video rental chain, as a successful case to illustrate the effectiveness of revenue-sharing strategy in collaborative supply chain management.

Traditionally, video rental stores have to spend typically $60 to purchase a tape from a distributor and then rent that tape to customers for $3 to $4. However, demand for new releases drops dramatically after the first few weeks, and video retailers have a hard time making any money on the rentals. Consequently, they can only afford to buy a few cassettes to accommodate that initial surge in demand. Customers consistently complained about the poor availability of new release videos. Blockbuster decided in 1998 to enter into revenue-sharing agreements with the major studios. The rental company agreed to pay its suppliers 30 to 45% of its rental income in exchange for a reduction in the initial price per tape from $60 to $8. The introduction of revenue-sharing model at Blockbuster coincided with a significant improvement in performance in the supply chain. It has been reported that Blockbuster's market share of video rentals increased from 24% in 1997 to 40% in 2002 after a revenue-sharing contract was adopted (Warren & Peers, 2002). The increase in the industry's total profit due to revenue-sharing strategy has been estimated at 7% (Moretimer, 2000). However, there are some limitations and drawbacks in revenue-sharing model. The first is that it is administratively burdensome compared with the straightforward wholesale price-only contract. Revenue sharing takes an organizational effort to set up the deal and follow its progress. If profits are only increasing by a very small percentage so that the revenue sharing does not cover the extra administrative expenses, then there is no incentive for the retailer to enter into a revenue-sharing contract. The second limitation, according to Cachon and Lariviere (2005), is when the retailer actions influence demand. Specifically, it is assumed that the retailer can increase demand by exerting costly effort, and that this effort is non-contractible. If a retailer is taking in only a small fraction of the generated revenue, this may not be sufficient incentive to improve sales. On the other hand, a supplier wants the retailer to buy the right quantity and to sell at a higher rate. The model may help to make sure the retailer buys the right quantity, but it may hurt its sales effort.

Collaborative computer-based information systems have become a major trend in today's business (Grossman, 2004). SCM evolved with the aim of integrating disparate functions like forecasting, purchasing, manufacturing, distribution, sales, and marketing into a harmonious ecosystem that would envelop the company's suppliers and customers. SCM promised to align all participants to act in unison to serve the end customer. Collaboration would enable managers to stop optimizing their individual silos to work together with partners—both internal and external—to achieve efficiency and effectiveness across the value chain. A truly collaborative partnership would encompass multiple customers and suppliers. OEMs would regularly communicate product availability, supply plans, and product content changes to distributors and other channel partners. Based on upstream forecasts and product changes, the channel partners would communicate demand requirements to manufacturing service providers. In this fashion, members of the outsourced supply chain would be assured of accurate, up-to-date information to help them make decisions that elicit common, supply chain-wide benefits. While collaborating, there is distinction between big and small companies; it is between big, aggressive, large muscled organizations and agile, flexible, adaptable organizations that can survive in an environment of rapid change, constant uncertainty, and disruptive technologies.

Involving suppliers early and giving them influence over design is associated with greater contributions of suppliers to cost reduction, quality improvement, and design for manufacturability (Liker, Kamath, & Wasti, 1998). Increasing competitive parity in the areas of cost and quality has forced global manufacturers to seek other sources of competitive advantage, with new product development rapidly becoming the focal point in the quest for sustained growth and profitability. The essence of today's new product development strategies is the simultaneous development of the new product and the accompanying manufacturing process such that quality is enhanced, costs reduced, and lead times shortened. The implementation of the integrated product development (IPD) process has come to depend on the use of multi-functional teams. Supplier involvement promotes better resource utilization, the development and sharing of technological expertise, and network effectiveness (Birou & Fawcett, 1994). Evaluation and monitoring of performance metrics are key aspects of the integration process, partnerships, and strategy. In the next section, we will discuss how customers evaluate suppliers' performance, how SMEs respond to their customers' evaluation actions, and the impact of these performance evaluations.

PERFORMANCE

Buying firm respondents who reported their firms' supplier development efforts to be satisfactory were more likely to have a proactive philosophy regarding suppliers' performance, put more effort and resources into their supplier development efforts, and exhibit a greater willingness to share information with their suppliers than their counterparts, who were generally dissatisfied with their firms' supplier development results (Krause & Ellram, 1997).

On its Global Procurement Web site (http://ch0107.whirlpool.com/SRM/generalhelp.htm), Whirlpool provides a list of requirements for potential companies wanting to become a Whirlpool supplier. All Whirlpool suppliers are required to pass a supplier quality audit. These requirements are based on ISO 9000, QS 9000, and ANSI/ASQC Q90-94 standards. They are to ensure the best cost, quality, manufacturing efficiency, and continuous innovation in design and manufacturing. All Whirlpool suppliers are to meet the Integrated Supply Management (ISM) guidelines as a common process for doing business using electronic communication. Whirlpool is also committed to establishing and maintaining a capable, qualified, competitive, and diverse supply base providing minority-owned, disadvantaged, and small businesses. Whirlpool also provides each supplier with the plan year's forecast, profit plan volume, and cost to be used later for total cost productivity targets.

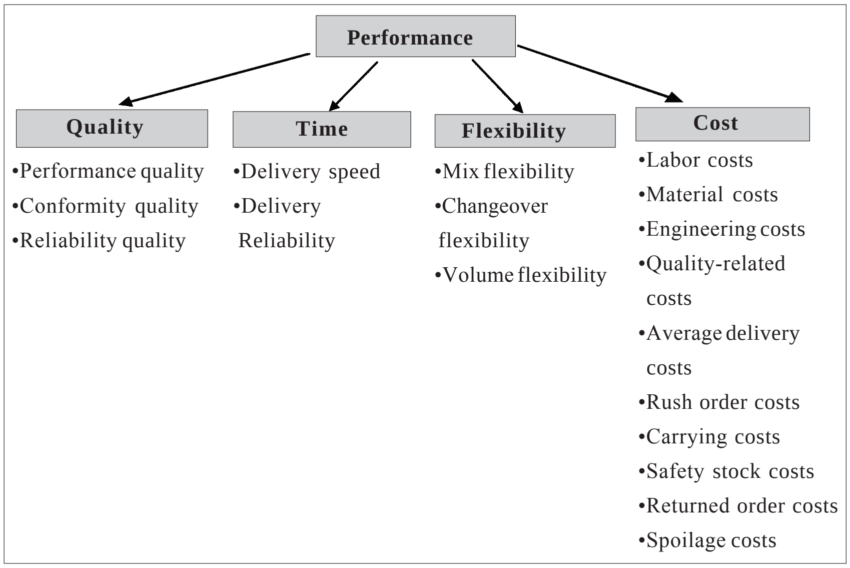
Information provided by the supplier performance will be used to assess efficiency in the supply chain (Wisner et al., 2005). FedEx not only has performance scorecards for its suppliers but also has developed a Web-based "reverse scorecard" that allows suppliers to provide constructive performance feedback to enhance the customer-supplier relationship.

A supplier's service level is, in general, insufficient for the manufacturer to warrant the desired service level at the customer end. The method by which the supplier achieves its service level to the manufacturer also affects the customer-service level. Procedures and metrics must be in place to collect and report performances of the eight processes that were discussed earlier in the integrated process section of this chapter. To assure that the integrated process is supporting the integrated strategy and the working relationships of partners, performance is continuously measured using metrics for each of the eight processes. These performance measures need to be both internal and external. As process integration improves across the supply chain, the overall performance will improve. Over time, under-performing suppliers and unsuitable customers will be eliminated. Suppliers can then concentrate on establishing beneficial relationships and forming strategic alliances to create a win-win situation.

As shown in Figure 3, evaluating and responding to the results of supply chain performance metrics and measurements have a huge impact on business performances. Four generic performance factors have been identified by Bozarth and Handfield (2005) as relevant to the supply chain management. These factors include quality, time, flexibility, and cost, as illustrated in Figure 3. Performance quality includes the basic operations characteristics of the product or service, conformance quality questions whether the product was made or service was performed to specifications, and reliability quality explores whether the product or service will perform consistently over a period of time and without failing or high maintenance costs. Time has two basic characteristics: speed and reliability. Delivery speed refers to how quickly the supply chain can fulfill a requirement, while delivery reliability refers to the ability to deliver products or services when promised. The ability to produce a wide range of products and services is the mix flexibility, while changeover flexibility questions the ability to provide a new product with minimal delay, and volume flexibility is the ability to produce whatever volume the customer needs. Cost categories include labor costs, material costs, engineering costs, quality-related costs, average delivery costs, rush order costs, carrying costs, safety stock costs, returned order costs, and spoilage costs (Bozarth & Handfield, 2005; Wisner et al., 2005).

In a study by Purdy, Astad, and Safayeni (1994), automotive supply organizations were interviewed regarding their perceptions of the effectiveness

Figure 3. Supply chain performance factors



of a North American automotive certification program. The major findings were that:

- suppliers viewed preparing for the performance evaluation as the most important aspects of the process;
- the evaluators detected only a small percentage of the suppliers' significant business and manufacturing problems;
- suppliers perceived an overemphasis on procedures and documentation on the part of the evaluators; and
- suppliers felt that the performance evaluation did not accurately reflect their effectiveness.

The same study concluded that the supplier evaluation program reflected the management style of the large bureaucratic customer organization, which was not necessarily appropriate for the size and nature of the supplier's business. Further, good performance on the evaluation did not directly correspond with further business contracts (Lyn et al., 1994). In today's world, definition of quality revolves around customer satisfaction, quality of product and service, timely delivery, and cost/price (Mehta, 2004).

INFORMATION TECHNOLOGY

Information technology (IT) offers huge potential for large suppliers as well as SMEs to achieve effective SCM mechanisms. In today's global marketplace, organizations are faced with ever-changing customer requirements and intensifying competition. To succeed, companies are looking at streamlining their supply chain through the successful deployment of Information Technology. Supply chain management expands the notion of integration beyond a single company to encompass all related trading partners in the supply chain. Suppliers, customers, third-party logistics providers, distribution centers, and relevant government agencies share the information and plans necessary to make the chain more efficient and competitive.

Manufacturers increasingly rely on IT to streamline their business processes. By integrating business processes across the supply chains, companies can quickly move information and materials to their trading partners and respond quickly to market changes. Internet technology is considered to be the most promising network infrastructure for supply chain connectivity. By having an integrated network infrastructure, companies can now manage their operations anywhere by accessing information using the Internet. Most companies are positioning IT as one of the key components for enhancing supply chain management, and they want to be updated regularly on new technologies that they can apply in their work.

Achieving integration in the global supply requires an enormous commitment by all members of the supply chain. In order to exploit competitive advantages by forming strategic alliances and partnerships and facilitating these relationships, companies must exchange information through increased communication and cooperation. The level of integration companies strive for now and in the future can only be possible through significant advances in information technology, which, in the past, has been costly and available only to larger companies with budgets that could support such endeavors. It has been argued that this helps explain the trend toward vertical integration as opposed to increasing horizontal communication efforts between suppliers, manufacturers, distributors, and customers. Information flow and sharing are essential in all components of supply chain. Supply chain information flow integrates all the facets of logistics as well (Vaidyanathan, 2005).

Although companies utilize technological tools such as electronic data interchange (EDI), and enterprise resource planning (ERP), there are still many issues arising from incompatible systems (interoperability) that drive inefficiencies. Additionally, as new technology develops, such as wireless networks, which still lack standard protocols, the problem does not appear to be going away too fast. This can be a major issue for the small- to mid-sized company, given budget restraints and the aggressive nature of larger budget companies to incorporate new technologies and information systems. Therefore, despite companies feeling they are actively sharing information with their supply chain partners, there continues to be inefficiencies and waste throughout the supply chain. The problem is further intensified when looking at partnerships on a global scale due to the traditional issues of cultural barriers and communication differences.

Internet technology has been increasingly used to enhance global supply chain through electronic commerce functionalities. Many Internet-based systems have been designed and developed for SCM to interconnect suppliers and customers. A four-phase migration model with technical, security, and financial requirements as a plan for the migration of the procurement process onto the Internet has been proposed by Yen and Ng (2003). The first part of the migration is the digitization of data in a local area network (LAN) to manage the information storage and retrieval within the company. The second phase is deployment of communication infrastructures such as EDI. The third phase is the installation of electronic commerce front-end system to implement procurement business processes such as Web sites and search engines. The fourth phase is the integration of vertical portal, that is, information processing with third-party service providers for financial transactions and logistics.

Small- and medium-sized enterprises are different than large enterprises in three primary ways that hinder e-commerce adoption (Smeltzer, 2002). SMEs seldom have mature technology. They usually emphasize product development and survival rather than supply chain integration. The large enterprises have costlier, mature integration software as well as internal technical development and maintenance capability (Smeltzer, 2002). Some of the large companies have integrated SMEs in their supply chain. As a $41 billion retailer, Sears has successfully connected every one of its 7000 suppliers by using a targeted technology, a proven process, and dedicated resources provided by a supply chain integration service (Smeltzer, 2002). The question confronting these suppliers is often not whether they should use SCM systems, but rather how they can take advantage of these systems and benefit from their use (Subramani, 2004).

Suppliers use IT for many reasons that include: requests for quotation (RFQ) received electronically by suppliers, support documents such as detailed part drawings and quality specifications accessed online, electronic transmission of purchase orders, shipment notifications, scheduling delivery windows at warehouse loading docks, electronic payment, electronic notification of changes, and inventory alerts based on preset triggers to communicate stocking levels of products in warehouses (Subramani, 2004).

Internet technology with its communication infrastructure has enhanced SCM initiatives. Companies are taking advantage of this technology and moving their procurement functions such as sourcing, negotiating with suppliers, payment, and other transactions onto the Internet. Such electronic procurement (e-procurement) results in control, flexibility, and cost savings. This provides suppliers with the ability to become proactive in doing their business. By implementing the supply chain onto the Internet, both suppliers and the customers will face both challenges and opportunities. Such challenges and opportunities include careful planning of the ways that people integrate changes and the benefits that the Internet can bring to the business, such as reduction in overall costs, respectively (Srinivasan, Reeve, & Singh, 2000). A large academic bookseller, Co-op Bookshop, launched electronic commerce and faced difficulties when competing globally. The lesson learned from this launch is that a company should study the existing customers and markets before it deploys e-commerce on the Internet (Loebbecke, Powell, & Gallagher, 1999).

E-procurement is more than putting purchasing decisions online; its functions also include linking suppliers and buyers into the purchasing network and rethinking of business processes such as transactions (Fisher, 2000a). With efficient information, such product information is structured by electronic catalogs with which e-procurement can form a good basis in order to attract more buyers to the shopping site (Avery, 2000a). Shell Services International launched its e-procurement service as a cost-cutting driver, and its electronic catalogs contain a broad list of suppliers ranging from huge contract partners to small chemical producers with which Shell has pre-negotiated discounts and service contracts. When a purchasing order is received, it will be automatically forwarded to the appropriate suppliers (Fisher, 2000b). E-procurement could reduce costs and cycle time by fostering a better relationship between buyers and sellers with a vertical supply chain Avery (2000b). The introduction of an e-procurement system in Texas Instruments has reduced the number of transactions in which purchasing was involved and replaced the internally based catalog system, saving a significant amount of cost (Atkinson, 2000a). The Texas-based Burlington Northern Santa Fe Railway planned to apply e-procurement for strategic sourcing and SCM, as it believed that collaboration with its suppliers could be facilitated in order to achieve full contract discount pricing (Atkinson, 2000b).

Yen and Ng (2003) classified the impact of electronic commerce in the procurement process into buyer and seller, and then further divided it into individual and inter-organizational categories. Individual and inter-organization classifications represent the internal efficiency and external impact, respectively. With *sourcing*, buyers can search for quick and complete information of materials from suppliers' online electronic catalogs while purchasing is enhanced. During *quotation* and *negotiation*, sending inquiries with the electronic and automated inquiry forms to suppliers can save time, and, in return, suppliers could direct the forms with quick and customizable responses, facilitating communication between buyers and sellers. With automated, synthesized, and modifiable *order placement*, cost and time are saved while purchase records can be viewed in a quick and timely fashion. Suppliers can benefit from efficient and error-free profiling management and more accurate demand forecasts in order to improve overall profitability. Again, communications between buyers and sellers can be enhanced while time is saved. Electronic *transactions* can take place without the need for physical forms of payment that are restricted by geographical and currency barriers. Suppliers can benefit from secure real-time collection of payment while the risk of unsuccessful receipt of payment is lowered, resulting in improved profitability. With *delivery*, uncertainty of receiving time is reduced by separated logistics and shipment, while information flow or communication between suppliers and logistic third parties is facilitated.

Electronic data interchange (EDI) is a way of conducting inter-organizational transactions electronically (O'Callaghan & Turner, 1995). The key components of EDI are: the electronic transfer of data, the use of standards, and the exchange of data with minimal human intervention. An event in a customer company's operational processes, for example, a purchase order, may trigger a computer application that generates an electronic message which is sent to, received, and processed by another computer application in a supplier's company. This message will trigger another event in the receiving supplier organization, for example, the delivery of products. Enabled by standardization of the message exchange, this communication takes place without human intervention. The organizations involved have to agree on contents, grammar, and organizational actions resulting from the message exchange. SMEs can improve their competitiveness by integrating their systems with their suppliers or other trading partners. Existing approaches to integration like EDI might help SMEs to overcome part of the integration problems, but they have their limitations (Themistocleous & Chen, 2004).

The Dutch coordination center for EDI reported that around 25.000 out of a potential 400.000 companies in the Netherlands are currently using EDI. The number of users has grown by 10.000 companies since 1994, but despite this relatively high growth in the number of EDI users, the current number still falls short of expectations (van Heck & Ribbers, 1995). In the U.S., for instance, Oakie (1997) reports that only 100,000 out of a potential 1.9 million companies are currently participating in EDI. Therefore, the adoption and implementation of EDI is still not prevalent. There are different reasons for this apathy to the adoption of EDI. One of the difficulties in EDI adoption is that its full benefit can be reached only if enough critical mass is achieved. To transact EDI messages, one needs to have partners who also are willing to adopt EDI. The other reason is that some EDI implementations are costly. One of the critical factors is the availability of EDI standards. The use of commercially available standards reduces the development costs and time and decreases the risk linked to the new EDI application (Krcmar, Bjÿrn-Andersen, & O'Callaghan, 1995). SMEs will adopt EDI if EDI message formats are available, if they decrease the risk linked to the new EDI standards, and if they reduce the development cost and time (van Heck & Ribbers, 1995). As more competitors and trading partners become EDI-capable, small firms are more inclined to adopt EDI in order to maintain their own competitive position (van Heck & Ribbers, 1995).

Another medium of e-procurement is the use of electronic business-to-business (B2B) commerce marketplaces. While there are many advantages to the use of B2B marketplaces, there are many disadvantages as well. The potential decrease in product quality is a big issue for B2B participants. Expectations will vary from one buyer to another, and the definition of quality will vary across suppliers. B2B may not be of interest to suppliers since the forced price reduction of supplies by new suppliers trying to gain a share of the market will hurt the supplier's margins and strain their ability to stay in the market (http://www.primetechnologywatch.org.uk).

Rovere (1996) argues that the role of SMEs should be investigated with regard to innovation and regional development studies with a focus on industrial districts. This argument is based upon the increasing importance of flexible organizations in today's economic environment, with the main elements of the flexible specialization model being networks of small firms, flexibility of equipment, and human resources. Rovere further argues that these ideas must be thoroughly considered in defining an IT diffusion policy for SMEs. The relatively inexpensive availability of IT products and services serves to create many new business opportunities for SMEs. If flexible production capabilities do indeed lie within the environs of networked SMEs, IT increases in importance to ensure the platform to allow for efficient information flow within and outside of SME networks.

Another problem posed to the SSM for the SMEs is integration. Enterprise resource planning (ERP) systems are an integrated software solution to manage a company's resources and to integrate all business functions, such as planning, inventory/materials management, sales and distribution, finance, human resources, and services. The complexity of ERP systems and the non-flexible nature of ERP solutions, combined with their high cost of implementation have impeded many companies' quest for integration. The major problem with ERP is integration, as ERP packages are not designed to tie up other autonomous applications (Cingil, Dogac, & Azgin, 2000). As a result, autonomous and heterogeneous applications coexist in companies with ERP systems, and integration problems have not been addressed. Therefore, the use of ERP systems no longer supports or leads to competitive advantages for organizations, especially SMEs (Themistocleous & Chen, 2004).

According to the United Nations report on e-commerce and development (avaliable at http://www.unctad.org/en/docs/ecdr2004ch2_en.pdf), SMEs in Latin America have recognized the need to increase their capacity to differentiate their products and services, and to link electronically with their customers and suppliers. However, none of the enterprises surveyed had advanced beyond the first stage of information and communications technology (ICT) adoption. For example, while most of them were on a local area network (LAN) and some of them used the Internet for looking up information, none used EDI or an Intranet, and very few communicated with clients via electronic mail, preferring to use the telephone or fax.

According to a study conducted by the World Wide Worx (http://www.theworx.biz/download/Exec%20Summary%20%20SME%20Survey%202003.doc), investment in information technology is having a major impact on the competitiveness of small and medium businesses in South Africa. Among the key findings of the survey was that SMEs are spending a higher proportion of their turnover on IT each year. In 2001, 47% of SMEs spent more than 1% of turnover on IT; in 2002, 48%; and in 2003, 49% expect to spend more than 1% of their turnover on IT. According to a Canadian net impact study (http://www.netimpactstudy.com/ca/pdf/release_final.pdf), 50.2% of Canadian SMEs are currently using or implementing the Internet. The same study concludes that a firm with $10M in revenues, with a 20% gross margin and 10% net margin, can achieve increases in net profit of up to 154% in a “best case” scenario, that is, if these average changes in revenues and costs were realized together.

In a recent survey, Deloitte Research undertook an exploratory study of IT purchasing by SMEs (available at http://www.deloitte.com/dtt/research/0,1015,sid%253D16418%2536cid%253D632D63293,00.html) in an effort to understand decision making in different stages of the information technology purchase process. The resulting study identifies the key factors impacting technology purchase decisions by small and medium enterprise owners. In particular, it found that: SMEs need information and help to manage their IT growing pains; price isn’t necessarily the bottom line when considering IT purchases; and vendor Web sites and reputations are extremely important in the minds of SME decision makers when looking for information and making purchase decisions.

Various forms of SCM applications are arising among the enabling technologies. Prominent vendors in SCM applications market include i2 Technologies, SAP, Oracle, and Invensys, which produce a range of hardware and software components that span communication, optimization, and modeling systems.

SMEs are becoming increasingly dependent on information technology to operate efficiently, serve customers effectively, and work with partners and suppliers more collaboratively. Faced with all the challenges and opportunities of competing in a fast-paced environment, growing companies must be especially confident that their networks can support business evolution. Building an effective network foundation is integral to, and an operational insurance policy for, achieving e-business transformation. It is vital that SMEs focus their attention on the critical success factors that drive growth in their particular market. They cannot afford to expend precious time re-architecting, re-learning, and managing networks. Network infrastructures should be the invisible plumbing that enables the transport of company information and communications and enables efficient processes.

CONCLUSION

The subject of global supply chain management is an important new frontier for businesses choosing to participate in the new global economy. The inherent processes range from raw material supplier to end-user and involve literally all functions in between. Consequently, the integration of these processes is crucial to achieving supply chain management success, which is only facilitated by adequate information exchange between partners within the supply chain—a task not easy to accomplish due to issues of interoperability. Yet, the ability for companies to successfully implement strategic relationships relies on their ability to develop or maintain an effective partnership strategy, as it is not always necessary to enter into full-scale partnerships with all suppliers perceived to be partners within the chain. Additionally, in today's uncertain global economy and associated issues of security and trust, many companies continue to re-evaluate their partnerships and foster those relationships that are more likely to lead to a competitive advantage. The literature emphasizes the importance of trust in developing such partnerships, as firms will attempt to reduce risk by not entering into partnerships lacking trust. However, the need to leverage the resources of the supply base and revenue sharing cannot be overlooked, and companies will pursue such relationships. In a changing world, the subject of truth and ethics is important when discussing supply chain management strategy.

Most discussions of supply chain management are presented in abstract terms and in ways that apply to product and service organizations alike. However, most small companies, and even larger corporations, focus on niche markets. Niche markets are where managers will correctly argue that profits are created and realized; therefore, the goal of many organizations is to develop business and market strategies to exploit these opportunities in the market. Similarly, as this chapter has detailed, it has been shown that an affective supply chain management strategy can benefit these very initiatives.

More specifically, the smaller firm in the supplier role has unique opportunities to develop business, market, and supply chain management strategies that are unique from those of the larger established companies. Realizing that the "buying" company within the supply chain—or end-user—is actively pursuing competitive advantage through marketing of its unique product or service, the small company is often better positioned to adapt to the needs of the customer. More precisely, the level of information available to key members of the smaller supplying organization and its integrated partners provide market opportunities that may not exist to larger corporations.

Supply chain management strategies, because of the unique circumstances of specific markets, can not be characterized as "one size fits all." In fact, global supply chain strategies are contingent upon market characteristics and business strategy, which seek to attain higher-level customer responsiveness at less total cost to the supply chain as a whole. Nowhere are the unique characteristics more prevalent than in the small- to mid-sized corporations, as each of these types of corporations seeks competitive advantage through management of the supply chain and, more specifically, management of the supply chain for a specific niche market.

Moreover, there are some unique obstacles and challenges in managing the supply chain given the scarce resources of the small- to mid-sized supplying company. More specifically, because of the involvement of so few within the supply chain management process in the smaller firm, there is greater responsibility for those individuals to manage this very important strategic process given the unique opportunities to exploit niche markets. The ability of a small firm to offer flexibility in terms of volume and product differentiation provides the competitive advantage businesses of all size pursue. Supply chain management strategy, then, is applicable to all sized firms and has unique characteristics for smaller entities. To maximize the Internet and supply chain management, SMEs must be included. The SMEs need to have the information technology capability to fully integrate into the supply chain. Only then will the supply chain management be effective to save time, decrease costs, improve relationships, and maximize overall responsiveness.

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Chapter 2.26

A Methodology for Developing Integrated Supply Chain Management System

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ABSTRACT

Integrated Supply Chain Management (ISCM) involves the linking of suppliers and customers with the internal business processes of an organization. ISCM solutions allow organizations to automate workflows concerning the execution and analysis of planning, sourcing, making, delivering, returns handling, and maintenance, to name but a few. Many of today's ISCM systems use primarily Web technology as the supporting infrastructure. Undoubtedly, the electronic (Internet-based) ISCM systems deliver the enterprises with a competitive advantage by opening up opportunities to streamline processes, reduce costs, increase customer patronage, and enable thorough planning abilities. However, there has been significant customer backlash concerning the inability of software vendors to deliver easy integration and promised functionality. Although various researchers have suggested strategies to overcome some of the failures in operating ISCM systems, there appears to be a lacunae in terms of architectural investigations in the analysis stage. The methodology proposed in this chapter seeks to resolve these gaps and provides a fundamental framework for analyzing ISCM systems.

INTRODUCTION

This is the age of communication based on Internet technologies. As a result, enterprises are able to conduct inter- and intra-organizational activities efficiently and effectively. This efficiency of communication has percolated in all arenas of organizational activities, including customer relationships, resource planning, and, in the context of this discussion, supply chains. Given the cost of logistics and their importance in order fulfillment process, organizations may want to capitalize on this opportunity to communicate in order to reengineer their supply chain operations that would sustain them in the globally competitive and challenging world of electronic business. With this invigorated growth of e-business, software vendors and consultants have been promising businesses the utopian Internet-based supply chain systems that would provide them with the capability to respond in real-time to changing product demand and supply and offer an easy integration functionality with backend information systems (PeopleSoft, 2002; Turner, 1993).

Although a number of Internet-based supply chain systems (or integrated supply chain management systems—ISCM systems) are available for adoption, enterprises do not guarantee to implement the systems in conjunction with their existing information systems. Furthermore, the ISCM systems may not fulfill the connection and implementation requirements among participants in the supply chain.

After the e-commerce hype had dissipated, surveys undertaken in 2001 tend to paint a different picture as to the success of these implementations. Smith (2002) concludes that at least 15% of supply chain system implementations during 2001 and 2002 were abandoned in the US alone. Although several reasons can be identified as the cause of implementation failure, the main problem rests with the fundamental analysis of ISCM operations and requirements.

The purpose of this chapter is to debunk some myths proposed by vendors with regard to the implementation of Integrated Supply Chain Environments (ISCE) and propose an analysis methodology for Integrated Supply Chain Management systems.

First, the chapter will examine some of the available literature regarding ISCE. The fundamentals of ISCE—technologies and processes—will be investigated in some detail. Vendors were quick to promote the benefits of ISCE yet were not so forthcoming as to possible barriers and other issues to watch for. Both of these also will be discussed in this chapter.

Second, an analysis methodology is proposed, which intends to address some of the issues identified previously and construct a theoretical model for enterprises to adopt in the analysis phase of developing ISCM systems. This chapter concludes with a future research direction in investigating technological issues of ISCM systems operation.

INTEGRATED SUPPLY CHAIN MANAGEMENT OVERVIEW

ISCM involves the linking of suppliers and customers with the internal supply processes of an organization. Internal processes would include both vertically integrated functional areas, such as materials, sales and marketing, manufacturing, inventory and warehousing, distribution, and, perhaps, other independent companies involved in the supply chain (i.e., channel integration). Customers at one end of the process can potentially be a supplier downstream in the next process, ultimately supplying to the end user (Handfield et al., 1999; Turner, 1993).

ISCM Solutions

While, in many cases, ISCM systems are still in their infancy, the concept of establishing information flows between points in the supply chain has been around since the 1980s. Through Electronic Data Interchange (EDI), customers and suppliers have communicated supply data through direct dial-up interfaces and other mediums (Zieger, 2001). However, the ability for the Internet to create a common communication infrastructure has made integration much more cost-effective. ISCM has promised to deliver the right product to the right place at the right time and at the right price (Comptroller, 2002).

From the supply chain software development perspective, there are generally four large vendors identified; namely, Oracle, SAP, PeopleSoft, and Ariba, and a multitude of medium-sized vendors in the ISCM solution space (Armstrong, 2002). All claim that ISCM will enable the enterprise to respond in real time to changes in demand and supply.

For instance, current ISCM solutions allow organizations to automate workflows concerning the execution and analysis of the following business activities (Comptroller, 2002; Gledhill, 2002; Peoplesoft, 2002):

1. **Planning:** Demand and supply planning, manage planning infrastructure.
2. **Sourcing (buy-side):** Strategic sourcing, eprocurement, services procurement, catalog management, collaborative contract/ supply management, e-settlements/vendor payments.
3. **Making (in-side):** Product life cycle management, demand planning, production management, production planning, flow production, event management.
4. **Delivering (sell-side):** Inventory, order management, promotions management, warehouse management, transportation management, delivery infrastructure management, e-bill payment, scm portal.
5. **Returns handling (from customers)**
6. **Maintenance**

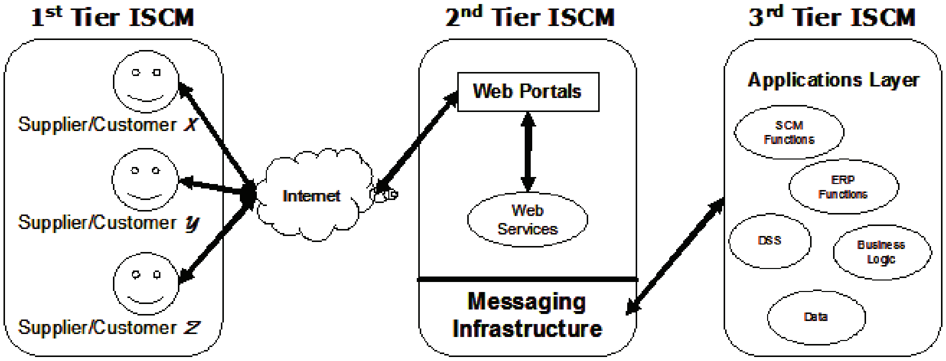
ISCM Systems Architecture

Turner (1993) stated that information systems would be the enabler of integrated logistics. Armstrong (2002) affirms that Turner's view has come to fruition. Many of today's ISCM systems primarily use Web technology as the supporting infrastructure (Dalton et al., 1998). It is not uncommon in these instances to develop a three-tier or n-tier network architecture in order to provide robust support for ISCM systems.

For example, Advanced Software Design Inc. (2002) illustrated the three-tier ISCM integration architecture (Figure 1) in use by the US Department of Defense (DoD). Suppliers and customers access the DoD ISCM through the use of Web portals (the first tier of the ISCM). Web portals provide the necessary Web services to establish a common graphical interface for the DoD's stakeholders in accessing supply chain data. Customers, suppliers, distributors, and delivery agents can access custom information and services supplied by the ISCM. Supplier services could include access to business-to-business (B2B) marketplaces, support, and other push/pull supplier functionality. Alternately, customers can customize the site in order to access catalogs from the organization and external suppliers; customer transaction details; and other product, customer, and technical support.

The portals are supported by a messaging infrastructure (second tier), which provides the

Figure 1. ISCM integration architecture



link to the underlying applications layer (third tier). The applications layer is independent of any particular interface (e.g., portals) and contains the necessary business logic and data access in order to perform operations. This includes access to SCM functionality, ERP systems, and decision support systems. Data and business logic also are stored independently.

The software architecture is constructed mostly in a Web-based environment that involves HTTP, server-side Java, and XML. ISCM systems are generally no different than other business applications but still require some interfacing with old technologies, such as aging ERPs and legacy systems (Zieger, 2001).

Benefits of ISCM Systems

ISCM delivers the enterprise with a competitive advantage by opening up opportunities to streamline processes, reduce costs, increase customer patronage, and utilize more thorough planning abilities (Turner, 1993). The benefits of ISCM systems are categorized into a number groups, including financial, customer, planning, production, and implementation. Each of these groups is further discussed in the following subsections.

1. Financial

   Cost Reduction: In some manufacturing organizations, the cost of the supply chain can represent 60-80% of their total cost base (Cottrill, 1997). One of the core benefits of driving efficiency through the supply chain is cost reduction. ISCM allows the organization to maximize profitability through reduced customer service, administration, and inventory costs. Less staff is required to maintain the supply chain, and order/inventory details can be made available to customers directly without human intervention (Comptroller, 2002; Cottrill, 1997; Gledhill, 2002). Some organizations have quoted 25% cost reductions per transaction, despite a 20% increase in orders (Turner, 1993).

   Quality Financial Information: Another benefit is the improvement and reliability of financial information. ISCM systems maintain centralized databases that are linked to other enterprise systems (e.g., ERP, CRM) providing integrity, consistency, and real-time data access to managers so that they can manage the supply chain with an organizational perspective (Comptroller, 2002; Turner, 1993).

2. Customer

   Retention: Supply chain systems, through customer portals, provide customers with an instantaneous and holistic view of the progress of their transactions within the organization. This level of service (coupled with benefits derived from production) result in higher customer satisfaction levels and, in turn, improve the firm's ability to attract new customers and, more importantly, retain them. Organizations have achieved customer service levels of 97% following the introduction of ISCM systems. This retention translates into greater revenue (Bergert, 2001; Comptroller, 2002; Cottrill, 1997; Gledhill, 2002; Turner, 1993).

   Behavior: The ability to capture customer transactions and preferences online provides the organization with the facility to track their behavior and, in turn, customize products and services to cater to them (Bragg, 2002).

   Promise: Because of the level of workflow automation and inventory statistics, organizations are able to provide accurate estimates of when orders will be filled at the time of ordering. This is known as capable-to-promise (CTP) capability. This capability allows the organization's customers to plan more effectively (Gledhill, 2002).

3. Planning

   Companies with ISCM systems have the ability to mathematically and graphically observe the performance of the supply chain, giving the manager the power to plan and make things happen (Turner, 1993). ISCM systems provide the organization with the capabilities to derive more accurate demand planning with improved precision, create shorter planning and production cycles, establish one central data repository for the entire organization, and facilitate enhanced communications through rapid information dissemination (Bragg, 2002; Comptroller, 2002; Gledhill, 2002).

4. Production

   ISCM provides the ability to holistically manage the supply chain, allowing managers to respond dynamically to any situation that may arise so as to minimize its impact on production.

   Inventory Management: By measuring the level of inventory and analyzing turnover, supply chain systems can improve turnover by reducing the need for safety stocks and the risk of retailer out-of-stocks. Inventory items need to be numbered consistently in order to facilitate measurement and tracking. These benefits reduce the overhead required to store high inventory levels (Cottrill, 1997; Gledhill, 2002). Turner's (1993) research claimed a 37% reduction in inventory levels as a result of ISCM implementation.

   Efficiency: ISCM systems measure the performance of the supply chain through the generation of supply chain metrics. This allows process quality issues to be tracked and rectified, isolates bottlenecks in the process, and measures lead times so they can be aligned with available capacity in order to maximize plant utilization. All of this ensures quicker time-to-market for the firm's products (Bragg, 2002; Comptroller, 2002; Gledhill, 2002).

   Other efficiency benefits include no data rekeying through simplified automated order placement, order status inquiries, delivery shipment, and invoicing (Bragg, 2002; Gledhill, 2002). ISCM implementations have resulted in a 50% overtime reduction for some organizations (Turner, 1993).

5. Implementation

   Consultants promise responsiveness and Plug & Play integrations. However, documented examples of supply chain failures by organizations such as Siemens AG, Nike, OPP Quimica, and Shell are evidence that the implementation of ISCM systems is not as easy as vendors claim. Claims of rapid integration and seamless linking seem to significantly underestimate the effort required to integrate ISCM with the rest of the enterprise (Oakton, 2003).

   For Nike, i2 ISCM software required a significant degree of customization in order to integrate the software to the rest of the organization. Customization to enterprise software comes with great risk and significant cost for ongoing maintenance. Nike's summation of the software was that it just didn't work. OPP Quimica (a Brazilian chemicals company) required the use of third-party integration software in order to assimilate i2 to the rest of the enterprise architecture. Shell's implementation proved problematic with the need to tie 85 ERP sites to a single SCM platform (Smith, 2002).

Issues and Barriers in ISCM Analysis

Similar to the hype attached to Enterprise Resource Planning (ERP) applications, there has been significant customer backlash concerning the inability of software vendors to deliver easy integration and promised functionality (Smith, 2002). Turner (1993) believes that "few companies claim to have fully implemented SCM and have sustained the benefits proposed ISCM would create" (p. 52). In fact, Fontanella (2001) indicates that only 25% of ISCM users are utilizing the full suite of supply chain applications and that only 12% of users are receiving data from inbound suppliers and customers—far from an integrated supply chain.

Many of these issues stem from a failure to undertake thorough analysis in the following key areas.

- **Focus on transaction systems over strategic systems to manage supply chains:** Organizations are not taking a strategic view of ISCM systems. More so, they tend only to focus on transactions systems (e.g., inventory control, order processing, etc.), which provide little visibility of the enterprise (Fontanella, 2001; Turner, 1993).
- **Failure to preempt change to business processes:** In a majority of implementations, analysis has focused on the technical aspects of integrating ISCM systems with the remaining architecture. One area that has been neglected is the effect on business processes. Organizations expect staff either to just accept change or to customize the software. Both of these options are generally flawed. In order to reap the cost savings from ISCM systems, significant analysis must be conducted regarding process reengineering in order to ensure collaboration and to continue to sustain benefits (Fontanella, 2001; Mol et al., 1997; Turner, 1993).
- **Failure to appreciate geographical, relational, and environmental considerations between buyer and supplier:** The nature of ISCM (especially with multinational corporations) involves transacting across the world—24 hours a day, seven days a week, 360°. Analysts fail to appreciate the geographical, relational, and environmental inhibitors for ISCM implementations of this scope (Mol et al., 1997).

  Cross-borders logistics, culture, language and economics, and regulatory climate are just some considerations that can affect the integration of business processes between regional offices and external organizations, creating communication issues throughout the supply chain. One ill-performing participant in the supply chain will affect the performance of the entire supply chain (Strausl, 2001).
- **Failure to accurately identify the costs and benefits of ISCM implementation:** Many implementations have been classified as failures because of ISCM system's perceived inability to reap benefits and produce cost savings, as expected. However, in many cases, it is the initial analysis of cost and benefits that has been flawed. Because of the nature and scope of ISCM implementations, it is difficult to accurately quantify attributable cost reductions from ISCM, because they could be derived throughout the supply chain and be complicated to calculate. In the same light, determining benefits share similar traits, with some having the additional complication of being intangible (e.g., benefits of a central database) and, therefore, difficult to quantify (New, 1994).
- **Insufficient capability:** The implementation and support of ISCM systems can be rather complex and, therefore, demands sophisticated resources and incremental implementations. Unfortunately, during the planning and analysis phases of implementation projects, organizations have failed to properly appreciate the level of complexity involved, resulting in significant under-resourcing. As a result, many organizations have suffered material cost overruns and delayed go-live times (Fontanella, 2001).

PROPOSED METHODOLOGY FOR ISCM SYSTEMS ANALYSIS

Due to the extent of failed ISCM system implementations, it is imperative to construct an appropriate analysis and development methodology that can be adopted as the roadmap for enterprises flourishing in ISCM systems development and operations. The proposed methodology demonstrates an overall picture for constructing an ISCM system from recognizing problems and analyzing requirements to the implementation and operation. It embraces eight phases:

1. Identifying information management structure
2. Identifying connecting components
3. Ensuring appropriate business processes
4. Establishing and developing interfaces
5. Developing new business processes
6. Confirming strategic alignment
7. Implementing ISCM systems
8. Testing efficacy of implementation

Following is a discussion and culmination of those eight phases within the proposed iterative framework.

Identifying Information Management Structure

Given the global nature of supply chain systems and their level of required integration, a common ICT (information and communication technology) infrastructure must be able to extend around the globe, to support open and rapid communication, and to integrate easily with the architecture of not just the organization but also the architecture of customers and suppliers. This will be conducive to information sharing (Comptroller, 2002).

The enterprise's information systems architecture must be properly analyzed to ensure that it satisfies the needs of ISCM systems and can support security boundaries, largely distributed database operations, and event-driven applications. The architecture needs to be durable, flexible, and embedded with the appropriate middleware in order to integrate as easily as possible (Zieger, 2001). It also must be sufficiently robust in order to cater to firewalls and other security measures and have 24/7 global access and redundant systems and processes in order to handle events when ISCM systems need to be off-line for maintenance, emergency, and recovery purposes.

In accordance with these criteria, the Internet-based structure can be considered the most appropriate platform to satisfy these requirements. Nevertheless, participants in the supply chain have various capability and maturity levels in information management structure. Hence, prior to adopting the Internet technology for integration, the existing information management structure of each participant must be determined.

Identifying Connecting Components

One of the most critical functions of supply chain management is to ensure the effective integration of information and material flows through the system. This includes understanding the value added to products and its related information flows (inputs and outputs) as it progresses through the supply chain (Michael-Donovan, 2002). This embraces analysis of the supply chain's real costs and cost and performance drivers (Seirlis, 2001).

Turner (1993) identifies some of the key components that need to be functionally integrated. These components also are considered the connecting components (or connecting business functions) among participants in the supply chain. These components include order management, customer service, invoicing, forecasting, distribution requirements planning (DRP), warehouse and inventory management, manufacturing planning, production control (MRPII), and integrated logistics.

Ensuring Appropriate Business Processes

In order to enhance the supply chain processes, it is important to understand what happens currently. Generally, supply chain processes may include the procurement, production, ordering, delivery, and inventory paths, both within the company and external parties.

First, analysts should analyze the supply chain processes and be able to appreciate the company's mix of products, end configurations, volumes, life cycles, channels, customer segments, and delivery outlets (Tyndall et al., 2002).

Each process then should be prioritized and broken down into its subprocesses, identifying each of its sources, outputs, transformations, timings, resources utilized, and requirements. This also would be an opportune time to gather metrics concerning each of the processes in order to establish a baseline for identifying problems and to measure future process improvement.

Additionally, any opportunities to benefit from quick-wins should be taken advantage of at this point (Michael-Donovan, 2002).

Establishing and Developing Interfaces

Once architectural issues have been resolved and data requirements have been determined, a structure needs to be established to enable common linkages between data providers and data recipients of the ISCM (i.e., customers and suppliers) and linkages within ISCM processes. This will require the need to ascertain whether there are any missing links and to determine how the data required will be sourced or provided and in which format.

The emerging technology for interface communications is XML (eXtensible Markup Language). XML uses HTML tags to enable the definition, transmission, validation, and interpretation of data. However, effort for this task should not be underestimated (Zieger, 2001). Significant resources may be required in analyzing sources from ERP and antiquated EDI systems. It has been suggested that third-party interface tools (e.g., Informatica & Brio) can be used to ease the transition for these types of systems (Zieger, 2001).

Developing New Business Processes

After conducting a detailed analysis of existing supply chain processes and identifying any inefficiencies and/or gaps in the process, a proposal should be created for the design of new processes. Not only should new processes cater to anticipated ISCM processing, but they also should be sufficiently visionary in order to accommodate other strategic initiatives (i.e., CRM, Supplier Management, Knowledge Management).

The new supply chain should be modeled in a manner so that supply chain blueprints can be generated (Comptroller, 2002; Zieger, 2001). Tyndall et al. (2002) suggest an iterative approach to process design, whereby a process is broken down into stages and then defined, analyzed, executed, assessed, and then redefined. This cycle continues until the appropriate performance expectations have been achieved. This process can become quite complex and convoluted, once organizations begin to incorporate backend systems and the processes of other organizations.

Based on metrics determined during the initial business process review, goals should be set for process improvement.

Confirm Strategic Alignment

At the completion of most of the analytical work, it is important to revisit some of the groundwork that would have been completed during the planning phase activity in the traditional SDLC.

It has been included in this framework to highlight the importance of ensuring an alignment between business strategy and expectations with the outcomes of the ISCM implementation—supply chain strategy is interdependent on the business strategic direction.

Analysts need to confirm that value is being delivered through ISCM by conducting a critical analysis on proposed benefits and costs in order to ensure that they are still realistic (Tyndall et al., 2002). In order to prevent misalignment of resources and skillsets, analysts also need to confirm that the business problem still can be solved with its current complement of staff.

Implementing ISCM Systems

This phase involves determining what activities will need to be undertaken to facilitate implementation of ISCM system—creating an action plan.

There are a number of factors that should be considered in this final phase of the methodology, such as setting up communication standards, developing business operation procedures, and establishing training programs.

Furthermore, this phase should be expanded to incorporate activities that can assist in the detailed analysis of implementation risks of the system. Conducting analyses in areas such as change management is one example. Inability to manage the implementation of change has been a key factor in project failure. Any enterprise system places great strain on the organization to adapt in order to reap the benefits. Change management involves more than simply conducting user-training programs but involves a continuing consultative relationship with end users to secure buy-in.

CONCLUSION AND FUTURE CHALLENGE

This chapter endeavors to propose an analysis and development methodology for ISCM systems. The discussion started with review and investigation of the current ISCM solutions and architectures, and identified a number of benefits, issues, and problems regarding the implementation of ISCM systems. Based on the examination of existing ISCM status, the proposed methodology for ISCM systems analysis is constructed by an eight-phase development framework. The methodology tends to illustrate a systematic roadmap for enterprises in developing ISCM systems.

The future challenge for enterprises in operating and maintaining ISCM systems stressed the overall maturity of technological availability and the flexibility of business processes aligning with the ISCM architecture.

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Section III

Tools and Technologies

This section presents extensive coverage of the technology that informs and impacts strategic information systems. These chapters provide an in-depth analysis of the use and development of innumerable devices and tools, while also providing insight into new and upcoming technologies, theories, and instruments that will soon be commonplace. Within these rigorously researched chapters, readers are presented with examples of the tools that facilitate and support the emergence and advancement of strategic information systems. In addition, the successful implementation and resulting impact of these various tools and technologies are discussed within this collection of chapters.

Chapter 3.1

Intelligent Agents in Decision Support Systems

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INTRODUCTION

Internet-based, distributed systems have become essential in modern organizations. When combined with artificial intelligence (AI) techniques such as intelligent agents, such systems can become powerful aids to decision makers. These newer intelligent systems have extended the scope of traditional decision support systems (DSSs) to assist users with real-time decision making, multiple information flows, dynamic data, information overload, time-pressured decisions, inaccurate data, difficult-to-access data, distributed decision making, and highly uncertain decision environments. As a class, they are called intelligent decision support systems (IDSSs).

Although various AI techniques such as artificial neural networks, genetic algorithms, case-based reasoning, methods from expert systems, and knowledge representation have been successfully incorporated into IDSSs, intelligent agents are one of the more promising AI research fields with broad applicability to IDSSs. Although there is no universally-accepted definition of an agent, the definition given by Woolridge (2002) is often cited as authoritative:

> *An agent is a computer system that is situated in some environment and that is capable of autonomous action in this environment in order to meet its design objective.*

Woolridge (2002) adds the capabilities of *reactivity, proactiveness*, and *social ability* for an intelligent agent, although many researchers, including the DSS community, do not make a distinction. Reactivity means that an intelligent agent can perceive the environment and respond to it as it changes. Proactiveness implies that it is able to take the initiative to meet its design objective. Social ability means that it can interact with other agents and possibly humans to perform such tasks as negotiation and cooperation. Delivery of these capabilities imposes demanding requirements on the part of the agent designer since the environment may change during execution of the software program and initial assumptions may no longer be valid, and yet the agent's goal remains the same. In complex environments, teams of agents or multi-agent systems have been developed that attempt to balance goal-direction with reaction to the environment. Agents, intelligent agents, and multi-agent systems are active areas of research both in themselves and in application to IDSSs.

The objective of this article is to review characteristics of intelligent agents and their applications to intelligent decision support systems. The article is organized as follows. In the second section we provide a background on intelligent agents and IDSSs. In the third section we discuss intelligent agents within IDSSs and provide examples of applications. In the final section, we examine future research trends.

BACKGROUND

Simon (1997) described the decision making process as consisting of three phases: intelligence, design, and choice. A fourth phase, implementation, was added by later researchers (Forgionne, 1991). The decision maker acquires information and develops an understanding of the problem during the intelligence phase. During the design phase the user identifies criteria, develops the decision model, and investigates alternatives. An alternative is selected during choice and the user acts on the decision during the implementation phase. A similar four-step decision making process is recognized by researchers for defense decisions and is called the observe, orient, decide, act (OODA) loop (Phillips-Wren & Jain, 2007).

Decisions are often characterized by the degree of structure involved in the decision (Turban & Aronson, 1998). A structured decision is deterministic with a known solution, while an unstructured decision is on the other end of the continuum with decisions with little or no agreement on the solution. In the middle are semi-structured decisions and this is the area where DSSs are most effective at providing support by using computing to assist with the decision. Semi-structured decisions are those that require some human judgment and at the same time there is some agreement on the solution method. Examples of support for decision making are mathematical models and statistical methods. In general, a DSS consists of input, processing, output, the user, and computing resources. Inputs include the database(s) needed for the decision and model base(s) that supply the models needed to evaluate and/or predict potential outcomes. During processing the model(s) is evaluated and a feedback loop to the input permits multiple what-if scenarios and alternatives. In output, the user is presented with alternatives and sometimes recommended courses of action. The user and computer are considered part of the system.

A DSS with embedded AI techniques is referred to as an 'intelligent decision support system.' What is intelligence in the context of DSSs? Turban and Aronson (1998) defined an IDSS as a DSS exhibiting some or all of the abilities that are indicative of 'intelligent behavior':

- Learn or understand from experience.
- Make sense out of ambiguous or contradictory messages.
- Respond quickly and successfully to a new situation.
- Use reasoning in solving problems.
- Deal with perplexing situations.
- Understand and infer in ordinary, rational ways.
- Apply knowledge to manipulate the environment.
- Think and reason.
- Recognize the relative importance of different elements in a situation.

The characteristics of intelligent agents given by the collective AI community (Bradshaw, 1997; Huhns & Singh, 1998; Jennings & Woolridge, 1998; Woolridge, 2002; Jain, Chen, &, Ichalkaranje, 2002; Russell & Norvig, 2003; Padgham & Winikoff, 2004; Design-Ireland, 2007) are comparable:

- **Autonomous:** Capable of working without human supervision.
- **Adaptive:** Ability to learn and change behavior as their knowledge base increases.
- **Proactive:** Ability to take an initiative on its own.
- **Reactive:** Responds to changes in its environment.
- **Communicative:** Ability to communicate with other systems, agents and the user.
- **Cooperative:** As an advanced capability, ability to act in coordination with other agents.
- **Mobile:** Ability to travel throughout computer systems to gain knowledge or perform tasks.
- **Goal-Directed:** Ability to work toward achieving a specific goal.
- **Persistent:** Ability to persist and maintain state over long periods of time.

It appears that intelligent agents can deliver the necessary behaviors within IDSSs.

As organizations increasingly deploy IDSSs on networked computers and within distributed systems, intelligent characteristics can be provided by multi-agent systems (Huhns & Singh, 2006). A multi-agent system "consists of a number of agents, which *interact* with one another, typically by exchanging messages through some computer network infrastructure" (Wooldridge, 2002). The agents in multi-agent systems may act on behalf of users or even other agents with differing goals and objectives. Successful interaction then requires cooperation, coordination, and negotiation between agents, and sometimes between the human user and agents, that do not share the same beliefs, goals, or interests. Agents can dynamically create teams and multi-agent systems are said to create an "artificial social system" (Woolridge, 2002) involving agent architecture, cooperation among agents and with humans, human-like learning, and trust.

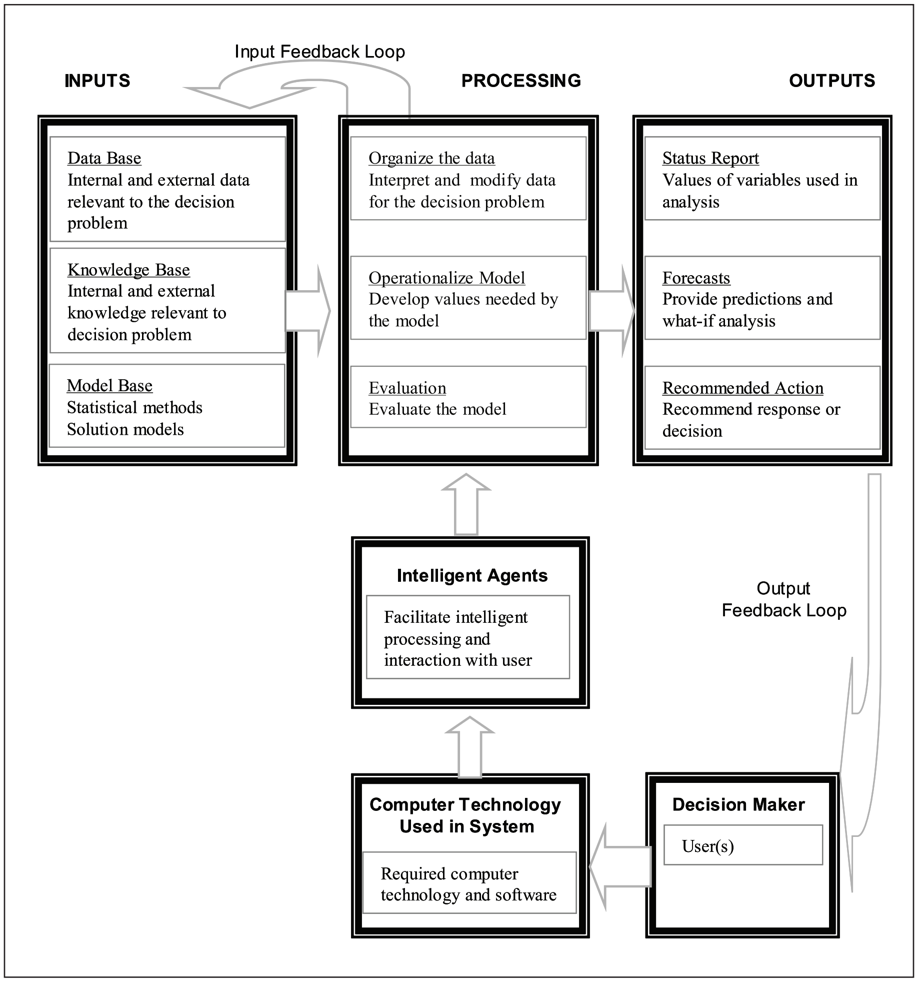
INTELLIGENT AGENTS IN DECISION SUPPORT SYSTEMS

Support for Decision Making

Recent advances in intelligent agents and multi-agent systems have led to a noticeable increase in the number of IDSS applications over the past several years. "Agent-based computing has already transformed processes such as automated financial markets trading, logistics, and industrial robotics. Now it is moving into the mainstream commercial sector as more complex systems with many different components are used by a wider range of businesses. Organisations that have successfully implemented agent technologies include DaimlerChrysler, IBM and the Ministry of Defence" (Sedacca, 2006).

Various frameworks have been proposed for IDSSs. For example, Linger and Burnstein (1997) provided two layers in their framework, a pragmatic layer that is associated with the actual performance of the task and a conceptual layer that is associated with the processes and structure of the task. Figure 1 illustrates a framework for an IDSS implemented with intelligent agents. The input has a database, knowledge base, and model base, some or all of which may utilize intelligent methods. Data directly relevant to the decision problem is contained in the database, for example, values for the states of nature, courses of action, and measures of performance. Problem knowledge, such as guidance for selecting decision alternatives or advice in interpreting possible outcomes is contained in the knowledge base. The

Figure 1. Framework of an intelligent decision support system implemented with intelligent agents



model base is a repository for the formal models of the decision problem and the approaches (algorithms and methodologies) for developing outcomes from the formal models (Phillips-Wren et al., 2006). Intelligent agents may autonomously perceive, obtain and develop needed data, knowledge, or models.

Processing involves organizing problem inputs, structuring the decision problem and decision model, using the decision model to simulate policies and events, and determining the 'best' problem solution. Intelligent agents may assist in these tasks by using knowledge drawn from the knowledge base to perform appropriate actions and present the results to the user.

During processing, status reports, forecasts, recommendations, and explanations may be created (Phillips-Wren et al., 2006). Status reports may reveal relevant states, courses of action, and measures of performance and show the current values for these problem elements. Intelligent agents could anticipate the need for status reports and communicate with the user. Forecasts may report the states and actions specified in the simulations and the resulting projected values for the measures of performance. Intelligent agents can assist these processes by anticipating requirements for the analyses such as variable values and acquiring them from appropriate databases. The recommendations may suggest values for the actions that best meet the measures of performance. Explanations will justify the recommendations and offer advice on further decision making, and intelligent agents could communicate with the user depending on user preferences. Such advice may include suggestions on interpreting the output and guidance for examining additional problem scenarios.

Input feedback from the processing provides additional data, knowledge, and models that may be useful for future decision making. Intelligent agents could anticipate the need for feedback and obtain the needed values of the variables autonomously. This feedback can be provided dynamically to update the models and inputs in real time without external intervention. Output feedback is used to extend or revise the original analyses and evaluations, and intelligent agents could interact with the user to refine or evaluate the decision further. Multi-agent systems could distribute the IDSS over multiple networks for collaboration between multiple decision makers while maintaining the functionality discussed.

In general, intelligent agents and multi-agent systems are being implemented in IDSSs for tasks such as obtaining values to quantify uncertainty and assess risk, providing up-to-date information in real-time, enabling collaborative decisions, evaluating consistency between data sources, handling routine decisions, monitoring and alerting the decision maker as problems arise, bringing together data from different media types or sensors, and expanding the knowledge set to include more information from more sources. The AI community is "shifting from inward-looking to outward-looking" (Mackworth, 2005) and intelligent decision support is poised for significant advancement. For example, in engineering designs of buildings, early research focused on AI to aid design processes such as computer-assisted drafting. Current efforts use AI as "the glue that holds larger *systems* together

Table 1. Decision process and dteps vs. intelligent agent and multi-agent system characteristics

DECISION PROCESS	**DECISION STEPS**	**INTELLIGENT AGENT AND MULTI-AGENT SYSTEM CHARACTERISTICS**								
		AUTONOMOUS	ADAPTIVE	PROACTIVE	REACTIVE	COMMUNICATIVE	COOPERATIVE	MOBILE	GOAL-DRIVEN	PERSISTENT
Intelligence	Problem Detection	√		√		√	√	√		√
	Data Gathering	√		√			√		√	√
	Problem Formulation		√	√	√	√			√	
Design	Model Classification		√			√				
	Model Building		√		√	√		√	√	
	Model Validation	√								
Choice	Evaluation				√	√			√	
	Sensitivity Analysis		√		√					
	Selection	√		√	√	√		√		
Implementation	Result Presentation			√	√		√		√	
	Task Planning		√		√			√		
	Task Monitoring	√							√	√

using reasoning *systems* that represent or manage processes, information, and interaction devices that use conventional procedural programming; effectively blurring the boundaries between AI and non-AI" (Maher, 2007).

Characteristics of intelligent agents and multi-agent systems support the decision process and decision steps as shown in Table 1. The decision making process includes the phases of intelligence, design, choice, and implementation discussed previously. The phases can be further refined into decision steps to clarify the actions that take place in each phase (Turban & Aronson, 1998) with one such refinement (Mora, Forgionne, Cervantes, Garrido, Gupta, & Gelman, 2005; Phillips-Wren et al., 2006) shown in Table 1. Characteristics of intelligent agents and multi-agent systems are then related to the decision steps in Table 1 to demonstrate the actions that can be performed by agents on behalf of the user or other agents. The comparison demonstrates that intelligent agents and multi-agent systems can support the tasks in decision making. However, they can not replace the human user who remains part of the IDSS as shown in Figure 1. The user maintains the final decision on accepting or not accepting the recommended course of action and implementing it, as well as interacting with the system to provide user-specific domain knowledge or preferences.

Applications of Intelligent Decision Support Systems

Several examples of applications of IDSSs with intelligent agents are shown in Table 2 to illustrate the depth and breadth of recent research efforts. Many other examples can be found in the literature (see, for example, Phillips-Wren & Jain, 2005).

A more detailed illustration is given by an application of intelligent agents for the non-expert who seeks information in a technical field (Wang et al., 2006; Phillips-Wren, 2006). An Internet-

Table 2. Sample applications of agent-based IDSSs

Industry or Research Area	**Sample Applications**		
	Author	Year	Brief Description
Securities Trading	Wang, Wang, Xu, and Kit	2004	Minimize transaction risk by aiding business exception management (i.e., monitoring, investigation, and reconciliation of transaction errors) with agents. Currently multiple organizations, human activities, and automated processes are involved. Web-enabled, agent-based, decision support to address dynamic, complex, and distributed processes. Result is faster, more accurate, and more flexible business exception management.
Electronic commerce	Lee and Park	2003	IDSS for Web-based, make-to-order (MTO) semiconductor manufacturing environment. During industrial manufacturing processes, various sampling methods such as spectroscopy are used to judge the quality of the final product. IDSS utilizes intelligent agent to autonomously generate available customized sampling methods and provides performance information to the customer. The customer then selects a process sampling method that is most suitable to their particular situation.
Planning and control	Santos, DeLoach, and Cox	2006	A multi-agent, distributed IDSS was developed to assist a commander on the battlefield with mission planning and execution. The environment is complex, distributed, collaborative, and dynamic with competing goals and user preferences. Agents assist in retrieving, analyzing, synthesizing, and distributing information to the decision maker.
Strategy	Li	2007	Web-enabled, multi-agent IDSS was developed to assist users in marketing strategies, competitive strategies, and associated electronic commerce strategies.
Healthcare	Sissons, Gray, Bater, and Morrey	2007	Agent-based IDSS to bring best-practices into oncology to develop an individual patient's treatment by examining objective research in order to suggest treatment.

based, suicide prevention Web site (PSN, 2006) was developed for the U.S. National Institute of Mental Health to, in part, provide an interface to the U.S. National Library of Medicine (NLM, 2007). A portion of the Web site involves information retrieval for the user from medical research literature. Agents persist in autonomously and proactively locating remote information by moving between resources, retrieving information, and communicating with the user.

Users of the Web resources are intermediaries between a person who may be suicidal and medical information that could be helpful in preventing suicide. Much of that information is contained in databases at a centralized location, namely, the U.S. National Library of Medicine. The difficulty for users is that the databases are large, mix various types of medical information, are constantly updated, and are catalogued according to medical terminology using a MeSH® system whose keywords are developed, and whose articles are categorized, by medical subject area specialists (NLM, 2007). Users, on the other hand, are generally non-experts without medical training who are generally unfamiliar with the specialized terminology. Access to needed information on suicide is greatly hampered and likely impossible without assistance. The amount of available information makes generalized information searches ineffective. One database alone, Medline, lists over 15 million references from more than 5,000 biomedical journals published in the United States and 80 other countries (NLM, 2007). Intelligent agents can provide an appropriate interface to the databases for this category of non-expert users.

Previous research (Wang, 2006) has shown that the information search process used in information retrieval corresponds to the decision making process as shown in Table 3. The similarities in the processes together with characteristics of intelligent agents and multi-agent systems shown in Table 1 suggest that an IDSS implemented with intelligent agents may be able to aid the user in locating the desired information.

Within the Web site, an agent-based IDSS was developed to allow a user to register, save, and update personal data that describes the type of suicide information of interest. User terminology describes in lay terms the type of suicide information that is desired. By registering these search preferences, the user initiates an intelligent agent that autonomously monitors the technical databases at the National Library of Medicine, seeks new information as the databases are updated or the user search preferences change, and reports new information to the user electronically as it

Table 3. Steps in the decision making process compared to the information search process (Wang, 2006)

Decision-Making Process	**Description**	**Information Search Process**
Intelligence	Recognize problem; Gain problem understanding; Seek and acquire information	Task Initiation Topic Selection
Design	Develop criteria; Specify relationships; Explore alternatives	Prefocus Exploration Focus Formulation
Choice	Evaluate alternatives; Develop recommendations; Make decision	Information Collection
Implementation	Weigh consequences; Implement decision	Search Closure

becomes available.

Intelligent agents in the technical information retrieval process are autonomous, proactive, communicative, mobile, goal-driven, and persistent. Intelligent agents autonomously communicate with remote databases at the National Library of Medicine on behalf of the user. They are mobile between the user, the Web site containing the user's search preferences, and the National Library of Medicine. Intelligent agents proactively search for new information without further user direction. They are goal-driven to find new information for the user by translating the user's interests into technical terms in accordance with the MeSH®, identifying new information, and contacting the user. Intelligent agents are unique in information retrieval since they infer the user's technical medical interests based on a non-technical description.

FUTURE TRENDS

The area of IDSSs, and especially implemented with intelligent agents and multi-agent systems, is an active and growing research area. As distributed systems continue to become more pervasive with globalization and networked applications, agent-based IDSSs will be able provide assistance for complex, real-world decision making problems.

The future presents research challenges in the application of intelligent agents and multi-agent systems to IDSSs, particularly in the interfaces between humans and machines. The challenge is to design robust human-agent teams, human-like agents, trust-based agent models, emotion-based agents, agent communication, cooperation models, and self-creating agent architectures. Adaptive IDSSs that personalize for different users and perceive user intent in action or language are actively being pursued.

One of the biggest challenges in this research field remains trust in autonomous systems in general, and in IDSSs in particular. Future research will need to address questions such as: What decisions are we willing to allow machines to make autonomously? What actions will we allow them to take and under what conditions? What security do we need in place? What checkpoints need to be implemented in systems? How much do we really trust them to act in our best interests?

CONCLUSION

Intelligent agents and multi-agent systems are sufficiently mature to offer significant promise in intelligent decision support systems. Such systems have the potential to transform business and personal decision making, particularly in distributed, network-centric environments.

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KEY TERMS

Decision Support System (DSS): An information system that utilizes database and model-base resources to provide assistance to decision makers through analysis and output.

Intelligent Agent: A software program with the ability to act autonomously on behalf of a user or other agents to achieve a goal.

Intelligent Decision Support System (IDSS): A decision support system with embedded artificial intelligence techniques exhibiting some or all of the abilities indicative of intelligent behavior.

Multi-Agent System: A system of intelligent agents that work together to meet their design objectives.

Semi-Structured Decision: Decisions in the middle between structured and unstructured decisions, requiring some human judgment and at the same time with some agreement on the solution method. Area of focus for most DSSs.

Structured Decision: A deterministic decision with a known solution.

Unstructured Decision: Decisions with little

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Chapter 3.2
Agents and Multi-Agent Systems in Supply Chain Management:
An Overview

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ABSTRACT

This chapter discusses the current state-of-the-art of agents and multi-agent systems (MAS) in supply chain management (SCM). Following a general description of SCM and the challenges it is currently faced with, we present MAS as a possible solution to these challenges. We argue that an application involving multiple autonomous actors, such as SCM, can best be served by a software paradigm that relies on multiple independent software entities, like agents. The most significant current trends in this area are shown, focusing on potential areas of further research. Furthermore, the authors believe that a clearer view on the current state-of-the-art and future extension will help researchers improve existing standards and solve remaining issues, eventually helping MAS-based SCM systems to replace legacy ERP software, but also give a boost on both areas of research separately.

INTRODUCTION

This chapter discusses the current state-of-the-art of agents and multi-agent systems in supply chain management (SCM). The growing complexity of the supply chain has increased the need for effective supply chain management, which may raise profit and reduce stock at a minimal cost. However, SCM is a complex problem of distributed nature and it often involves sensitive data that companies may be reluctant to reveal. Multi-agent systems (MAS) appear to be an ideal solution to this problem, as they can handle complex and distributed processes in an effective way. Considerable ongoing research efforts on MAS have yielded a wide variety of prototypes and applications although the adoption of agents by the software industry proceeds at a cautious pace. Agent-based solutions for the SCM problem abound in the literature underlining the significant interest in this approach and its huge potential.

Section 1 provides a general description of SCM and explains the reasons that make effective SCM critical, both within a single company and across the chain. Section 2 discusses the main problems that SCM is currently faced with and section 3 explains the reasons why MAS are an ideal solution to this problem. Section 4 describes the various approaches and current trends and focuses on current problems that arise and areas that need further research. Finally, section 5 presents the main conclusions.

Current Trends in SCM

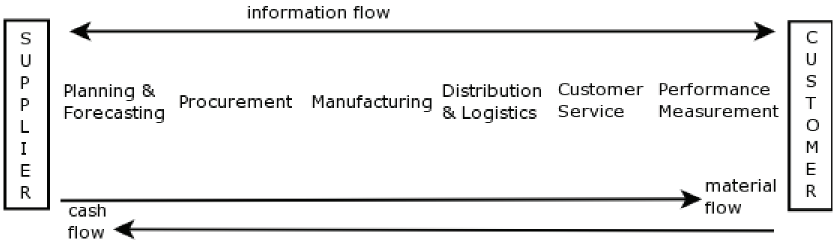
According to Stanfield (2002), "supply chain management deals with the management of materials, information and finance in a network consisting of suppliers, manufacturers, distributors and customers" (p.11). Practically, according to Kim, Tannock, Byrne, Farr, Cao, and Er (2004), "the activities involved in the material flow are to deliver to the end-user via procurement of raw materials, manufacturing, distribution and customer service" (p.10). All these activities must be managed using suitable information flows. This is easily illustrated in Figure 1.

The above factors cause increasing emphasis to be placed on integrating, optimizing and managing the entire supply chain from component sourcing, through production, inventory management and distribution to final customer delivery. Recent technological advances have facilitated this job, replacing approximate estimations by human experts by more precise calculations, as managing the supply chain is a complex task with increased sensitivity on small changes.

Increasing competition has emphasized the need for more flexible, robust and powerful supply chain management. The current trend in production is changing "from mass-production to customisation, and from technology and product-driven to market and customer-driven" (Kim et al., 2004, p.9). Bielli and Mecoli (2005) state that "current scenario in production and logistics fields must accomodate globalization, needs for increasing quality of goods, rapid changing in market demand, customer-service policies, flexibility of production processes, e-business and e-commerce" (p.147).

Many companies see the need for complete visibility into their supply chain as the starting point for managing them and many solutions are already implemented in this area. The next stage is to go further and implement solutions that are designed to change business practices and make supply chains more efficient.

Figure 1. Flows in the supply chain (Adapted from Speckman, Kamauff, & Myhr, 1998)



SCM PROBLEMS

Managing the supply chain is an extremely complicated task, which requires correct coordination of distributed heterogeneous information. Each part of the chain plays a different role in the functionality of the entire chain and it is difficult to conceive a suitable model, especially when the latter is designed to be more generic rather than to describe a particular chain. "The speed and accuracy required to increase the company's profit, as well as the current trends for customisation and flexibility, require the adoption of 'just-in-time' practices" (Stanfield, 2002, p.11). However, these practices not only require a totally transparent chain, but also increase its sensitivity on real-world problems, such as delays, specification changes and compromises. The most important problems of SCM are discussed below.

Bullwhip Effect

As explained by Kombrough, Wu, and Zhong (2001), a very well-known phenomenon in SCM is the so-called bullwhip effect, where the variance of orders amplifies upstream the supply chain. Figure 2 illustrates this effect.

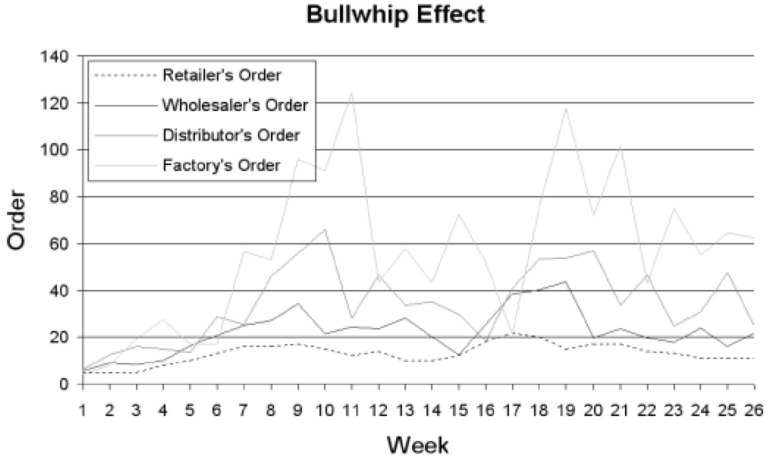
Such results are commonly observed in real-life situations. Small fluctuations on one end of the chain often become surprisingly large on the other end, hindering the flawless functionality that one would expect from a well-designed supply chain. As a result, there is a growing interest in efforts to eliminate the bullwhip effect, or at least minimize it.

Kombrough et al. (2001) state that the bullwhip effect can be minimized under the assumption that all divisions of the supply chain work as a team. Yung and Yang (1999) claim that information sharing and, more generally, coordinating information and planning along the supply chain can minimize the bullwhip effect. Ganapathy and Narayanan (2003) suggest simulation methodologies to lower demand amplification, but this, of course, requires extensive collaboration between the different levels of the supply chain system.

Coordination

It is also necessary to discuss the importance of correct timing and coordination in SCM. The most immediate consequence of incorrect coordination is a bottleneck effect, where products are accumulated in one part of the chain, while there is a shortage at its end. This can lead to products eventually becoming useless, or can force a modification of the manufacturing and

Figure 2. The bullwhip effect



supplying process, with immediate impact on product quality, cost and competition.

Ganapathy and Narayanan (2003) present time delay, added together with delays from other levels, as the major cause of the bullwhip effect. Chan and Chan (2004) state that one common weakness is the assumption of deterministic demand. Facing uncertain demand, retailers prefer to place an order late in most cases in order to gather enough time to collect more information. However, this leads to insufficient production times and hence increased production cost.

MAS AS A SOLUTION

Generally speaking, the best way to define software agents and distinguish them from other software entities is to do so based on some common attributes that they have. As stated by Ta, Chai, and Liu (2005), agents' main characteristics are autonomy, sociability, capacity for cooperation, capacity for reasoning, adaptive behavior and trustworthiness. One can easily understand that all of these capabilities are, not only necessary, but also vital to SCM.

However, there is still not a commonly accepted definition on what an agent might be. Wan (2004) states that an agent is merely an object with initiative. Of course, initiative is an important feature of an agent, but one can easily understand that there's more in an agent than initiative. Other authors, such as Caglayan and Harrison (1997), define an agent as "a software entity that accomplishes a specific task, usually on the Internet, according to the user's requirements". This definition, though commonly used, is also too vague and does not give a complete picture of agents.

A multi-agent system (MAS) is a system, in which many agents communicate and interact. This interaction may be either cooperative or selfish. According to Sycara (1998), the main characteristics of a MAS are:

- Each agent has incomplete information or capabilities to solve the problem
- There is no global control on the system
- Data is distributed
- Computations are asynchronous

As explained earlier, SCM is a problem of distributed nature, which requires processing of heterogeneous data in an intelligent way. Resource allocation is crucial to the supply chain's functionality and negotiation and cooperation between the parts of the supply chain are necessary. This shows that MAS are an ideal solution to this problem, since they are designed for distributed problem solving and negotiating.

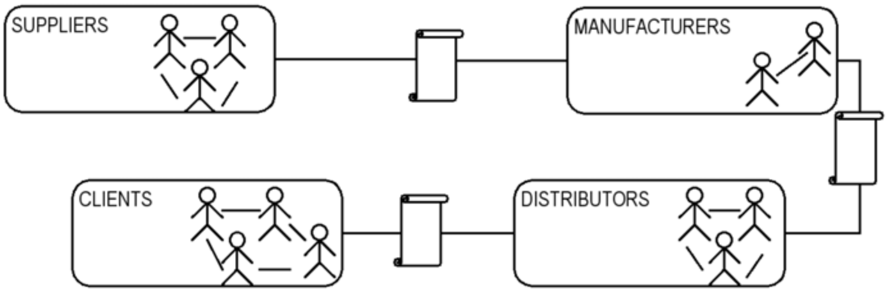
According to Wu, Ulieru, Cobzaru, and Norrie (2000), since SCM is fundamentally concerned with coherence among multiple, globally distributed decision makers, a multi-agent modeling framework based on explicit communication between constituent agents (such as manufacturers, suppliers, retailers and customers) seems very appealing.

"Agent technology may facilitate the integration of the entire supply chain as a networked system of independent echelons, each of which utilizes its own decision-making procedure" (Jiao, You, & Kumar, 2006). Ulieru and Cobzaru (1999) argue that "agents are suitable for integrating supply chain functions because they can extend applications like production, distribution and inventory management functions across supply chains spanning various organisations without the need for additional interfaces, especially when a common infrastructure is used."

STATE-OF-THE-ART

MAS are still a new research area, not yet fully adopted by industry. As a result, the agent-based solutions for SCM to be found today are relatively limited. A simplistic approach would be to merely simulate the supply chain by substituting

Figure 3. Simplistic MAS modeling of a supply chain



each part of it by an agent, as in Figure 3. This solution increases the chain's performance, but it does not totally exploit the huge potential of agents and MAS.

Various Approaches

Negotiation and Cooperation

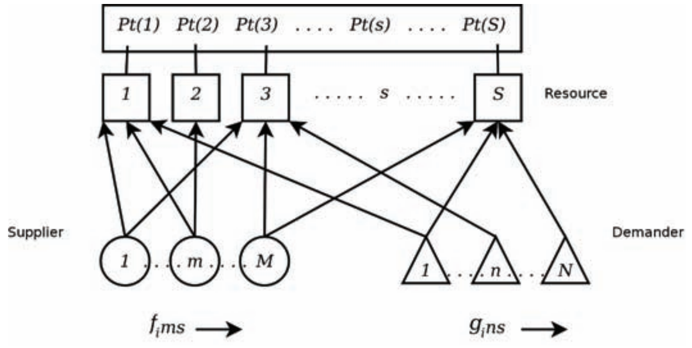
The most common approach on agent-based SCM is negotiation and cooperation. Many people, like Kaihara (2001, 2000), have discussed bidding mechanisms. One strategy (2001) is based on market-oriented programming, whose mechanism is shown in Figure 4. *Pt(S)* is the price of resource *s* at time *t*, while *ftms* and *gtns* represent the supply function of supplier *m* and the demand function of demander *n* on resource *s* at time *t*.

Agent activities in terms of products required and supplied are defined so as to reduce an agent's decision problem to evaluate the trade offs of acquiring different products in market-oriented programming. Kaihara defines several functions that formulate agents' strategy for the resource allocation in SCM, taking into account the budget constraints of each agent.

Kaihara (2000) discusses the advantages of double-auction mechanisms. He formulates supply chain as a discrete resource allocation problem with supply/demand agents and demonstrates the applicability of economic analysis. Finally, he introduces an agent-based double auction algorithm based on market mechanisms and demonstrates that it can provide several advantages on resource allocation.

Lou, Zhou, and Chen (2005) give a definition of *agile SCM* and discuss coordination mechanisms for both self-interested and cooperating agents. "The *agile supply chain* is an operational strategy focused on inducing velocity and flexibility in a supply chain" (p. 171). The two differences between an agile supply chain and a normal supply

Figure 4. The bidding mechanism proposed by Kaihara (Adapted from Kaihara, 2001)



chain are (a) speed, which is the ability to respond quickly to the changing of customers' requirements, and (b) flexibility, namely the ability of reconfiguring quickly according to changing. The coordination mechanism in ASCM is shown in Figure 5.

The main doctrine of the coordination mechanism for cooperating agents is "as decentralized as possible, as centralized as necessary", and the reasoning process is shown in Figure 6.

As shown in Figure 5, coordination for self-interested agents is done at two levels, namely strategic-level coordination and operational-level coordination.

Chan and Chan (2004) introduce a coordination framework for distributed supply chains by using the distributed constraints satisfaction problem (DSCP). They propose a coordination framework by adopting the DSCP philosophy for distributed supply chains, which are modeled by MAS, subjected to uncertainties. In their simulation, they demonstrate that the proposed mechanism outperforms traditional stochastic modeling.

Chan and Chan (2005) perform a comparative analysis of negotiation-based information sharing in agent-based supply chains. They model a distributed make-to-order (MTO) manufacturing supply chain as a MAS. In this case, information can only be exchanged through negotiation in the agent-based framework. In their simulation results, they show that partial information sharing has comparable performance in terms of total cost and fill rate against full information sharing based on negotiation. Considering the associated

Figure 5. Coordination mechanism in multi-agent based ASCM

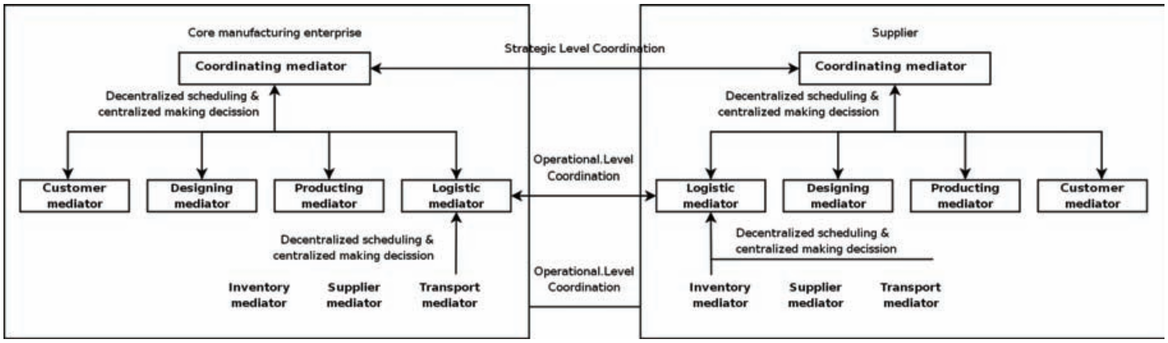


Figure 6. Reasoning process for cooperating agents

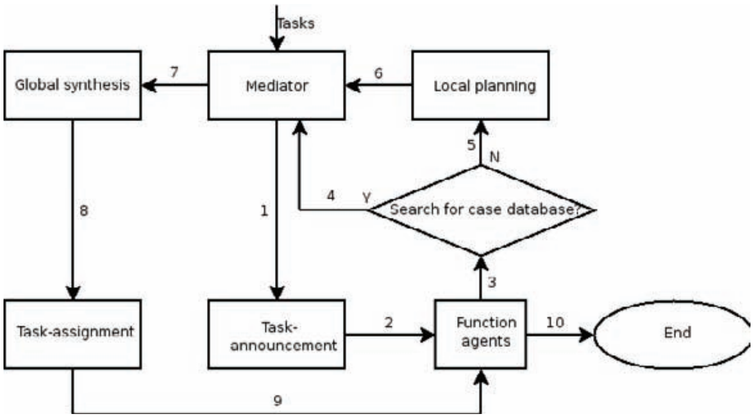
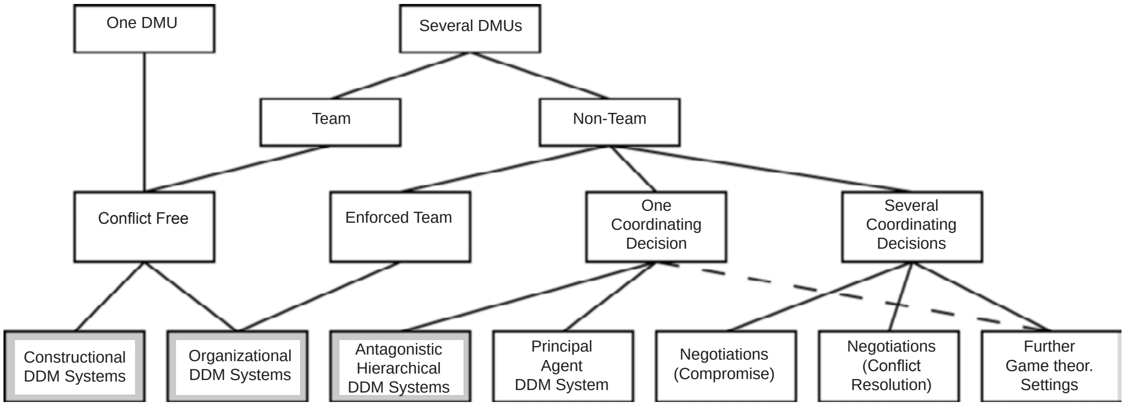


Figure 7. Classifications of DDM systems (Adapted from Schneeweiss, 2003)



cost and limitations to achieve full information sharing, they prove that partial information sharing is more practical in real applications.

Sauer and Appelrath (2003) present an approach using teams of cooperating agents in a hierarchical as well as heterarchical way. Traditional hierarchical implementations lack incorporation of feedback from lower levels and possibilities of reactive scheduling, so the authors use a hierarchical and heterarchical approach. To simplify the generation of such a hierarchy of agents, they develop and describe a framework for scheduling agents and they use an example to illustrate how it is used to build teams of cooperating agents.

Distributed Optimisation / Resource Allocation

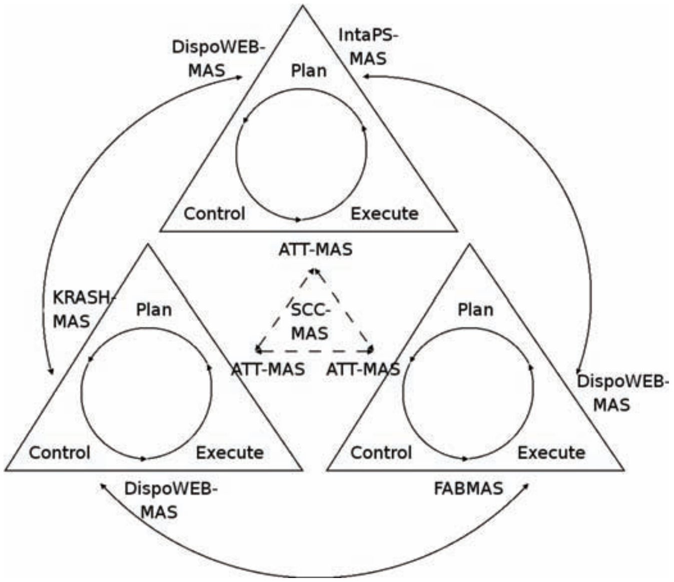
SCM is also often seen as a *distributed optimisation* and *resource allocation* problem. Schneeweiss (2003) describes a unified approach on distributed decision-making (DDM) by providing a general theoretical framework for it and characterizing the main directions or approaches in DDM in view of the general features of such a framework. He classifies DDM settings as shown in Figure 7 and discusses a general coordination scheme, showing how it might be specialized for particular DDM problems.

Silva, Sousa, Sa da Costa, and Runkler (2004) use ant colony optimization (ACO) for the supply chain. This algorithm builds a so-called “pheromone matrix”, an indirect record of the optimization steps, that is manipulated at all times during the optimization process. This concept is presented for a supply chain system with a logistic, a supplying and a distribution subsystem. After describing the general ACO framework, they implement the algorithm for each of the optimization problems and then they introduce the framework for the multi-agent platform, where the communication protocol is based on pheromone matrices updating.

Frey, Stockheim, Woelk, and Zimmermann (2003) discuss a MAS architecture based on production planning and control. They are integrating many individual projects: DISPOWEB for SCM scheduling, KRASH, IntaPS and FABMAS for shop floor production planning and control, and ATT/SCC for proactive tracking and tracing services. The integration is made by providing interfaces and gateways between these systems, as shown in Figure 8.

Smirnov, Sheremetov, Chilov, and Cortes (2004) use genetic algorithms (GA) for resource allocation. The proposed approach considers configuring as: (1) coalition formation and (2) product and resource allocation tasks in a multi-

Figure 8. Integration of the MAS projects by Frey et al. (2003)



agent environment. Their first approach uses GA to find a suboptimal solution applying the theory of games with fuzzy coalitions. Their second approach uses genetic algorithms directly and constraint satisfaction problem solving for resource allocation tasks. They use FIPA-compliant agents using ontologies for task description.

Moyaux, Chaib-draa, and D'Amours (2004) use game theory to analyze collaborative strategies in a forest supply chain. They use collaboration in an attempt to reduce the bullwhip effect, under the assumption that each company is one single agent using one of three ordering schemes, where each ordering scheme represents a level of collaboration. They run a simulation to evaluate each company's inventory holding and backorder costs and use the outcome of this simulation to build a game in the normal form, which is then analyzed using Game Theory. They identify two Nash equilibria incurring the minimum cost of the supply chain, both of which include collaboration between companies: collaborating companies have no incentive to stop collaboration.

Symeonidis, Kehagias, and Mitkas (2003) describe a multi-agent SCM system that acts mostly as a recommendation engine. It uses data mining techniques to discover new customer trends and dynamically incorporate the extracted knowledge into the company selling policy. Agents can be periodically retrained to improve their knowledge. In the paper, the architecture and development details of this system are presented and their application is demonstrated on a real test case.

Simulation of the SCM / Particular Assumptions

Another area of research is simulation of the SCM and/or particular frameworks. Web services, for example by Mi, Jianjun, Zunping, Yinsheng, and Binyu (2005) or by Hassan and Soh (2005), is a very commonly used technology. Mi et al. (2005) define a strategy for aggregating the agents, both normal and mobile agents, into the Web service architecture and the functionalities for them to control the business conducts. They also devise a UDDI ranking frame based on analysis of supply chain activities, deploying Web Service-oriented technologies and protocols for modeling, managing and executing business-oriented functionalities. Their framework is illustrated in Figure 9.

Figure 9. UDDI-based Web service framework

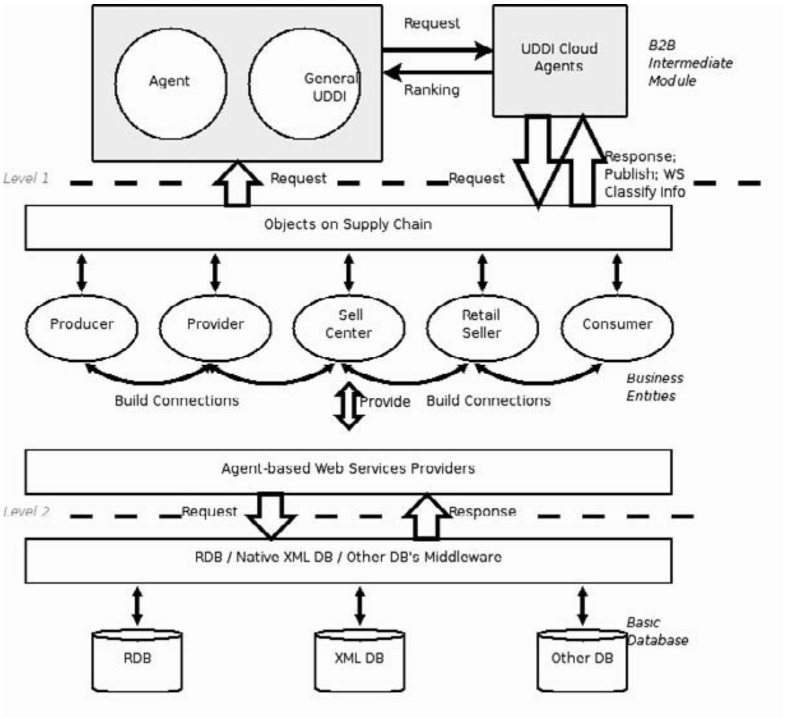
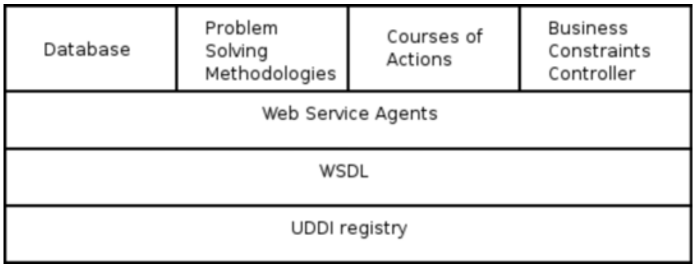


Figure 10. Structure of an agent as proposed by Hassan and Soh (2005)



Hassan and Soh (2005) propose an agent structure to provide more agility to the supply chain in an attempt to overcome its traditional problems. They focus on two aspects of SCM: removing inefficiencies in supply chains by real-time knowledge sharing and automated supply chain configuration by negotiating methods being used by agents. They argue that Web services are not only easier to implement, but also take care of the problems of legacy application connectivity. Figure 10 shows how an agent is structured and placed in the supply chain net.

Web services are also examined by Maximilien and Singh (2005). The authors present a multiagent framework for dynamic Web services selection. Based on their trust model (2005) and on their architecture for autonomic Web service selection (2003), they provide a basis that incorporates providers' offering advertisements and consumers' preferences, but also enables the gathering and sharing of ratings of services. Based on the requirement that "trust should be self-adjusting", their application uses a service agent, which selects the suitable implementation of a particular service, according to the customer's policy. Their results show that the agents' trust assignments are dynamically adjusted, enabling agents to select the best policies, according to consumers' needs.

Qing and Renchu (2001) provide a review of modeling methodologies and model a distribution system in a supply chain. They consider the following approaches to modeling supply chain systems: (a) simulation-based method, (b) network design method and (c) rough-cut method. However, these traditional models are based on mathematical and statistical tools and rely on the assumption of linearity, while many phenomena in a supply chain are of non-linear nature. They model a distribution system based on a MAS, with agents configured as manufacturer, distributor, transporter, retailer and customer interconnected through the network.

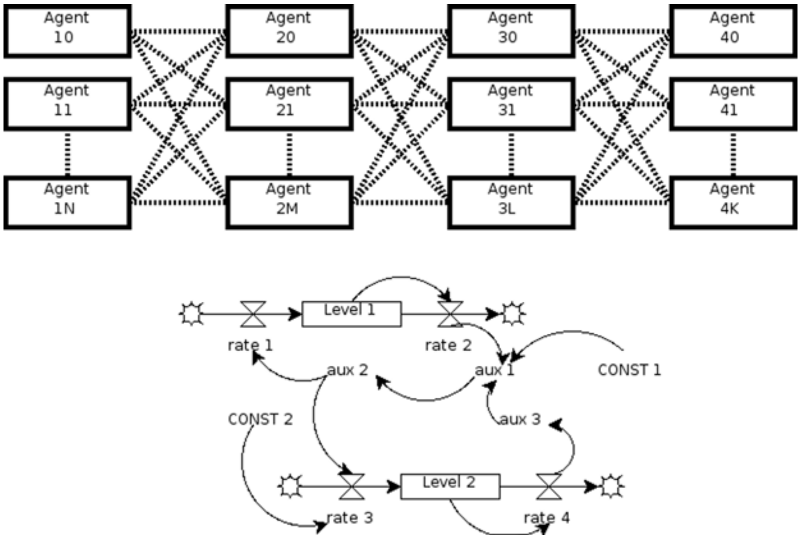
Schieritz and Groessler (2003) perform a study integrating agent-based and system dynamic modeling and make a distinction between the macro and micro level of a supply. Their approach discusses the strengths and weaknesses of system dynamics and discrete agent-based modeling and integrates these two methodologies. They model a supply chain with two levels of aggregation, as shown in Figure 11.

The macro level shows a network of agents that are potential supply chain participants, while the micro level shows the internal structure and functionality of each agent.

Giorgini, Kolp, and Mylopoulos (2006) propose architectural styles for MAS, which adopt concepts from organizational theories. They start by presenting organizational styles identified in Organization Theory and in Strategic Alliances. They detail the structure-in-5 and the joint venture as organizational structures and present four case studies, two for each structure. Each case study describes an existing company. They continue by presenting the software qualities that characterize MAS architectures and demonstrate the application of the two organizational styles they described using the classical mobile robot case study. They conclude by presenting a framework to select architectural styles with respect to their identified software quality attributes, based on a requirements-driven methodology.

Li and Feng (2003) propose a J2EE-based multi-agent platform, decomposing each function of the supply chain into groups of various agent

Figure 11. Macro and micro level of supply chain



types. In their platform, each group is formed by a scheduling agent which supervises several vertex agents. The enterprise's internal supply chain behavior is simulated by interaction among groups, while behaviors of different enterprises are coordinated by interaction among platforms. They think of their platform as "an effective tool for building the virtual organization of enterprises", designed to meet businesses' requirements for project information sharing, process integration and coordination of decisions.

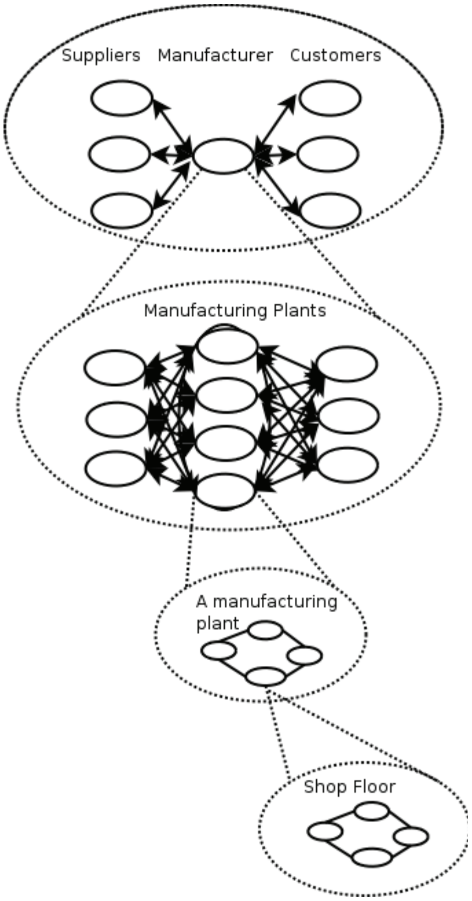
Nissen (2000) proposes a set of techniques and tools, aiming to integrate agent design for the supply chain into e-commerce. He models the enterprise supply chain process at user, supplier and contractor levels and designs the agents structure from above using Grafcets. Subsequently, he analyzes the supply chain of an operational enterprise and deploys a supply chain agent federation to demonstrate its effective performance along the supply chain. He states that his work facilitates the process of agent development, giving end users the potential to develop their own agents in an e-commerce context.

Goh and Gan (2005) construct a framework based on the requirement to enable dynamic interoperation of units within a supply chain. They argue that effective coordination of activities within the supply chain is inevitable for manufacturing excellence. To address this need, they identify the core requirement for activity coordination and construct a framework based on the requirement to enable dynamic interoperation of units within a supply chain for successful global manufacturing. Figure 12 illustrates their proposed framework.

Decision Making and Learning

Another approach on agent-based SCM is *decision making and learning.* Sheremetov and Rocha-Mier (2004) deal with collective intelligence as a framework for SCM. They consider a large multi-agent system where there is no centralized control and communication, but also, there is a global task to complete. Their proposed framework is focused on the interactions at local and global levels with the agents in order to improve the overall supply chain business process behavior. Learning consists of adapting the local behavior of each entity with the aim of optimizing a given global behavior. They use reinforcement learning algorithms at the local level and a Q-neural algorithm to optimize the global behavior. Their work demonstrates that the SCM problem is a good experimental field for the investigation and application of the Collective Intelligence theory.

Figure 12. The framework proposed by Goh and Gan (2005)



Guo and Mueller (2004) use knowledge models with historical and context information. Their approach is threefold: first, they develop a multi-agent architecture and learning algorithms that enable us to combine background models learned from history data with context-related knowledge about the current situation. Second, they use a large real data set to show that adding situated knowledge actually improves the performance of a supply chain decision support system. Third, for their settings they evaluate the degree to which agent-assisted decision support is actually usable/sufficient to improve human decision-making and to support automated decision-making in dynamic supply network management scenarios.

Simek, Albayrak, and Korth (2004) use reinforcement learning (RL) algorithms for procurement agents. They use the well-known Q learning algorithm of reinforcement learning in evaluating production orders within a SCM framework and making decisions. They introduce their SCM model and show that RL performs better than traditional tools for dynamic problem solving in daily business, but also show some cases where RL fails to perform efficiently.

Kwon, Im, and Lee (2005) use optimization and case-based reasoning (CBR) models on a Web services-based platform. They think that, despite the advancement of optimization techniques, this approach has not been fully extended to addressing more complicated problems such as revenue maximization and stochastic dimension. They compare the performance outcomes of the prototype system, which uses linear programming and mixed integer programming, with their optimization model shown in Figure 13 using a variety of scenarios.

Zhang and Xi (2005) discuss a decision support system for partner choice and measurement in a supply chain. Their study presents a perspective and technical framework based on decision support system and agents. This framework is shown in Figure 14. The model they propose exhibits basic characteristics of agents, that is, intelligence, flexibility, integration and collaboration, and it provides a technical support on partner choice decision and assessment.

Agent-Based SCM for Particular Supply Chains

Many researchers have modeled agent-based SCM systems for a particular supply chain, or under other particular assumptions. For example, Liu, Zhang, and Hu (2005) discuss a supply chain for a motorcycle corporation, Xue, Shen, and Wang (2005) present a framework for construction supply chains, and Yi, Kim, and Kim (2002) use a MAS simulation for a harbor supply chain.

Figure 13. MAS with CBR models on a web services-based platform

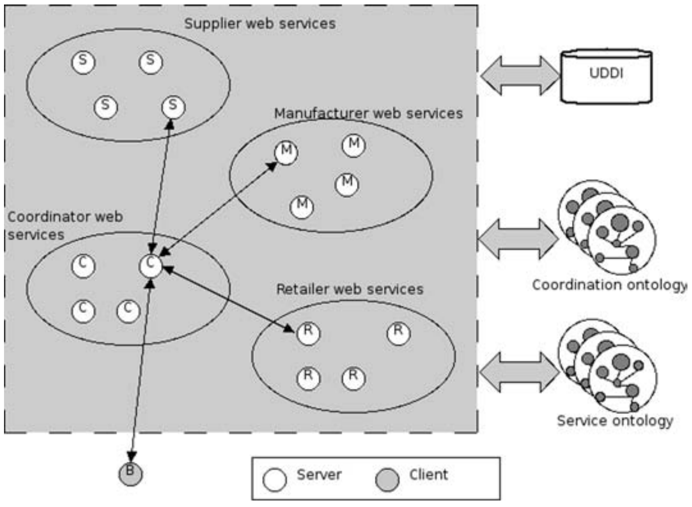
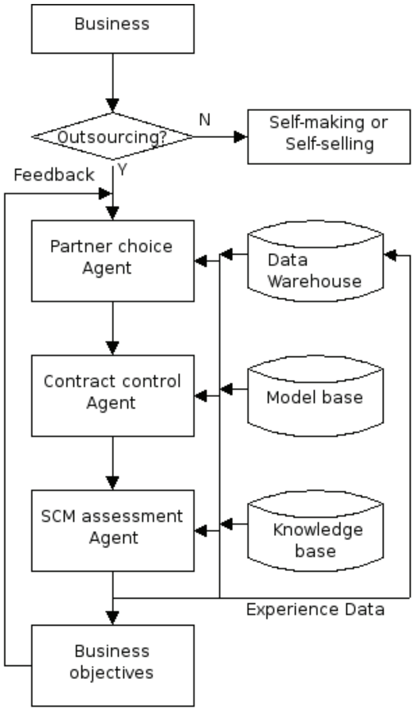


Figure 14. Decision support system for partner choice



It is also worth mentioning some different approaches on the view of the supply chain. For example, Mangina and Vlachos (2005) emphasize the role of sales and marketing on a food supply chain, modeling it as illustrated in Figure 15. Unfortunately, though sales and marketing is undoubtedly a very important factor in SCM, it usually seems to be ignored in most traditional and newer SCM models.

Shuwang, Ren, Zhifeng, and Guangfu (2003) introduce the concept of a green supply chain, aiming to reduce or eliminate environmental impacts of products in their life cycle by preventing excess consumption of resources. The green supply chain is shown in Figure 16.

Bonura, Corradini, Merelli, and Romiti (2004) emphasize quality control, an important aspect that again seems to be missing from most supply chain models in bibliography. More precisely, they define the extended supply chain, to take quality control into account, as shown in Figure 17.

Figure 15. A food supply chain according to Mangina and Vlachos (Adapted from Mangina & Vlachos, 2005)

Figure 16. The green supply chain

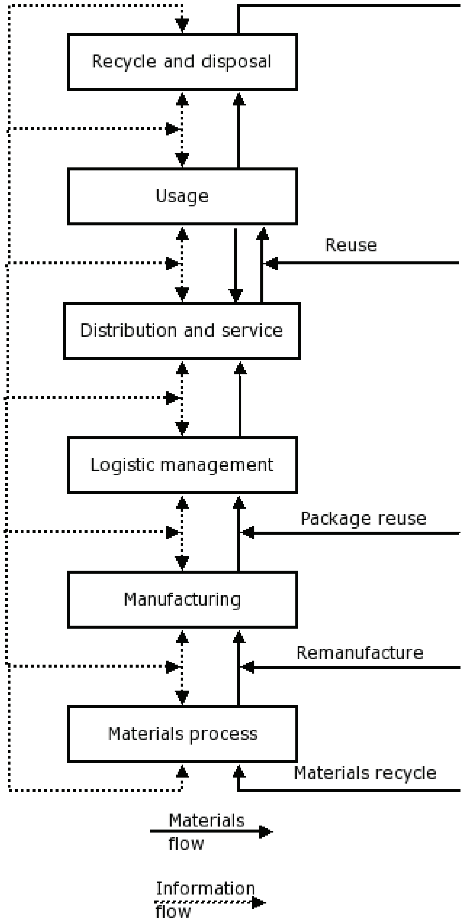
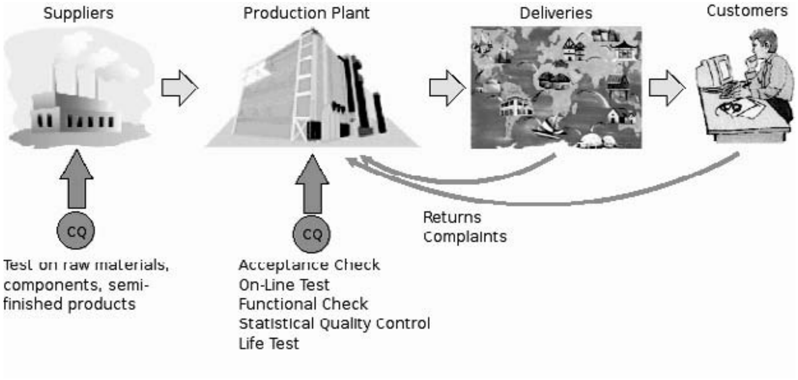


Figure 17. The extended supply chain



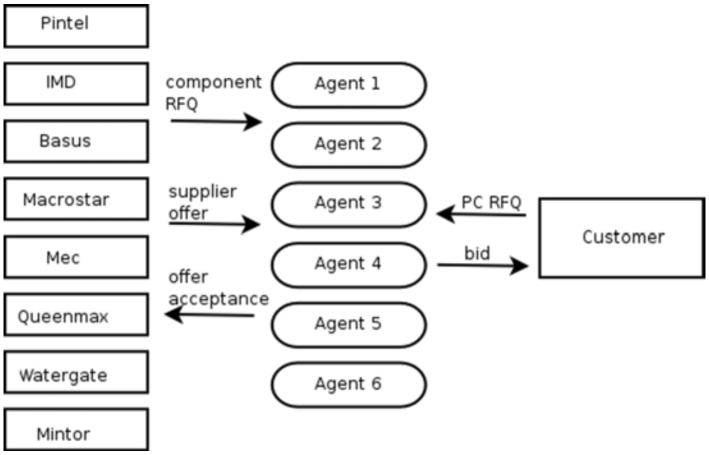
Failures in assembled products may be detected at many points of the product life, therefore an early diagnosis could depend on the retrieval of all significant information recorded along the extended supply chain. The basic idea proposed in this work is to define a society of Autonomous Agents created to support the traceability of components information in a federated enterprises environment.

Trading Agent Competition

Finally, the trading agent competition for SCM (SCM TAC) has given an important boost on SCM research. As described by Kiekintveld and Wellman (2005), in the TAC/SCM scenario, "six agents representing PC assemblers operate in a common market environment over a simulated year. The environment constitutes a supply chain, in that agents trade simultaneously in markets for supplies (PC components) and the market for finished PCs. Agents may assemble for sale 16 different models of PCs, defined by the compatible combinations of the four component types: CPU, motherboard, memory, and hard disk."

Figure 18 diagrams the basic configuration of the supply chain. The six agents (arrayed vertically in the middle of the figure) procure components from the eight suppliers on the left, and sell PCs to the entity representing customers, on the right. Trades at both levels are negotiated through a request-for-quote (RFQ) mechanism, which proceeds in three steps:

Figure 18. The TAC SCM game



- Buyer issues RFQs to one or more sellers
- Sellers respond to RFQs with offers
- Buyers accept or reject offers; an accepted offer becomes an order

Arunachalam and Sadeh (2004) provide a description of the 2003 SCM TAC, while Zhang and Zao (2004) discuss an economic model for it. They consider that the most important issues in the TAC SCM game are "daily production, product pricing and market-clearing price prediction" (p. 63), then differentiate the quantity competition (defined as a variation of Cournot model) and price competition (extension of Bertrand game). They argue "the results of their paper provide the solution to the decision-making problem of TAC SCM" (p.63).

Kiekintveld and Wellman (2005) analyze the 2004 SCM TAC, discussing differences in agents' behavior and strategic interactions, as well as the different ways that the agents responded, as these are the most important factors that shaped market prices and determining agents' classification in the competition.

Jordan, Kiekintveld, Miller, and Wellman (2006) compare the results of the 2005 competition to the games played in previous years by considering market efficiency, sales competition, and the bullwhip effect. They present a way to measure and compare market efficiency in the game to find "statistically significant increases in intra-tournament market efficiency, whereas agents are generally decreasing in manufacturer market power" (p. 99).

Borghetti, Sodomka, Gini, and Collins (2006) present a way to evaluate TAC SCM agents' performance, using benchmarking tools that manipulate market environments based on market pressure. They claim that these tools can be used to inspect agents' behavior and check for possibly unwanted behaviors under special conditions, and use them for their agent MinneTAC.

Of course, many publications have been made about specific TAC agents, for example MinneTAC by Gini, Ketter, Kryzhnyaya, Damer, McGillen, Agovic, and Collins (2004), Botticelli by Tschantz, Benisch, Greenwald, Grypari, Lederman, and Naroditskiy (2004), or TacTex05 by Pardoe, Stone and VanMiddlesworth (2006). Toulis, Kehagias, and Mitkas (2006) present their agent Mertacor, which participated in the 2005 TAC and finished third in the final round. This agent is based on "a combination of OR, statistic and heuristic modeling techniques" (p. 1198). Its main advantages are its robust inventory management system and flexible learning models that correctly captured the dynamics of the TAC market, while heuristics also played an important role.

Overall Problems

According to Goh and Gan (2005), the fundamental issue of a supply chain, namely "interoperation among suppliers, manufacturers and customers" (p. 330), is still not addressed. Smooth negotiation and coordination mechanisms, optimization to generate optimal solutions, developing adaptive systems and emphasizing on a real-time information sharing and updating are significant, but not sufficient to enable global manufacturing when the fundamental issue is not addressed.

Jiao et al. (2006) observe that "most current MAS approaches assume that a fixed number of entities share a common target in a closed environment" (p. 239). However, on a real-case global manufacturing supply chain, this is not always the case. Not only each supply chain entity has its own interests, but also there is no obligation for any company to remain within the supply chain for a certain period of time. Moreover, all agents should be loosely coupled and not coordinated by any central controller.

However, even after having considered the aforementioned problems, the huge potential of agents and MAS is still not exploited. Agents are powerful decision-making entities, capable of taking over complex tasks. On the other hand, when it comes to SCM, their usage is still mostly limited to recommendation rather than autonomous functionality.

Another area of research on SCM MAS can deal with evaluating and increasing the agents' intelligence. Very little research has been done on intelligence itself (Sheremetov & Rocha-Mier, 2004) and nobody has addressed the issue of possibly evaluating it, even in specific environments or benchmarks. The trading agent competition is a benchmark only for single agents. It evaluates their performance under very particular conditions, which are quite distinct from real-life situations. On the other hand, SCM requires intelligent solutions, as it deals with critical and complex problems.

The supply chain can be so sensitive that even very small deviations or fluctuations on one part can badly influence, not only this particular part, but also the whole chain. Current solutions have limited capability to learn from their past (especially in an unsupervised way), which is essential in an efficient MAS. Apart from this, efficiency is usually evaluated in terms of increased profit, which might be the desired result and an easily measurable quantity, but it is a rather short sighted approach and can only relate to the structure and the essence of the MAS by experimenting or trial-and-error. The real problem, however, is the agents' intelligence itself, as well as the intelligence of the whole MAS. This issue is usually not faced and the MAS intelligence, or even its performance, is hardly evaluated in depth. As a result, one can easily see the need for research on this topic.

CONCLUSION

Current trends in SCM demand customization, high quality, flexibility and customer-service policies in a highly competitive environment. This has emphasized the need for more flexible, reliable and powerful SCM systems. Agent-based technology, with its inherent capabilities for distributed problem solving, flexibility and handling large amounts of data, provide an ideal solution to this problem. However, this technology is still a large area of research, which shows the lack of not only a commonly deployed system, but also of a unified approach on this area.

The most important areas of research today are negotiation and cooperation, distributed optimization and resource allocation, decision making and learning, as well as particular frameworks and simulation. Many researchers have modeled SCM systems based on a particular supply chain or suggested enhancements to the supply chain, such as the green supply chain or, more commonly, the agile supply chain.

However, most SCM products today are designed to be used in only one company, and they are designed for recommendation rather than making their own decisions. On the other hand, no evaluation is made on the agents' performance and intelligence. This indicates a large potential for future research on this area, promising fruitful results.

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Chapter 3.3

Application of Agent-Base Technology as Coordination and Cooperation in the Supply Chain Based E-Business

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ABSTRACT

This chapter explores the utilization of a multi-agent system in the field of supply chain management for electronic business. It investigates the coordination and cooperation processes, and proposes and discusses a newly developed model for an enhanced and effective cooperation process for e-business. The contribution made by this research provides a theoretical solution and model for agents that adopt the enhanced strategy for e-business. Both large organizations and SMEs will benefit by increasing and expanding their businesses globally, and by participating and sharing with business partners to achieve common goals. As a consequence, the organizations involved will each earn more profit.

INTRODUCTION

Today's Internet-connected world has created an enormous revolution among business organizations. Nowadays, running a global business electronically is one of the most important emerging issues. Many researchers and software developers have been investigating and developing software tools and mechanisms that allow others to build distributed systems with greater ease and reliability for conducting e-business. When a computer system acts on our behalf, it needs to interact with another computer system that represents the interests of another party, and these interests are generally not the same. In this context, Wooldridge (2002) specifies:

> *It becomes necessary to endow such systems with the ability to cooperate and reach agreements with the other systems, in much the same way that we cooperate and reach agreements with others in everyday life. This type of capability was not studied in computer science until very recently.* (p. 3)

Traditional purchasing and selling for business-to-business (B2B) and business-to-consumer (B2C) have been conducted through different complex processes involving negotiation, as well as cooperation and coordination. It was quickly realized that e-commerce represents a natural, and potentially very lucrative, application domain for multi-agent systems. Artificial intelligence (AI) has been largely focused on the issues of intelligence in individuals, but surely a large part of what makes us unique as a species is our social ability. Not only can we communicate with one another in high-level languages, we can cooperate, coordinate, and negotiate with one another. As many species have a strong social ability (e.g., birds) like this, we also need cooperation and coordination in multi-agent systems to conduct fruitful, successful, and sustainable e-business.

It has been found that cooperation and coordination are important issues in conducting e-business. In recent years, there have been many research studies in e-business negotiation, but there is little work in e-business negotiation through cooperation and coordination. For example, large organizations mostly have enough products to sell. On the other hand, small and medium enterprises (SMEs) that are suffering from a lack of capital cannot compete with large organizations. However, some SMEs want to purchase products from large organizations and sell them to their customers. Another example is supply chain management (SCM) where at each and every stage (for instance, procurement of material, transformation of material to intermediate and finished goods, and distribution of finished products to customers) cooperation and coordination are needed. In these cases, they can cooperate with each other by exchanging products, and a deal between them can be made because both participants are able to "fine-tune" their profit. That means they can work together to achieve particular goals.

Therefore, if we can perform this type of activity electronically, it will be easier and faster, and, at the same time, very complex issues can be avoided. To perform these activities electronically using a cooperation and coordination process, models need to be investigated for performing flexible and reliable tasks. Many different disciplines including sociology, political science, computer science, management science, economics, psychology, and system theory are dealing with fundamental questions about coordination in one way or another. Furthermore, several previous writers have suggested that theories about coordination are likely to be important for designing cooperative work tools (Finnie, Berker, & Sun, 2004; Holt, 1988; Winogard & Flores, 1986). Therefore, it is possible to develop computer-supported cooperative work with the prospect of drawing on a much richer body of existing and future work in the application of multi-agents in supply chain based e-business.

The main objective of this chapter is to explore the operation of a multi-agent system in supply chain management for electronic business. It focuses on the coordination and cooperation processes, and discusses a newly developed model for an enhanced and effective cooperation process for e-business. The main contribution of this research is a theoretical solution and the model for agents that adopt this strategy for their e-business transactions. Both large organizations and SMEs will benefit, as the strategy will enhance their global business by participating and sharing with other businesses to achieve common goals. As a consequence, the organizations involved will be more profitable and competitive.

The chapter is organized as follows: first, factors in conducting e-business are discussed.

Then agent-based technology is outlined as a multi-agent system that is necessary for a supply chain system. A definition/theory of coordination is introduced, and some related work on coordination and cooperation is reviewed. The next section discusses cooperative problem-solving processes. Then a theoretical model and architecture on coordination and cooperation is explained in the context of trading agent competition supply chain management (TAC/SCM). The concluding section provides an overview of the chapter.

FACTORS IN CONDUCTING E-BUSINESS

The following factors have been identified in conducting e-business:

General Problems

- **Finances:** It has been found that some SMEs do not have enough resources to conduct e-business; however, they are particularly interested in being involved. Therefore, large organizations and SMEs have a good opportunity to work together to conduct global e-business.
- **Price war:** When a buyer seeks goods through an Internet catalogue, for various reasons, the price of some products are too cheap, while others are too expensive. As a result, customers feel a level of confusion about making the right decision.
- **Postpurchase/local customer service:** It has also been found that if somebody buys goods from the Internet, the company may not have a local retailer in that city. In this case, if any problem is found with the goods, postpurchase/local customer service becomes a complex issue to solve. As a result, some customers are not interested in buying goods from the Internet. Therefore, currently, local retailers need to stock similar goods. Moreover, to conduct e-business globally, many retailers need to participate. For that reason, cooperation is required for transactions with large organizations and with SMEs.
- **Lack of a pricing strategy:** In the real world, a pricing strategy is an important issue. To develop an effective pricing strategy, sometimes an incentive like a discount is needed. This is possible when a manager thinks its time to give a discount via a special promotion or to clear old stock. It is also possible to implement a pricing strategy in the online world.
- **Lack of customer satisfaction:** From the above points, customers can feel dissatisfied.

Problems in Supply Chain Management

- **Lack of information sharing:** Information sharing is one of the most significant issues in SCM and plays an important role. As for example, a retailer such as K-Mart may place huge orders for a particular product for their planned promotion. If suppliers had prior knowledge of this promotion, they also could plan for a production increase.
- **Lack of information access limitation and lack of transparency:** At times, users are unable to find an exact outcome due to restricted access to some information. This results in a lack of transparency. As a result, it obstructs making the right decision within the right time frame.
- **Lack of sharing the benefits of coordination equitably:** The coordination benefits are not being shared equitably in the supply chain, which is a challenge (Chopra & Meindl, 2003, p. 503). Consequently, if agents agree to work together, the problem can be resolve accordingly.

- **Lack of agreement to work together:** Agreements are not generally found in real-world SCM. This is due to one stage of the supply chain having objectives that conflict with other stages that generally have different owners. For this reason, the main objective of each owner is to maximize its own profit. As a result, this diminishes the overall supply chain profit. Today, the supply chain is comprised of potentially hundreds or even thousands of independently owned enterprises. For instance, Ford Motor Company has thousands of suppliers from Goodyear to Motorola. To make an overall profit for the supply chain, the partners need to reach an agreement for working together. This can lead to the overall profit being maximized. Therefore, each participant in the cooperative venture will benefit accordingly.
- **Lack of communication among business organizations/supply chains (level of product availability):** Good communication can yield good results. Companies in the supply chain often do not communicate through the various stages of the supply chain and are unwilling to share information. As a result, companies become frustrated with the lack of coordination.
- **Timely manner:** Sometimes, some information is not accessible in a timely manner. Therefore, this can obstruct the right decision being made in a timely fashion.
- **Lack of use of technology to improve connectivity in the supply chain.**
- **Lack of trust:** Because of the above obstacles, trust is decreased and frustration appears at various stages of the supply chain, making coordination efforts much more difficult. On the other hand, high levels of trust involve the belief that each stage is interested in the other's welfare and would not take actions without considering the impact on the other stages.

If the organizations work together electronically towards some shared common goal, then there is a possibility that the problems defined above can be fully or partially overcome.

Benefits of Conducting E-Business

The following are the expected benefits in conducting e-business when organizations work together:

- **Reasonable and flexible price:** If different organizations work together, they will be able to sell goods at a reasonable and leveled price. An e-business can easily alter the price of the products in one entry of the database, which is linked to its Web site. According to current inventories and demand, this type of ability allows an e-business to increase revenues by adjusting prices. Airline tickets are a good example where low-cost available tickets are shown on a Web site for flights with unsold seats. This can reduce the price war between competitors.
- **Reliable product:** By working together, it is also possible to sell reliable products to customers.
- **Globally available and less transportation cost:** Because organizations can work together globally, then the goods can also be available globally. For example, a customer in Thailand can place an order on the Internet. If there is a warehouse situated in Thailand for that item, then it is easier to get the item; otherwise the seller would need to ship the item. In the case of limited stock, it might not be profitable to have an item available globally when there are high transportation costs. Consequently, by globally working together, organizations can earn more profit and lower transportation costs.
- **Reduce operational cost:** Operating costs can also be decreased if a manufacturer is using e-business to sell directly to customers,

as there are fewer supply chain stages for the product as it makes its way to a customer.

- **Reduce delivery time:** If a warehouse exists locally, then this will also lower the delivery time, in addition to delivery costs.
- **Enhanced customer service locally:** If a problem arises for the product, then it can be serviced locally. As a result, a customer will feel more confident in buying further products.
- **Fewer inventories:** E-business can reduce inventory levels and costs by improving supply chain coordination and creating a better match between supply and demand. For example, Amazon.com requires fewer inventories than local retail bookshops. As a result, e-business reduces inventory cost.
- **24-hour access from any location:** Customers are able to place their order any time day or night and from any location through the Internet. Therefore, it is possible for an organization to increase sales.
- **Maximum profit:** All of the above points have the potential to maximize profit for organizations.
- **Expansion of business:** By working together, large organizations have the opportunity to expand their business with the cooperation of SMEs. Thus, SMEs also have the opportunity to share tasks with large organizations. Ultimately, through collaboration, organizations can collectively increase their profits.
- **Duplication of work:** Reducing the duplication of work can save both time and money. For example, a pricing strategy for a product can be negotiated electronically, and then can be used for the collaborating organizations.

In summary, factors in conducting e-business can be categorized as general problems associated with the operation of the organization (finances, pricing strategy, and customer service), and more specific problems in managing the supply chain (lack of information sharing and access, and lack of agreement to work together). To examine the supply chain further in an electronic context, the use of agent-based technology is investigated.

AGENT-BASED TECHNOLOGY

Agent-based technology has emerged as the preferred technology for enabling flexible and dynamic coordination of spatially distributed entities in a supply chain. Authors have defined agents from different perspectives. The main focus of this chapter is a discussion of software intelligent agents, and the definition presented is adapted and based on Wooldridge and Jennings (1995). An agent is a computer system that is situated in a particular environment, and is capable of *flexible autonomous actions* in that environment in order to meet its design objectives. Autonomy is a complicated concept, but it can be simply explained that the system should be able to perform without the direct intervention of humans (or other agents). At the same time, it should have control over its own actions and internal state. The meaning of *flexible actions* is that the system must be:

- **Responsive:** Agents should be able to perceive their environment, which may include the physical world, a user, a set of agents, or the Internet and can respond timely according to changes that occur in it.
- **Proactive:** Agents cannot only perform based on their environment, but should also be able to exhibit opportunistic, goal-oriented behavior by taking the *initiative* according to their intention.
- **Social:** Agents should be able to interact with one another as humans do, based on their own problem solving ability to help others with their activities, as required.

Therefore, if the above characteristics exist in a single software entity, then we can consider it is an intelligent agent that provides the capability of the agent paradigm. This paradigm is different from the software paradigm, for instance, object-oriented systems, distributed systems, and expert systems.

Multi-Agent Systems

By using agent-based systems, the key abstraction used is that of an agent. It might be conceptualized in terms of an agent, but implemented without any software structures corresponding to agents at all. A situation exists with an agent-based system, which is designed and implemented in terms of agents. Again, a collection of software tools exist that allow a user to implement software systems as agents, and as societies of cooperating agents.

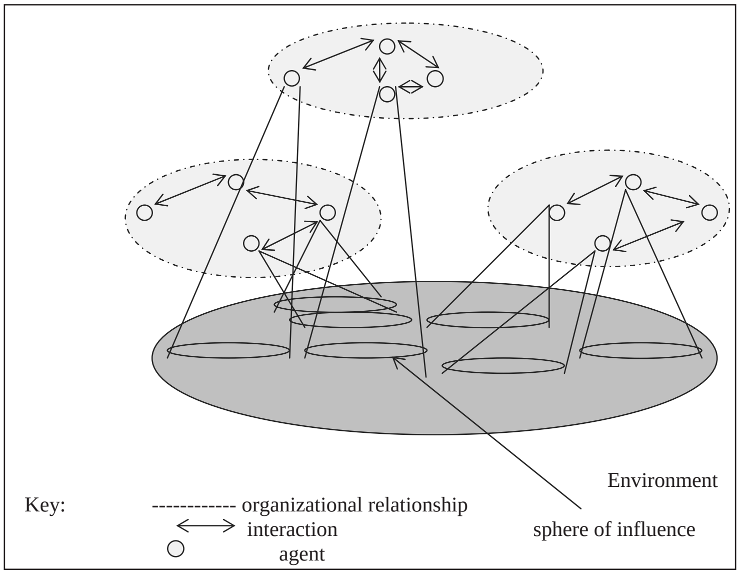
There is no such thing as a single agent system. Therefore, we should always consider the system of agents as a multi-agent system, where the agents will need to interact with each other and cooperate as required. Jennings (2000) illustrates the typical structure of a multi-agent system (see Figure 1). The system consists of a collection of agents that are able to interact with each other by communication. The agents perform their activities in the environment and different agents have different "spheres of influence," and have control over, or at least are able to, influence different parts of the environment. In some cases, the spheres of influence may coincide or may require dependency relationships between the agents. For instance, two robotic agents have the ability to move through the door, but they may not be able to move simultaneously. Another example might be "power" relationships, where one agent is the "boss" of another agent.

Dependency Relations in Multi-Agent Systems

In multi-agent systems, the agents need to be dependent in some way to be able to perform their tasks. The basic idea of such dependency was identified by Sichman and Demazeau (1995) and Sichman (1994) and there are a number of possible dependency relations:

- **Independence:** In this case, no dependency exists between the agents.

Figure 1. Typical structure of a multi-agent system (Jennings, 2000)



- **Unilateral:** This type includes one agent depending on the other agent, but not vice versa.
- **Mutual:** Both agents depend on each other according to the same goal.
- **Reciprocal:** The first agent depends on the other for a goal, while the second agent depends on the first agent for another goal. These two goals may not be same, and mutual dependency implies reciprocal dependence.

The above dependency relations may also be qualified by whether or not they are *locally believed* or *mutually believed*. The locally believed dependency is when the agent believes the dependency exists, but may not believe that the other agent is aware of it. The mutual belief is when one agent believes that the dependency exists and the other agent is aware that this dependency exists.

The suppliers, manufacturers, retailers, and consumers are all in a supply chain related network, which needs proper, efficient, and timely coordination, cooperation, and negotiation. Therefore, overall benefits will be achieved when applying multi-agent systems to improve efficient performance among these entities.

In summary, the use of a multi-agent system has emerged as a flexible and dynamic method for coordination of spatially distributed entities in a supply chain. Efficient performance is possible between business partners in an online environment through coordination and cooperation.

DEFINITION/THEORY OF COORDINATION

We all have a common understanding about coordination and cooperation from our everyday lives. At times, we need to coordinate and cooperate with others for a variety of reasons. When we watch a winning soccer or cricket team or high-quality synchronized swimming, we notice how well the program is organized. In contrast, we could spend hours waiting to return something, or when we thought we had booked an airline ticket that had already been sold, or when a company repeatedly fails to make its expected profit, then we may become very aware of the effects of poor coordination. The dictionary definition of coordination is: *the act of working together harmoniously*. It is essential that an intention to work together "harmoniously" includes handling conflict as well as cooperation.

Malone and Crowston (1990) specified that computer science does not deal primarily with people; however different computational processes must certainly "work together harmoniously," and as numerous researchers have pointed out, certain kinds of interactions among computational processes resemble interactions among people (e.g., Fox, 1981; Hewitt, 1986; Huberman, 1988; Miller & Drexler, 1988; Smith & Davis, 1981). Malone and Crowston's (1990) observation is not completely correct, due to the fact that software developers implement computational processes according to user requirements. Therefore, it is possible to develop software agents, which will perform coordination tasks for human beings in order to facilitate e-business.

Literature Review: Cooperation and Coordination

Finnie, Berker, and Sun (2004) proposed a multi-agent architecture for cooperation and negotiation in supply networks (MCNSN), which incorporated a learning capability for some agents, and discusses the issues that need to be addressed for coordination, cooperation, and negotiation. They mainly concentrate on case-based reasoning (CBR) as a framework for learning the best strategy between buyers and suppliers and also focus on customer relationship management (CRM). They did not concentrate on business-to-business (B2B) cooperation and coordination.

Beck and Fox (1994) developed the mediated approach to coordinate the supply chain, which has a global perspective and gathers information on commitments from other agents when there is an event disrupting supply. They conducted an experiment, which showed that the mediated approach has a better performance than the negotiation approach. Although the multi-agent approach in SCM has received considerable attention, a number of unresolved questions remain in cooperation and negotiation in supply networks (Schneider & Perry, 2006). A multi-agent system (MAS) was considered by Finnie and Sun (2003) in such a way that only some agents had the CBR capability.

Several reasons have been identified for multiple-agent coordination (Jennings, 1990; Nwana, 1994):

- **Dependencies between agents' actions:** Interdependencies occur when goals undertaken by individual agents are related, either because local decisions made by one agent have an impact on the decisions of other community members (selling a commodity depends on a salesperson for customer service and customers), or because there is a possibility of a clash among the agents (two cars may simultaneously attempt to pass on a narrow road, resulting in the risk of a collision). Ultimately, dependencies prevent anarchy or chaos and coordination is necessary among the agents to achieve common goals.
- **Meeting global constraints:** Commonly, some global constraints exist that a group of agents must satisfy if they agree to participate. For instance, a system of agents allocating components to organizations may have constraints of a predefined budget. Similarly, if one organization fails to sell their products for some reasons, then other organizations can coordinate to minimize the problem.
- **Distributed expertise, resources or information:** All agents may not have the same capability, but have different resources and specialized knowledge in various areas. For example, treating a patient in the hospital requires different expertise (anaesthetists, surgeon, heart specialist, neurologist, ambulance personnel, nurse, and so on), resources (equipment like an x-ray machine and ultra sound machine) and information (different reports) to diagnose the patient. In this type of case, it is not possible to work individually. Therefore coordination and cooperation are both necessary to solve the entire problem.
- **Efficiency:** When an individual agent works independently, time can be a factor. If another agent helps to finish that work, then it can be completed twice as fast. For instance, if two people plant 50 seedlings each, then 50% of the time is saved.

Nwana, Lee, and Jennings (1996) specified that coordination may require cooperation, but it would not necessarily need cooperation among all agents in order to get coordination. This could result in disjointed behavior, because for agents to cooperate successfully, they must maintain models of each other as well as develop and maintain models of future interactions. If an agent thinks that other agents are not functioning correctly, then disjointed behavior may still give a good result. Coordination may be completed without cooperation. For example, if somebody drives very close towards your lane, you might get out of the path, which coordinates your actions with the other person, without actually cooperating. To facilitate coordination, agents need to cooperate with others by sending communication messages. This results in agents having the opportunity to know the goals, intentions, outcomes, and states of other agents.

In summary, coordination and cooperation are practiced daily in physical world transactions, and the notion of creating a similar environment in the virtual world is not a trivial problem. Electronic cooperative problem solving using a multi-agent system is a complex challenge to address.

COOPERATIVE PROBLEM SOLVING

In the context of cooperation in multi-agent systems, Franklin and Graesser (1997) offer a cooperation typology (see Figure 2) with a number of characteristics. If each agent pursues its own agenda independently of the others, then it is termed an independent multi-agent system. There are two types of independent multi-agent systems: (a) discrete and (b) emergent cooperation. The discrete system involves agents with agendas that do not have any relation to each other. Therefore, discrete systems do not have any cooperation. Becker, Holland, and Deneubourg (1994) specified that the puck gathering robots form an independent system, each moving in a straight line until an obstacle is encountered according to its agenda, it then backs up and goes in another direction. From an observer's point of view, this puck gathering is an emergent behavior of the system, as it looks like the agents are working together. However, from the agents' point of view, they are not working together. The agents only carry out their individual tasks.

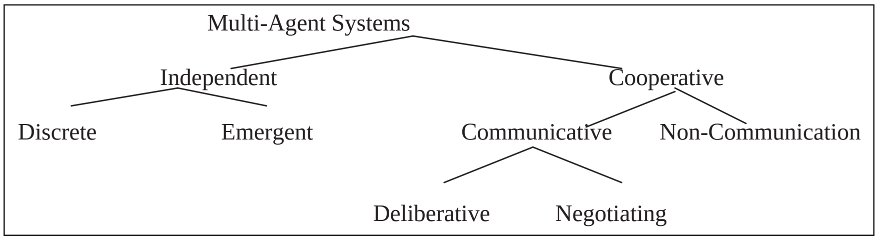
On the other side of the independent system is the agent who is cooperating to its own agenda with other agents in the system (*cooperative systems*). This type of cooperation can be either communicative or noncommunicative. Communicative systems intentionally communicate with the other agents by sending and receiving messages or signals. The noncommunicative systems are those in which the agents coordinate their cooperative activity by observing and reacting to the behavior of the other agents, for example, lionesses on a hunt (Franklin, 1996). Intentional communicative systems are divided into two categories: (a) *deliberative*, where agents jointly plan their actions to achieve a particular goal; and such cooperation may, or may not entail coordination; and (b) *negotiating*, where agents act like deliberative systems, except that they have added challenge of competition.

Doran and Palmer (1995) offer a viewpoint that specifies cooperation as a property of the actions of the agents involved. Thus, given a multiple-agent system in which the individuals and the various subgroups therein may be assigned one or more goals, possibly implicitly, then cooperation occurs when the actions of each agent satisfies either or both of the following conditions:

1. Agents have an implicit common goal (cannot be achieved in isolation) and actions tend towards that goal.
2. Agents carry out actions that enable or achieve their own goals, and also the goals of the other agents.

This definition does not require that the goals be explicit within the agents. For instance, two robots carrying a large object jointly, which is an example of the definition of the variant (1) assume that both have the goal of the moving object. If

Figure 2. Cooperation typology (Adapted from Franklin & Graesser, 1997)



two robots are building two towers separately with different colored bricks, then if one of the robots finds colored bricks that match the other robot, it passes them to the other robot, which is an example of the variant (2). Therefore, agent developers need to know the more specific tasks and choices of actions to cooperate and achieve the intended goal.

The Cooperative Problem Solving Process

Wooldridge and Jennings (1999) developed a model that consists of four main stages:

a. **Recognition:** Where an agent is identified for potential cooperation.
b. **Team formation:** Where the agent applies for assistance.
c. **Plan formation:** Where the newly-formed collective agents attempt to prepare a joint contract.
d. **Execution:** When members of the team play out the roles they have negotiated.

Some questions arise in regard to the above stages:

1. Are the agents performing their task properly?
2. Has an agent left or decommitted in the middle of its task?
3. If it has, then who will complete that task?
4. Who will coordinate these tasks?

Gaps in the cooperation process have been recognized, and this research has identified that two more stages are necessary. The additional stages consist of *monitoring* and *post-execution evaluation* to support the completion of the cooperation activity. The monitoring stage will provide progress reports of the agents' tasks, and the evaluation stage will generate the overall result of the cooperative work. These six stages, four identified by Wooldridge and Jennings (1999) and two identified by this research, are discussed in the following section.

Recognition Stage

This stage commences when an agent in a multi-agent environment realizes that it has a common goal, and identifies the potential for cooperative action. Reasons for recognition include when an agent thinks that it is not able to complete the goal in isolation, or believes that cooperative actions can achieve that goal. For example, a supplier agent has excess goods in stock, but cannot sell these without the help of proper buyers. Therefore, cooperation is needed to achieve the goal. Alternatively, a large company may be able to achieve its goal but does not want to in isolation. This large company believes that if another company works with it, then it would be more beneficial. For example, a small company does not have enough capital to do business properly and a large company does, and wants to expand its business globally. This large company is looking for another company so that it can achieve its goal. Therefore, if the small company and large company work together, then the cooperative actions can provide good results for both companies more quickly and more accurately.

In regard to the above situation, the authors categorize the agents in the following manner:

Definition 1. Types of the agents

a. **Able agent:** Those agents that prefer to work with the group.
b. **Unable agent:** Any agent that does not prefer to work with a group.
c. **Partially able agent:** Those agents that prefer to cooperate and commence to do work, but cannot complete the task.

If an agent has the ability to do the task in the environment, then it is favorable to complete the task.

Theorem 1. An Able agent finishes its task if and only if the environment (*En*) is favorable, which can expressed from the definition as:

$Able_{ag}\ Favourable\ En \rightarrow \text{Achieve goal}$

Proof. Assume that an agent is going to do its task, which is possible if its surrounding environment is favorable to complete its task. On the other hand, because this agent has the ability to complete its task, it can complete it successfully. In the case of an Unable agent, we can introduce the following theorem:

Theorem 2. An Unable agent cannot finish its task even if its environment (*En*) is favorable, which can be expressed:

$Unable_{ag}\ Favourable\ En \rightarrow \neg\text{Achieve goal}$

In regard to cooperation, a set of able agents will complete their task.

Theorem 3. A set of able agents finish its tasks if and only if the environment (*En*) is favorable, which can be formalized as:

$Able\ ag_i\ Favourable\ En \rightarrow\ \text{Achieve goal}$

Theorem 4. A set of able agents cannot finish their tasks although the environment (*En*) is favorable can formalized as:

$Unable\ ag_i\ Favourable\ En \rightarrow \neg\text{Achieve goal}$

Therefore, it has been identified that agents are able and unable to have the potential for cooperative work. Then, it needs to go to the next stage of the cooperation process.

Team Formation Stage

After an agent identifies the potential for cooperative action with respect to one of its goal, what will the rational agent do? Wooldridge and Jennings (1999) proposed that an agent will attempt to *solicit assistance* from a group of agents that it believes can achieve the goal. If the agents are successful, then each member has a nominal commitment to collective action to achieve the goal. The agents have not undertaken any joint action in this stage; they are only aware of being able to act together. Actually, in this stage, there is no guarantee for successful forming of the team, only an attempt to form a team. The able agents will attempt to do some action α to achieve at least some goal. Therefore, it can be formalized as:

Theorem 5. $\text{Happens}\{\text{Attempt}\ Able\ ag_i\ \alpha\} \rightarrow$ Achieve goal

The characteristics of the team building can assume that it is mutually believed that:

1. The group can jointly achieve the goal.
2. Each agent in the group is individually committed to carry out its task towards the goal or failing that, to at least cause the group to achieve the goal.
3. The individual agent has an individual goal.
4. There is a common goal which is jointly achievable.

The main assumption about team formation is that all agents attempt to form a group, and the group believes that they will have individual commitments and can jointly complete their task. If team building is successful, then it will proceed to the next step.

Plan Formation Stage

In this stage, after successfully attempting to solicit assistance, a group of agents have nominal commitment to collective action. This action will not be commenced until the group agrees on what they will actually do.

From the previous section, the authors have found that to perform collective action, it is assumed that the agents have a common belief that they can achieve their desired goal. The agents believe that there is at least one action known to the group, which will take them "closer" to the goal. Therefore, the possibility is many agents that know the actions of the group carry out the task in order to take them closer to the goal. In addition, in some cases, it is also possible in collective actions that some agents may not agree with one or more of these actions. Furthermore, in collective actions, agents will not simply perform an action because another agent wants them to (Wooldridge & Jennings, 1995). Therefore, it is necessary for the collective to make some agreement about what exactly needs to be done. This agreement is reached via *negotiation*.

Negotiation has long been recognized as a process of some multi-agent systems (Rosenschein & Zlotkin, 1994; Sycara, 1989). At the time of negotiation, the agents usually make reasoning arguments for and against particular courses of action, making proposals, counter proposals, suggesting modifications or amendments to plans. These continue until all the negotiators have agreed upon the final result. Negotiation is also an extremely complex issue. But in the case of joint negotiation, it is a bit simpler than self-interested individual agents.

In negotiating a plan, collective negotiation may also abort due to irrelevant circumstances. The minimum requirement to occur for negotiation is that *at least one* agent will propose a course of action, which is believed will take the collective closer to the goal. Therefore, negotiation may also be successful. Like team formation, we assume a group of agents also attempts to do something collectively. A group of agents g attempts to achieve a goal after performing mutual actions α which is completely or partially satisfied and can be formalized as:

$$\{\text{Attempt } g\ \alpha\} \rightarrow ?;\ \text{Achieve goal}$$

The minimum condition to occur in negotiation is that the group will try to bring about a state in which all agents agree to a common plan, and intends to act on it. The authors assume that if any agent shows its preference, then it will attempt to bring this plan about. Similarly, if the plan has any objection, then it will attempt to prevent this plan from being carried out. In this way, the agents will agree on a plan to carry out their actions. If the plan formation stage is successful, then the team will have a full commitment to the joint goal and will proceed to execution phase.

Execution Stage

When the agents have a collective plan to do something, then they are ready to move to this phase, as the group knows what to do. That is, each agent has its own target and the group has its intention to perform actions to achieve the goal. The group mutually believes that the action they intend to perform in order to achieve the goal can actually happen.

Monitoring Stage

How do we know that all the agents are performing their tasks according to the plans? What if an agent is unable to complete its task in the middle of the plan? Who will take this responsibility, or will another agent perform this task? How will it be solved? For these reasons, the authors identified that it is necessary to have a monitoring phase when the execution stage is carried out. An agent will need to monitor the execution phase; if something unusual occurs, it can be solved accordingly. For example, if an agent cannot finish its task, then the monitoring agent will request another agent to complete this task and the agent who could not finish its task can be defined as a partially able agent.

Evaluation Stage

This research identified some additional questions:

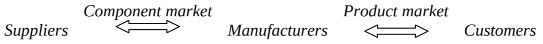
1. Which agent completed its task?
2. Which agent did not complete its task?
3. Which agent partially completed its task?
4. Which agents did extra tasks?
5. How do we know which agent performed what action?

Therefore, the authors recognized that it is also necessary to evaluate the execution stage by using an agent to evaluate and allocate reward benefits. From this evaluation, processes can be improved or updated according to necessity. After this stage, the agent can go back to the first stage to begin a new cooperative work. Therefore, we can consider it as *enhanced and effective cooperative stages*, as depicted in Figure 3.

In summary, the model developed by Wooldridge and Jennings (1999) has been extended by this research to include two more stages, the monitoring stage and the evaluation stage. The new model, shown in Figure 3, is applied to the TAC SCM game as a case study to investigate its potential performance.

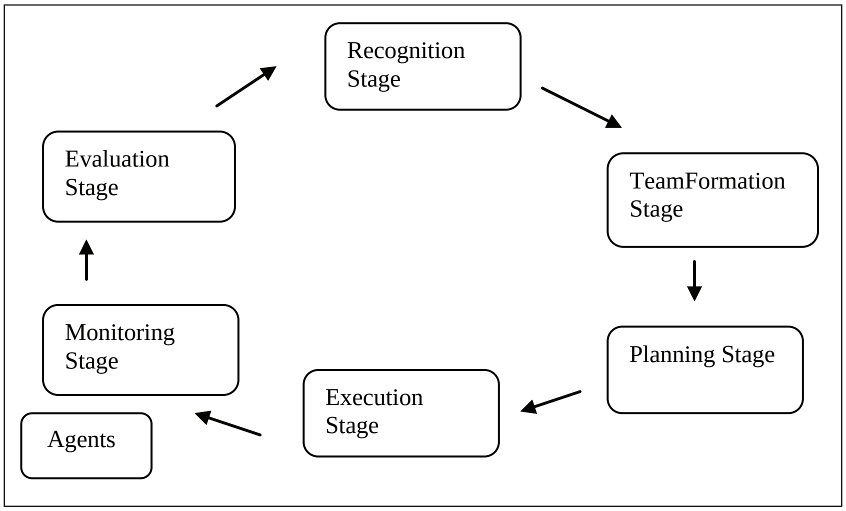
TAC SCM Game Overview

The TAC SCM is an international competition where six software agents are the manufacturers of personal computers (PC) in a simulated common market economy linked with two markets: the *component market* and the *product market*. The full specification can found at http://www.sics.se/tac/tac06scmspec_v16.pdf. TAC SCM is designed as a traditional supply chain model where supplier and end users (customers) are directly involved in an electronic market. Each manufacturing agent can manufacture 16 different types of computers, characterized by different *stock keeping units* (SKUs). SKUs consist of different combinations of components in 10 types.



During each TAC day of the game, customers send a set of request for quotes (RFQs) to the agents. Each RFQ contains a SKU, a quantity, due date, a penalty rate, and reserve price (the highest price that customers are willing to pay). Each agent responds to the RFQ by sending an offer that states a price less than the reserve price. The agent that sends the lowest price wins the bid.

Figure 3. Enhanced and effective cooperative processing stages



The winning agent delivers the entire order by the due date and is paid in full if it is delivered within five days of due date. If the order is not delivered by the due date, a penalty is incurred based on the number of late days. Consequently, if the agent cannot deliver the entire order within five days of its due date, then this order is canceled and the maximum penalty is incurred.

On the other hand, agents can send a RFQ to the suppliers for the required components and the expected delivery date. The suppliers can respond to the RFQ the next day with offers specifying the price per unit. Offers either have a delivery date on the day requested or a delivery date later than the requested day. The agent can accept or reject these offers according to their requirements and enter into an agreement with the supplier. The agent will be charged for the components on delivery. This simple negotiation mechanism must follow when agents purchase their components from suppliers. This mechanism only focuses on the accept or reject method.

Each agent must solve daily problems:

- Bidding problems for a customer's order of PCs.
- Negotiating a supply contract when the procurement problem deals with components that need to be purchased from the supplier.
- Production problems concerned with everyday scheduling.
- Allocation problems that deal with matching SKUs in the inventory to orders.

At the end of the game, the agents receive awards based on profits.

Product Market Performance

As we know, a pure competitor or monopolist can simply choose its price or output policy and directly calculate the resulting gain or loss. In an oligopoly market setting, the choice of a price, output, or other marketing policy does not uniquely determine profit, because the outcome for each firm depends on what its opponents decide to do. The Cournot and Chamberlin descriptions of oligopoly suggest the kind of interdependence that arises explicitly here, but do not take into account uncertainty about opponents' decisions (Meyer, 1976) .

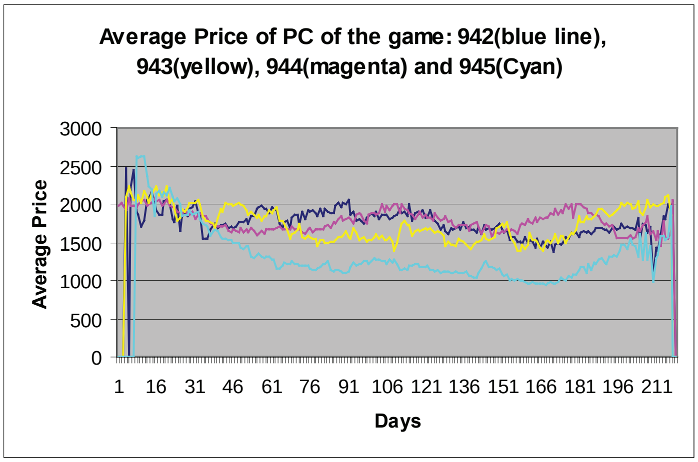
The market price of PCs for all the agents depend on the quantity they produce. This means that the profit for each agent is linked directly to the profit of the other. Consequently, different agents have their own cost functions, which imply different payments for inputs. Therefore, each agent has its own policy to bid for a customer order, which it will enhance to win the bid.

The PC market is another vital part of TAC SCM in which agents are directly involved in winning. In the competition, the authors recognize the following critical questions to resolve or improve the agents' performance as price competition:

- How does the agent bid for a customer's reserve price for a PC?
- What strategies need to be adopted for this?
- How much does the agent need to reduce the price to win the bid?

To improve the performance of the agent, it is necessary to learn from the history of the game. For example, Figure 4 presents the average price of PC of the competition. The agents can learn from the chart when the market price of PCs are high, medium, and low. Equilibrium prices arise when supply equals demand: $Q^s_i = Q^d_i$ for product *i*. If $Q^s_i \geq Q^d_i$, agents will bid price P_i lower ; if $Q^s_i \leq Q^d_i$, agents will bid price P_i higher. Usually the price of the product increases at the beginning of game due to lack of supplies. Therefore, the agents who supply the product at the time of low market supply can get a higher price and, as a result, can earn more market share with more profit. Consequently, the agent who can adopt this

Figure 4. Market price of PC of the game 942–945



strategy of increased productivity, and bids according to the market situation will have a better opportunity to maximize profit.

Huq (2006) analyzed the product market of the TAC/SCM 2004 game and observes the lack of cooperation among agents involved in component purchasing and product selling. The average market demand for PCs in the semifinal and final round game can be depicted in Tables 1 and 2, where the second column is the average PCs delivered by the agents; the third column is the total average market demand. The authors subsequently find that the free agent bids on an average with a higher average price and a higher percentage of orders.

In summary, the TAC SCM has a distinct lack of cooperation among the agents involved in component purchasing and product selling, and this led the authors to conclude that the game was a likely case study to investigate modeling coordination and cooperation.

MODELING COORDINATION AND COOPERATION IN TAC/SCM

According to the TAC/SCM, all manufacturer agents are rational or self-interested and their main focus is to maximize profit. If we assume that the agents cannot achieve their goal in isolation or that they would prefer to work with each other, then this has the potential for cooperation. In this context, all the manufacturer agents can work together towards their goal. On the one hand, manufacturer agents will be able to increase their production capacity and sell the final products to

Table 1. Average total PCs delivered in semifinal of Gr-1 (TAC3 and TAC4)

Agents	Average Delivery	Total Average Price	% of Order	Average
FreeAgent	46882	291505	16	1656
SouthamptionSCM	61759		21	1508
Mr. UMBC	51587		18	1527
ScrAgent	40995		14	1504
KrokodilAgent	41551		14	1538
Socrates	48732		17	1323

Table 2. Average total PCs ordered by agents in final round

Agents	Average PC Delivery	Total Average Market Demand	% of Order Price	Average
FreeAgent	41659	201227	21	1842
SouthamptionSCM	45465		23	1670
Mr. UMBC	44665		22	1481
ScrAgent	13765		7	1434
KrokodilAgent	24487		12	1869
Socrates	31186		15	1764

customers, and on the other hand, suppliers will benefit by supplying more components to the manufacturers, which will result in more profit. The following discussion proposes a theoretical model, which will be able to solve the coordination and cooperation problem of the TAC/SCM game.

The authors have found in the TAC/SCM competition that three or four agents always dominant the market of buying components or selling the products. Therefore, this research characterized these agents as big agents and the other agents as small/medium agents (SMAs). Again, it was also found that SMAs could not purchase enough share of the components to produce a final product to sell. This is a technical/strategic or financial problem for the SMAs. Consequently, if the SMAs purchase components from big agents and sell to customers, then it is possible to survive. Otherwise, the SMAs cannot compete with the big agents. In the real world, usually the intention of large organizations is to extend their business and make more profit. This increases production which ultimately leads to increased profit. Using this strategy, we assume that big agents want to extend their business, and at the same time, the SMAs would like to work with big agents. This way, big agents and SMAs can work together to achieve their common goals. As a result, every agent will be benefited by participating in shared activities. Therefore, to work together the agents need to follow the stages defined in the previous section, Cooperative Problem Solving Process. In this regard, the following characteristics can be defined (see the agent types in Definition 1 of the Recognition Stage of the Cooperative Problem Solving Process section):

Theorem 6.

a. There exist some group of agents *g* such that the individual agent *i* believes that the *g* can jointly achieve goal.
b. either:
c. An agent *i* cannot achieve goal individually.
d. an agent *i* believes for every action that could be performed to achieve the task, it has a goal of not performing the goal.

Theorem 7. The outcomes ensure their profit if and only if the *cooperative agents* complete their task successfully.

If the *cooperative agents* complete their task successfully, then all the participating agents will share the profit, otherwise it will be considered an incomplete task.

Theorem 8. The *cooperative agents* are those if and only if they agree to work together.

In the Cooperative Processing Stage, only those *able agents* that are determined to complete their tasks towards a common goal are considered *cooperative agents.*

Definition 2. A *decommitted agent* is an agent that started its task but did not complete that task, and therefore needs to be penalized.

Definition 3. Let a set of *able agents* that share their work to achieve a common goal be called *cooperative agents,* which is:

$$ag_i \in A = \{ ag_1, ag_2, \ldots\ldots ag_n \} = \phi \quad (1)$$

Definition 4. The accumulated task of the *cooperative agents A*, the utility *u* of that task can be considered as unique, and can be expressed as:

$$u(A) = \Sigma \; A_i = \; n1 \qquad (2)$$
$$i = 1$$

Definition 5. Profit allocation to the agents: The percentage of the utility of each agent can be worked out according to the contribution of each agent, which can be expressed as:

$$u(ag_i) = \frac{u(ag_i) \times 100}{u(A)} \qquad (3)$$

Definition 6. Cooperative action takeover: If any agent fails to complete its task, then other agents will need to complete that task to achieve the goal.

If any agent is unable to finish its allocated tasks due to unavoidable circumstances, then the other agents will take over that unfinished task enthusiastically to achieve the goal.

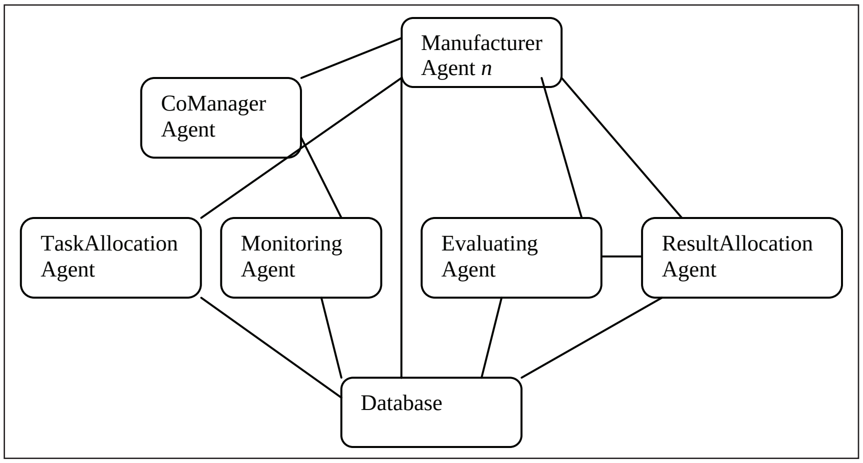
Definition 7. The set of *cooperative agents A* are a finite set and said to be bounded.

The *cooperative agents* must be limited in number for efficiency in task allocation, as it is not possible to have an unlimited number of agents working together. The *cooperative agents* are bounded, for instance: (a) the agent who invests or sells the greatest is called the upper bounded; and (b) the agent who invests or sells the lowest is called the lower bounded.

Architecture of the Cooperative Processing Agents

Let us consider that a number of companies in different locations have agreed to sell some products to customers within a limited time frame. Assume that the agents are going to work together according to the Cooperative Processing Stages. A proposition for architecture of effective cooperative processing is shown in Figure 5. In this figure, there is a collection of manufacturer agents *n* in the domain. When these agents have agreed to perform tasks to achieve a specific goal, to complete the cooperative processing, other agents are needed. This research argues that these agents are Task Allocation Agent, Monitoring Agent,

Figure 5. Architecture of effective cooperation model



Evaluating Agent, Result Allocation Agent, and Coordination Manager Agent (CoManager).

When a problem is decomposed into smaller subproblems, the *Task Allocation Agent* is responsible for allocating tasks to the a*ble agents* in order to achieve the goal. The *Monitoring Agent* is responsible for monitoring the performance of the agents' tasks, that is, which agent is doing its task and which is not. Finally, this agent will produce a report to the *CoManager Agent*. According to this report, the *CoManager Agent* will reallocate the unfinished task to the agent that is willing to undertake that task.

The *Evaluating Agent* will evaluate all tasks from the *Monitoring Agent*. The *Evaluating Agent* will provide analytical and objective feedback on efficiency and effectiveness of the performance of agents. Finally, it will produce an overall final report including benefits of each agent to the *Result Allocation Agent*. Eventually, this final report allows the agents to learn lessons. The *Result Allocation Agent* then processes the benefits deserved by each agent, and finally produces a benefit report to the agents.

The contribution made by this research is the addition of the monitoring and evaluation stages for the Cooperative Problem Solving Process, and the results described in this section. The TAC/SCM was used as a case study to illustrate the concepts outlined in the theorems and definitions.

FUTURE TRENDS

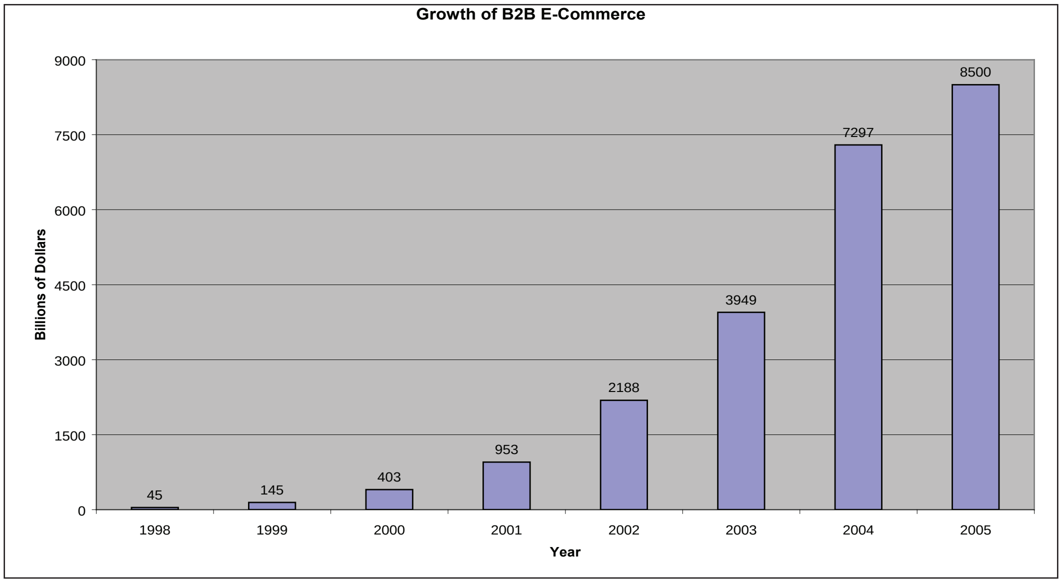
The potential for B2B e-commerce is now projected to be much larger than that for consumer oriented e-commerce (Chan, Lee, Dillon, & Chang, 2001). Conducting electronic B2B transactions is an emerging and potentially lucrative issue. For example, in the supply chain, manufacturer organizations or retailers are dependent on supplier organizations. There are many processes in selling and purchasing that can be conducted electronically. Particularly, at the time of purchasing, many processes are complex and involve negotiation, cooperation, and coordination. In the real world, these processes are very time consuming and complicated. Therefore, if we can utilize these processes electronically, we can avoid complexity and will be able to reduce costs and time taken. Figure 6 shows how B2B e-commerce has grown from 1998 to 2005.

As a result, we can predict that this trend in e-business utilization will increase into the future. As described in the previous sections, both large organizations and SMEs will be able to work together to conduct e-business on a global basis. In regards to implementing cooperative work utilizing multi-agent systems, the agents need to follow the stages defined in this chapter. As a result, all the participant organizations will benefit in overall performance outcomes. In conclusion, the authors argue that team effort, rather than individual effort, will give more robust and sustainable results. The cooperation and coordination protocol, and information sharing among various agents can be future research areas, which will facilitate in building the software that enables coordination and cooperation activities.

CONCLUSION

This chapter identified problems in conducting e-business and managing the supply chain. It also identified expected benefits for supply chains with agents working together in coordinated and cooperative processes. The utilization of a multi-agent system in supply chain management and the *cooperative problem solving stages* have been presented and discussed. To apply these stages, the proposition for architecture of effective cooperative processing for agents and some characteristics in modeling coordination and cooperation for TAC/SCM have been outlined. The ultimate goal is to develop the capability of organizations to work effectively together in online e-business transactions. In addition to this,

Figure 6. Projection growth of B2B e-commerce drawn from a report by Gartner Group



large organizations can expand their businesses and SMEs can work with large organizations. Finally, it can reduce time for selling and buying activities and increase the total profits of the supply chain. In addition, it will facilitate the ability to cooperate and coordinate among multi-agents in e-commerce. Further, it will enhance customer satisfaction and streamline B2B transactions by reducing transaction costs of tasks at every stage of the supply chain. Therefore, it will increase trust and confidence in the component market and product market.

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Chapter 3.4

Supporting Executive Intelligence Activities with Agent-Based Executive Information Systems

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ABSTRACT

This chapter examines the theoretical underpinning for supporting executive intelligence activities and reviews conventional studies of executive information systems (EIS) over the last two decades in responding to the current executives' information processing needs and the current Internet era. The reviews suggest the need for designing advanced EIS that are capable of responding and adapting to executive information. This chapter recognizes the necessity of revitalizing EIS with advances in intelligent technologies and Web-based technologies. Empirical studies were conducted to elucidate executives' desires and perceptions of the prospect of agent-based technologies for supporting executive intelligence activities in the more integrated and distributed environment of the Internet. Based on the insights gained from empirical studies, this chapter concludes by presenting a three-level agent-based EIS design model that comprises a "usability-adaptability-intelligence" trichotomy for supporting executive intelligence activities.

INTRODUCTION

It is widely recognized that there is an increasing complexity and dynamism of operational and strategic information in electronic and distributed environments. Executives are now seeking assistance for continuous, self-reactive and self-adaptive approaches to acquiring, synthesizing, and interpreting information for intelligence with a view to determining the course of action that is executive intelligence activities. Executive information systems (EIS) originally emerged as computer-based tools to provide executives with easy access to strategic information and to support and enhance their information processing activities. EIS were popularized in the 1990s but EIS study has not advanced to a great extent in either research or practice in recent years. Conventional EIS studies have established a range of views and guidelines for EIS design and development, but the guidelines underpinned by extant research have failed to develop robust and intelligent EIS.

The most common deficiency of conventional EIS is their inflexibility, relying on processes designed for static performance monitoring and control and predetermined information needs. The emergence of the intelligent software agent, as a concept and a technology, provides the prospect of advanced solutions for supporting executive's information processing activities in the more integrated and distributed environment of the Internet. Nevertheless, executives' desires and perceptions of agent-based support must be elucidated in order to develop systems that are likely to be considered valuable in practice and stand the test of time when implemented.

The objectives of this chapter are threefold. First, the chapter examines the theoretical underpinning for supporting executive intelligence activities and the need for designing advanced EIS that are capable of responding and adapting to executive information. Second, the chapter reviews conventional studies of EIS and confirms the need for revitalizing EIS with emerging technologies. Third, the chapter proposes a model for designing an advanced EIS with agent-based support. This chapter starts with a review of theories and debates on understanding the need for supporting executive intelligence activities. It then provides a review of the emergence of executive information systems (EIS) in responding to the executives' information processing needs over the last two decades and identifies the problems with conventional EIS in the current Internet era. It recognizses the necessity of revitalizing EIS with advances in intelligent technologies and Web-based technologies. This chapter also discusses the current development and applications of intelligent technologies and the potential contributions of intelligent software agents could make to revitalize conventional EIS.

Based on the insights gained from empirical studies, this chapter concludes by presenting a three-level agent-based EIS design model that comprises a "usability-adaptability-intelligence" trichotomy for supporting executive intelligence activities. The emphasis of this agent-based EIS design model is an intelligent and executive-centered system that focuses on these three dimensions.

THEORETICAL UNDERPINNING OF EIS DEVELOPMENT

As the business environment becomes more volatile and competitive the appropriate handling of information and knowledge has become a distinct core competence. The capability to know itself, know its "enemies," and know its business environment significantly affects a company's success or failure. The challenge is that organizations and their environments are systems that continually present a variety of disturbances through signals and messages that senior executives should attend to (Auster & Choo, 1994; Daft, Sormunen, & Parks, 1988). As a result, senior executives are facing increasing complexity and variety in operational and strategic issues.

From the notion of cybernetics, Ashby (1956) formulated the law of requisite variety that has contributed significantly in management and organizational studies. The variety of a system is defined as the number of possible states it is capable of exhibiting. It is a measure of complexity but a subjective concept depending on the observer. Ashby's law of requisite theory states that in order to control a system the control measures must have as much variety available as the system itself exhibits. In other words, only variety can counteract variety.

The law of requisite variety applies to the situation where executives have to learn to live with probabilistic systems as they are continually confronted by new and unexpected events. Executives have to exhibit enough variety in order to counteract the variety of disturbances. The challenge is that executives are facing ever-increasing amounts and complexity of operational and strategic variety. The capacity of the channels of communication to be used for perceiving the disturbances and for transmitting the control measures suggests the concept of intelligent support in this study. Senior executives are seeking assistance in the search of variety that can cope with the organizational environment that continually creates disturbances. The search of variety allows executives to have a better understanding of how to manage in a complex and dynamic organizational context. In this case, the better an executive is capable of perceiving disturbances and exhibiting control or action, the better their capability in reducing or removing the impact of the disturbances.

With the increasing availability of electronically distributed information, senior executives suffer from information overload, especially an over abundance of irrelevant information (Maes, 1994; Shapira, Shoval, & Hanani, 1999). Senior executives simply cannot relate simultaneously to all information available to them. They have to select and then make sense of what is selected. Ackoff (1967) foresaw this dilemma with the introduction of management information systems (MIS). He strongly believes that the emphasis of an executive support system should shift from supplying relevant information to eliminating irrelevant information. He argues, "Unless the information overload to which managers are subjected is reduced, any additional information made available by an MIS cannot be expected to be used effectively" (Ackoff, 1967, p. 148).

Based on the implications of Ashby's law of requisite variety, Beer (1979) introduced the viable system model (VSM). The VSM provides a theoretical basis for supporting executive intelligence activities because it is concerned with planning the way ahead in the light of external environmental changes and internal organizational capabilities. One of the subsystems in VSM model is concerned with Intelligence, called System Four. System Four emphasizes the scanning of the organizational environment and the filtering process. System Four can, therefore, act as a "scanner" that scans all unidentified relevant information from the overall environment. The scanning process allows the organization to adapt its internal environment to meet its external environment. As senior executives can easily be overloaded with irrelevant information, System Four can also act as a "filter" that captures only strategic information for senior executives. The information scanning and filtering process puts senior executives in a better position to react to threats and/or opportunities, as well as to anticipate future changes despite the turbulent environment. Using the VSM, Carvalho (1998) describes the role of computer-based support systems in organizations and suggests that EIS should aim to provide intelligence support as required in System Four.

Simon's (1965) intelligence-design-choice model states that executives spend a large fraction of their time surveying the organizational environment to identify new varieties that call for new actions in the "intelligence" phase. In the "design" phase, executives probably spend an even larger fraction of their time, individually or with their subordinates, to design and develop possible courses of action for handling situations where a decision is needed. They then spend a small fraction of their time in the "choice" phase, selecting from those available courses of actions to meet and solve an identified problem. According to Simon (1965), the three phases sum up what executives do in most of their time.

Here, the support for "intelligence" activity is of particular importance, because intelligence activity precedes design, and design activity precedes choice. The intelligence activity phase is the first principal phase, which emphasizes the search for variety, occasions, or conditions that call for decision. In the intelligence activity phase, the environment is examined and problem areas as well as opportunities are identified. Often, this phase is triggered by dissatisfaction with problems and organizational objectives. Besides the recognition of problems or opportunities, the intelligence activity phase also involves classification of the opportunity or problem from the business environment. Simon's (1965) model implies that intelligence activity support is critical for intelligence processing activities. Any advanced information systems that can provide intelligence activity support will assist executives in the recognition and classification of environmental conditions and so will reduce the fraction of time expended on this activity.

The above review provides a theoretical foundation to underpin the design of advanced EIS that are capable of responding and adapting to environmental changes.

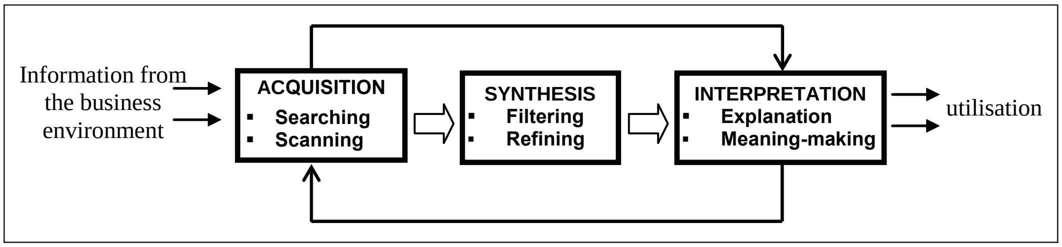
EXECUTIVE INTELLIGENCE PROCESS AND ACTIVITIES

As senior executives need to respond to their changing and unpredictable environment continuously that can help or support executives in the following three aspects of intelligence processing. First, advanced EIS are needed to reduce the amount of information from the environment and capture only relevant information, secondly, to capture and process information according to individual executives' specific needs and interests, and thirdly, to learn and adapt to information changes and to anticipate future changes.

Support for executive intelligence activities (see Figure 1) is essential for senior executives to better cope with the increasingly dynamic and complex executive information through value-added information seeking, information gathering and information manipulating activities. The theory of information retrieval (IR) suggests that efficient information search and processing can be achieved through a closed-loop process that involves evaluation and modification either through the user's explicit relevance feedback or the system's implicit relevance feedback (Belkin & Croft, 1992). Hence, there is a need to support executive intelligence activities through a closed-loop process, whereby actions could be suggested and/or taken continually in order to process information on behalf of senior executives.

The study of environmental scanning suggests that scanning is the key means for obtaining intelligence about the past, the present and the future (Aguilar, 1967; Hambrick, 1982; Lozada

Figure 1. Executive intelligence activities



& Calantone, 1996; Stoffels, 1994). The concept of environmental scanning underlies the understanding and the need for information acquisition in executive intelligence activities (see Figure 1). In order for executives to understand their internal business environment and to attend to signals and messages generated from the external business environment, they need a system that is capable of providing a broad range of information. The information is typically spread across several computer systems within the organization as well as the external information on markets, customers, suppliers, and competitors, influenced by political, economic, social, and technological issues. It is more than just providing historical data through basic query and reporting mechanisms. It involves sophisticated information scanning and searching activities through macroscopic viewing (radar) and microscopic search (search) of potentially relevant information. Scanning activities provide early signals from potential threats and opportunities and help executives understand the external forces of change. Search activities provide specific information on newly arising issues and help executives understand the details of those issues. Although companies have little control over external events, this acquisition activity can reduce remoteness and increase the predictability of future possibilities.

The concept of information filtering (IF), originating from the theory of information retrieval (Belkin & Croft, 1992), provides the basis for information synthesis in executive intelligence activities (see Figure 1). The goal of IF is to screen through a massive amount of dynamically generated information through user profiling and relevance feedback (explicit and implicit) and to present users with information likely to satisfy their information interests. Similar to the goal of IF, information synthesis acts as a "variety reducer" by screening out irrelevant information and refining information through relevance feedback for their relevancy. Irrelevant information will be eliminated and relevant and useful information will be extracted through filtering activities. One key activity in information filtering is user profiling. User profiling enables elimination of irrelevant information and personalization of information delivery according to user preferences (Balabanovic & Shoham, 1997; Shapira, Shoval, & Hanani, 1997). Information refining activities involve both explicit and implicit relevance feedback by the user or the system itself (Belkin et al., 1996; Kelly & Teevan, 2003; Morita & Shinoda, 1994; Salton & Buckley, 1990; White, Jose, & Ruthven, in press). User relevance feedback is used to create and refine user profiles. A continuous creation and modification of user profiles through user relevance feedback (both explicit and implicit) will gradually improve the results of information processing activities.

Finally, information interpretation is pertinent to executive intelligence activities (see Figure 1). Information interpretation involves making sense of the incoming information (Thomas, Clark, & Gioia, 1993). It entails the process of translating the viewed and searched events, the process of developing models for understanding, the process of generating meaning, and the process of assembling conceptual schemes (Daft & Weick, 1984; Gioia, 1986; Liu, 1998a; Taylor & Crocker, 1981). Synthesized information is further processed to resolve the equivocality of information and to give meaning and understanding about the organization's events. Explanations are key functions in information interpretation activities, in which explanations help provide adequate justification on information such as the meaning of data, the reasons for advising a particular course of action, and the justification for a particular piece of information (Gregor, 2001; Gregor & Benbasat, 1999). However, these activities pose challenges because executives are cognitively complex individuals who tend to use their innate mental models to perceive and understand the searched and viewed events (Agor, 1984; Isenberg, 1984; Kuo, 1998; Liu, 1998a).

CRITICAL REVIEW OF EIS IN THE CONTEXT OF INTELLIGENCE SUPPORT

Many information systems have been developed to support executives' information processing activities, such as management information systems (MIS), decision support systems (DSS), executive information systems (EIS) and executive support systems (ESS). EIS, in particular, emerged as computer-based tools to provide executives with easy access to strategic information and to support and enhance executives' information processing activities (Millet & Mawhinney, 1992; Rockart & Treacy, 1982; Watson, Houdeshel, & Rainer, 1997; Watson, Rainer, & Koh, 1991). Since the early 1990s, many studies have been conducted on EIS as companies and researchers foresaw the great potential (Belcher & Watson, 1993; Edwards & Peppard, 1993; Jordan, 1993; Millet & Mawhinney, 1992; Wetherbe, 1991; Watson & Frolick, 1993; Watson et al., 1991; Warmouth & Yen, 1992). However, only a few papers on EIS have been published since 2000 (notably Averweg, Erwin, & Petkov, 2005; Salmeron, 2002). Conventional EIS studies have established some consensus on guidelines for EIS design and development. However, the guidelines underpinned by preceding research have failed to develop robust and intelligent EIS. What is often reported is EIS failure (Bussen & Myers, 1997; Lehaney, Clarke, Spencer-Matthews, & Kimberlee, 1999; Rainer & Watson, 1995; Xu, Kaye, & Duan, 2003).

The design of EIS typically focuses on office support applications, planning and control process, and improved analytic and modeling capabilities (Rockart & De Long, 1988). Key functions of earlier EIS design are mainly standard office automation packages and management reporting facilities on key performance indicators (KPIs) and critical success factors (CSFs) (Millet & Mawhinney, 1992; Rockart & Treacy, 1982). The improved analytic and modeling capabilities are mainly developed to provide status and trends of internal and historical information (Millet & Mawhinney, 1992). Hence, it is rather a management control and planning system with performance measures based on critical success factors. This has failed to meet the primary purpose of EIS, which is to provide executives with easy access to both internal and external information that is relevant to their critical success factors (Watson et al., 1991; Watson et al., 1997). Conventional EIS are also inflexible in adapting and meeting changing information needs due to the predefined rules for exception, manipulation, reporting, and control. (Bajwa, Rai, & Brennan, 1998; Young & Watson, 1995; Salmeron, 2002).

Conventional EIS studies indicate that most EIS were used predominantly for communication, performance monitoring, and control (Edwards & Peppard, 1993; Nord & Nord, 1995; Vandenbosch & Huff, 1997). This implies the inability of conventional EIS in managing strategic information due to their internal focus. However, EIS can increase executives' confidence in decision-making (Nord & Nord, 1995), and improve executives' efficiency through successful information acquisition (Rainer & Watson, 1995; Vandenbosch & Huff, 1997; Watson, Watson, Singh, & Holmes, 1995). This suggests the need for supporting information scanning and searching in EIS.

It has been emphasized by many researchers that value added presentation of data via user-friendly interface such as graphical, tabular, and/or textual information presentation is essential in EIS design (Nord & Nord, 1995; Watson et al., 1995). Data should be processed (i.e., summarized, aggregated, analyzed), prepared and reported to executives using a friendly and colourful interface. Ease of use is considered relatively important in EIS design and development (Nord & Nord, 1995; Rainer & Watson, 1995; Watson et al., 1995). These guidelines suggest some basic ideas for EIS design and development, yet they are unable to develop robust and intelligent EIS.

Other EIS studies also attempt to explore factors contributing to the success of EIS adoption and implementation. Most of the studies imply that there are relationships between EIS success and support from top management, IS or vendor (Bajwa et al., 1998; Rai & Bajwa, 1997) and between EIS adoption and environmental uncertainty (Rai & Bajwa, 1997). However, these studies provide not many useful guidelines for successful EIS design and development.

Despite the integration of data manipulation and decision support tools into EIS, the key deficiency is that they do not efficiently support intelligence processing activities (Liu, 1998a, b; Montgomery & Weinberg, 1998). In particular, current EIS do little in the way of actively and continuously scanning the business environment, automatically filtering out irrelevant data and information, and constantly providing signals or warning of potential opportunities and threats. The advent of artificial intelligence (AI) (sometimes called soft computing) techniques, such as fuzzy logic, neural networks, and genetic algorithms gives the possibility of developing intelligent support systems, such as expert systems (ES) and knowledge-based systems (KBS). However, ES and KBS are mainly adopted to support operational and tactical decisions, rather than strategic decision (Eom, 1996; Wong, Chong, & Park, 1994). In practice few ES are successfully adopted and implemented due to the limited functions, high cost of development and organizational resistance (Grove, 2000; Watson et al., 1997; Wong & Monaco, 1995). Grove (2000) raises several problems and limitations associated with current ES/KBS applications: (1) Experts are often unable to express explicitly their reasoning process; (2) ES tend to perform poorly due to the limitations in its coded expertise, which relates to a narrow domain; and (3) the stand-alone mainframe, AI workstations or PC platforms causes limited use of ES and difficulty in information sharing, as well as difficulty in software installation and upgrades.

Nevertheless, one of the subfields of artificial intelligence (AI)—distributed artificial intelligence (DAI)—has led to the advent of the intelligent software agents (or software agents). The emergence of this concept and technology provides the opportunity for intelligence support in information processing activities. The intelligent software agents offer potential because these agents are integrated in the distributed environment of the Internet. With the overwhelming flow of distributed information produced for the senior executives from an increasing number of sources, intelligent agent-based support systems have the potential to fulfil the following three key functions in intelligence processing, first, the screening and filtering of data and information, second, the personalization of information gathering and processing according to individual users, and third, the learning and adaptation of system to information changes.

The Internet, or Web-based technologies, can overcome some of the drawbacks of conventional EIS, especially with regard to cost, geographically distributed location, ease of use, development cycle, architecture and additional advanced features such as intelligent software agents (Basu, Poindexter, Drosen, & Addo, 2000; Gopal & Tung, 1999). White (2000) suggests that executives are becoming more comfortable and confident using the Internet. Web-based technologies have also led to the emergence of portal solutions through the intranet, extranet, and enterprise information portal (EIP). The enterprise information portal (EIP) is a single point of access, where it gives users a unified view of all corporate knowledge assets using the new universal interface, the Web browser. An executive, for example, can do a single search to access competitors' information that may reside in corporate databases, business libraries, file archive, or on the Web. With the advent of intelligent software agents and the proliferation of Web-based technologies EIS design, development and implementation will be revitalized in the near future.

THE POTENTIAL OF INTELLIGENT TECHNOLOGY FOR INTELLIGENCE PROCESSING

Many intelligent software agents have been developed or are currently under development in academic and commercial research laboratories, but they are yet to be deployed in the commercial world (Nwana, 1996; Wooldridge & Ciancarini, 2001; Wooldridge & Dunne 2005; Wooldridge & Jennings, 1995). Software agents, like remembrance agents (Rhodes & Starner, 1996), Letizia (Liebermann, 1995, 1997; Liebermann, Fry, & Weitzman, 2001) and Let's Browse (Lieberman, Van Dyke, & Vivacqua, 1999) adopt a strategy that is mid-way between the conventional perspectives of information retrieval and information filtering. In this instance the user achieves efficient information searching and processing through a closed-loop process that involves evaluation and modification either through the explicit relevance feedback or implicit relevance feedback from the system itself. Automatically and unobtrusively collecting user profiles and monitoring the user's processing behavior is one mechanism for software agents to gather relevance feedback from the user or the system. Therefore, software agents offer the potential to automatically scan the distributed heterogeneous environment and proactively search information that best matches a user profile learned through relevance feedback. Information acquisition can become more intelligent as software agents are capable of looking ahead in the user's information processing activities and act as an advance scout to recommend the best paths to follow and save the user needless searching.

Adaptive software agents, like Amalthaea (Moukas & Maes, 1997) learn the user's interests and habits using machine learning techniques and maintains its competence by adapting to the user's interests (which may change over time) while at the same time scanning new domains that may be of interest to the user. A software agent can learn by itself, as well as learning from multiple agents. Learning among multiple agents may be collective, which means that the agents adapt themselves in order to improve the benefits of the system (Klusch, 2001). Here, software agents offer the potential to personalize information acquisition through intelligent information filtering and to deal with uncertain, incomplete, and ambiguous information through intelligent information refining. Hence, information synthesis that consists of information filtering and information refining can be intelligently supported and enhanced by software agents. In this case, software agents perform the information filtering process according to specific user's interests identified and learned over a period of time. Software agents also perform the information refining process through learning from multiple agents.

Proactive software agents, like Watson (Budzik, Bradshaw, Fu, & Hammond, 2002) and I2I (Budzik et al., 2002) proactively and automatically retrieve potentially useful information from online repositories to recommend to users based on their ongoing information processing activities. The goal of proactive software agents is to foster an awareness of relevant information resources available to users. In this case, software agents must be able to reason about the contents of a document, in the right context, in order to provide helpful recommendation, the meaning of the information, the reasons for advising a particular course of action, and the justification for a particular piece of information for example. Using knowledge engineering, software agents offer the potential to make the implicit control knowledge more explicit. In this case, information interpretation could possibly be achieved through intelligent explanation and reasoning services, natural language processing, and knowledge representation. However, the software agent has to be highly user-specific, as well as domain-specific with relatively fixed representation of knowledge because it requires substantial efforts from knowledge engineers to encode implicit control knowledge using complex algorithms (Klusch, 2001).

Many software agent applications are yet to be deployed in real applications due to the following challenges (Nwana, 1996; Wooldridge & Ciancarini, 2001; Wooldridge & Dunne, 2005; Wooldridge & Jennings, 1995):

- **The identification of appropriate techniques for the development of useful software agents:** Software agents are still very much limited by the current state of the art in machine intelligence.
- **The development of software agents is too diverse:** Researchers tend to suggest agent-based solutions based on what they see fit, in accordance with their own respective definitions and approaches.
- **The ability to demonstrate that the knowledge learned with software agents can truly be applied to help users and reduce users' workload in a specific context and domain:** Most of the conceptual architectures of agents are generic solutions that are designed for a wide range of applications.
- **The infancy of development of software agents suggests that users do not actually have a clear vision of how agents can be deployed to assist them:** This also leads to a potential lack of acceptance by users in terms of using and trusting software agents to perform the tasks on their behalf.
- **The ability of software agents to negotiate with other peer agents:** Software agents tend to be distributed by their very nature, working and collaborating with other agents under a multiagent environment.

Although software agents and their applications are still in the early stage of development, they will advance increasingly as research and development in software agents have been mushrooming across different fields, such as intelligent information gathering and processing, personalized information acquisition and knowledge sharing.

EMPIRICAL STUDIES

Software agents offer the potential to support information processing intelligently but executive criteria for agent-based EIS support must be made known in order to develop a system that is considered useful by executives. Executive criteria refer to critical requirements for an agent-based support systems based on executive's desires and perceptions in judging the usefulness of the agent's functions or attributes. The authors conducted empirical studies in order to identify executive criteria for an agent-based EIS to support executive intelligence activities. First, four focus groups were conducted to explore and reveal the current state of executive's information environment and information processing behaviour in the light of Internet era, from which to examine the validity of the conventional views of EIS purpose, functions, and design guidelines. Initial executive criteria for agent-based EIS design were also identified in the focus group study. Second, 25 senior executives were interviewed for deeper insights on value-added attributes and processes of executive criteria for building agent-based EIS. Value-added attributes are functional requirements needed for an agent-based system to assist the executive in information processing activities. Value-added processes are specific activities performed by agent-based system that add value (i.e., enhance) to the executive intelligence activities.

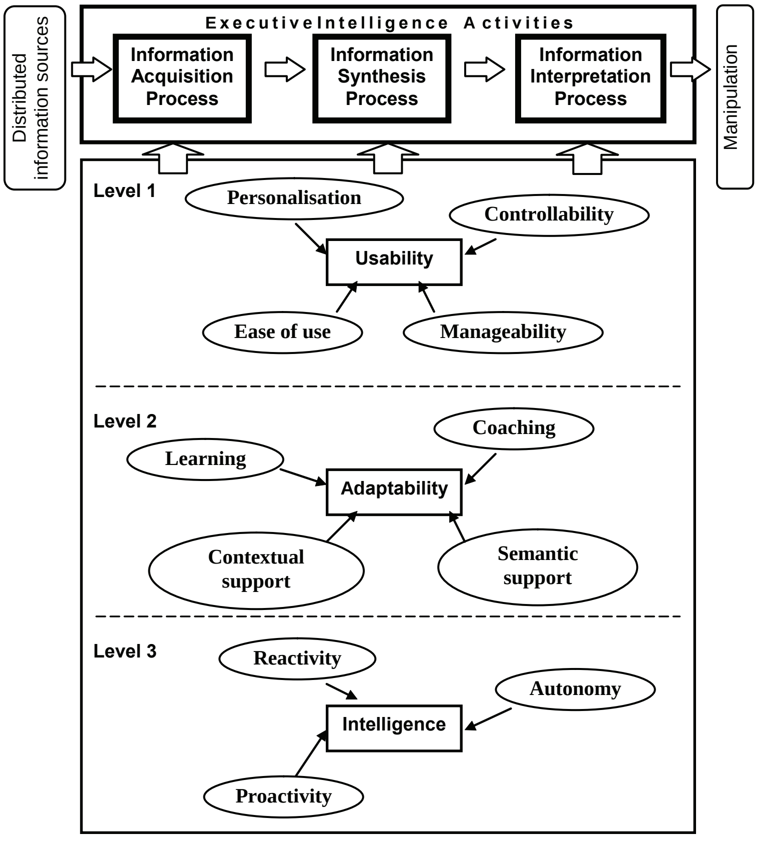
All the discussions were recorded and transcribed verbatim for later analysis. The categorization of meaning approach was adopted for qualitative analysis, in which raw data were organized into structured, meaningful themes according to predefined or newly emerging themes and categories (Dey, 1993). With the high volume of raw data obtained from all the transcripts, qualitative analysis software, NVivo was selected and employed for efficient handling, managing, searching, display, and analysis of findings. Each transcript was analyzed and coded into either the predefined code scheme (nodes) or newly emerging nodes. For a more detailed interpretive conceptual analysis, meanings were sought from the quotes to identify consensus, dilemmas, and contradictions through reading and re-reading of transcripts (Nicholas & Anderson, 2003).

AGENT-BASED EIS DESIGN MODEL: "USABILITY-ADAPTABILITY-INTELLIGENCE" TRICHOTOMY

The findings from empirical studies suggest a "usability-adaptability-intelligence" trichotomy for agent-based EIS design models that comprises executive criteria of value-added attributes and processes for building a usable, adaptable and intelligent EIS. Usability refers to the extent to which a system can be used by specific users to achieve specific goals of information processing in a specific domain of work and information. Adaptability refers to the extent to which the system fits the specified and right context of work and information, with the ability to strengthen the responsiveness of system in coping with the executive information. Intelligence refers to the extent to which the system exhibits self-determined activities that performs a specific task on behalf of an executive, with no or very little executive interaction. The agent-based EIS design model is illustrated in Figure 2.

Under the criterion of usability design, the empirical findings suggest implications for value-added processes on the following value-added attributes: personalization, controllability,

Figure 2. An agent-based EIS design model



manageability, and ease of use. First, the personalization attribute in an agent-based EIS should involve the process of designing and building a comprehensive and specific user profile for individual executives. The executive profiles would comprise individual executive's information domains, roles and preferences. The goal of personalization according to senior executives is to customize according to application-dependent information, application-independent information and user-agent interaction information, thus, reducing the generic information.

Second, the design of controllability attribute in an agent-based EIS allows the flexibility for executive to take control and make changes of information process criteria. Executives should have explicit control over their respective user profiles via explicit user action and user control. Explicit user action allows executives to determine their specific requirements of information process, thus facilitating executive learning in intelligence processing. User control allows executives to make changes on the information process criteria as their information needs and interests change over time, thus making the system more acceptable to the executives.

Third, the manageability attribute in an agent-based EIS suggests the provision of appropriate information density and the reduction of information overload without losing potentially critical information. The provision of appropriate information density can be achieved through paragraphing, summarizing and highlighting imperative messages that are useful. Dissecting information into appropriate units with options for further explanation and understanding can also increase the level of manageability.

Fourth, the key elements for ease of use attribute in an agent-based EIS are simplicity, accessibility and browseability. Simplicity can be achieved through easy functionalities and user-friendly interface. The reduction of steps needed for information access can increase the level of accessibility. Browseability can be achieved through uncluttered information presentation and organization.

In terms of adaptability design, the following value-added processes are identified on the following value-added attributes: coaching, learning, contextual support, and semantic support. First, coaching attributes in an agent-based EIS suggests that executives can assess the information via user's explicit feedback. The system can also seek confirmation and clarification from executives. This interactive process can gradually update and refine executive profiles. As a result, an agent-based EIS would adapt to changes of information needs and requirements.

Second, the design of learning attributes in an agent-based EIS suggests intuitive learning of executive's interests and behaviors based on implicit observation, monitoring and assessment of the system with the intention of understanding executive's interests and mimicking executive's information processing behavior. The implicit relevance feedback must be personalized to executive profiles. The purpose here is to learn and understand executive's information processing behavior and thus conduct continuous, self-reactive and self-adaptive activities of information processing.

Third, the design of contextual support attributes in an agent-based EIS involves the ability to increase information richness through the collection and provision of associative information and context-aware information. The system should be able to monitor and update the collection and provision of associative information and context-aware information in the executive profiles.

Fourth, the design of semantic support attributes in an agent-based EIS includes the ability to increase information relevancy through the collection and provision of associative meanings of information and semantic-aware information. The process includes complex knowledge-based natural language processing activities and the development of ontological domains.

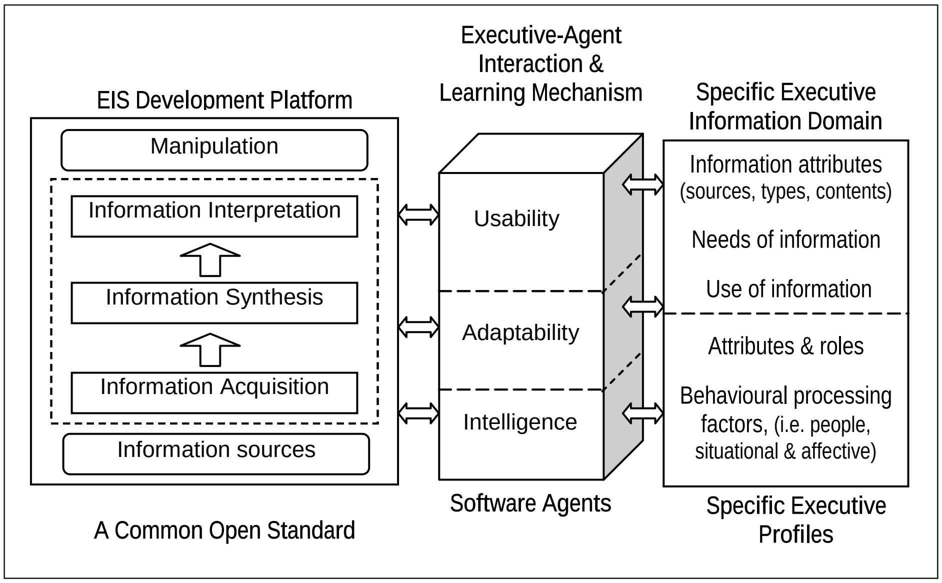
Under the criterion of intelligence design, the findings and discussion suggest preliminary implications for value-added processes on the autonomy, proactivity, and reactivity attributes. First, the design of autonomy attributes in an agent-based EIS should be a semi-autonomous function that involves executive's occasional interaction or input. The system is expected to perform information search autonomously on static information but not dynamic information. Executive's input or feedback is expected for dynamic information. Second, the proactivity attributes in an agent-based EIS should be a proactive interface agent that is capable of performing information manipulation, such as alert notification, ranking and recommendation, with some kind of proactive assistance via user interfaces. The goal is to increase executive's awareness of information. Third, the design of reactivity attribute in an agent-based EIS should be a semi-reactive function that performs self-determined tasks with executive's knowledge. The system should be able to trigger executive of any changes in the information process.

GUIDANCE FOR BUILDING AN AGENT-BASED EIS ARCHITECTURE

The empirical findings suggest guidance for building an agent-based EIS architecture for supporting executive intelligence activities. The architecture will consist of a common EIS development platform, a specific executive profile and information domain, and an executive-agent interaction and learning mechanism. Figure 3 illustrates this architecture.

The EIS development platform will facilitate and enhance executive intelligence activities. This platform will progressively enable the key functional features to be developed, such as searching tools, decision support tools and user interface tools. It is an open standard platform in the sense that the functional features are essential to any EIS and are common to all EIS users. Distributed information sources are widely scanned, filtered and interpreted for manipulation. With the support of software agents, information can be autonomously and proactively scanned or searched, at the same time filtered and/or refined according to executive's information needs and interests. Data manipulation tools such as categorizing, ranking,

Figure 3. An agent-based EIS architecture



and alerting tools can be incorporated in the standard EIS development platform. Data manipulation tools are important because executives with severe time constraints would want to have the needed information processed beforehand. This can save their time and quicken their subsequent information processes if necessary.

All functional features in the EIS development platform would have to be highly dynamic and would probably have to operate in real time as executive's concerns and strategic issues change over time. Web-based technologies and intelligent technologies are potential and appropriate for building the intelligent functions with usability-adaptability-intelligence criteria. The representation and processing of ontological knowledge and semantic metadata, user profiles and natural language input, coupled with the application of machine learning techniques enable the intelligent EIS to acquire and maintain knowledge on itself and its environment.

Executive's information needs and behavior in acquiring and processing information is dynamic and heterogeneous. Hence, it is impossible to establish a common executive information domain. The executive information domain represents an executive's information needs, preferences of information attributes (i.e., sources, types, and contents), and use of information. It is also unlikely that common profiles of executives and processing behaviour in acquiring and using information can be formulated. Executive profiles represent an executive's attributes and roles, as well as the factors that influence or shape executive's information processing behavior. Therefore, the executive information domain and executive profiles must be specific to individual executive, company, and industry sector. A comprehensive and specific executive information domain and executive profile should be incorporated into the EIS architecture so that a personalized rather a general system is built for individual executive.

The key to make the common EIS platform work in conjunction to specific executive information domain and executive profiles is the executive-agent interaction (EAI) and executive-agent learning (EAL) mechanism. The EAI and EAL mechanism are agent-based applications supported by multiple software agents. User programming, knowledge engineering, and machine learning are potential approaches to adopt to build appropriate agents for interaction and learning. The building of EAI and EAL mechanisms will be based on the usability-adaptability-intelligence trichotomy of agent-based EIS design model. Research shows that user profile bases, knowledge bases, and case bases are useful to teach the software agents what to scan, what to filter, and what to process according to individual users. However, these static rules will not reflect executives' dynamic information needs and changing behavior. The agents must also be able to learn continuously in order to make the EIS more adaptable. The EAI mechanism comprises agents that react on explicit feedback, a coaching approach in which executive explicitly and interactively updates and refines his profile so that the system can adapt to changes of his information needs and requirements. The EAL mechanism involves no executive's intervention, but the agents learn through implicit feedback. The agents learn about executive's interests and behaviours based on implicit observation, monitoring and assessment with the intention to understand executive's interests and mimicking executive's behaviours. Over time, the EAI and EAL mechanism will become more and more autonomous, proactive and reactive in assisting executive intelligence activities.

THE CHALLENGES FOR DEVELOPING AN AGENT-BASED EIS

The real challenge lies not on the decision support capability of the EIS, but on the ability to process intelligence. The dilemma which requires due considerations when designing EIS concerns the ability to scan for information to the maximum capability of the system whilst providing manageable, relevant data and information to executives in a systematic way. The technical challenge related to intelligence processing is the software agents' capability to understand an executive as an individual user with specific domain of work and information, and to fit the intelligence processing into the right context and content of work and information.

The application of software agents in executive intelligence activities could potentially change executives' information processing behaviour. This is a two-way impact between the executives and the EIS. It can be envisaged that an executive's information role will not be weakened or replaced by software agents, because the agent is coached by the executive, and is a part of the executive's information processing process. On the other hand, executives may fear that software agents would take over some of their intelligence roles and limit their development, thus resist substantial reliance on software agents.

CONCLUSION

This chapter has argued that there is a need for revitalizing EIS with emerging intelligent technologies. An intelligent agent-based EIS will support and enhance executive intelligence activities through identifying, collecting, and processing potentially strategic information in a turbulent environment. The results of the empirical studies suggest an agent-based EIS design model for system developers, managers and researchers in the field of EIS. The agent-based EIS design model provides guidance for developing and utilizing software agents for continuous, self-reactive and self-adaptive activities or approaches of acquiring, synthesizing and interpreting information for executives to obtain strategic intelligence with a view to determining the course of action.

With advances in the development of software agents and Internet technology, an agent-based EIS platform for supporting executive intelligence activities is likely to be one of the future trends in EIS development and implementations in organizations. Future research can look into the development and implementation of an agent-based EIS architecture based on the proposed "usability-adaptability-intelligence" trichotomy of agent-based EIS design model. The architecture can consist of a common EIS development platform, a comprehensive and specific executive information domain and profiles, and an executive-agent interaction and learning mechanism. The development of specific domain and profiles and executive-agent interaction and learning mechanism involve the design and development of software agents using the appropriate techniques. The development and implementation process will involve close collaborations between system designers and executives for continuous improvement and success.

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Chapter 3.5

Beyond Intelligent Agents:
E-Sensors for Supporting Supply Chain Collaboration and Preventing the Bullwhip Effect

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ABSTRACT

This article presents a new concept for supporting electronic collaboration, operations, and relationships among trading partners in the value chain without hindering human autonomy. Although autonomous intelligent agents, or electronic robots (e-bots), can be used to inform this endeavor, the article advocates the development of e-sensors, i.e., software based units with capabilities beyond intelligent agent's functionality. E-sensors are hardware-software capable of perceiving, reacting and learning from its interactive experience through the supply chain, rather than just searching for data and information through the network and reacting to it. E-sensors can help avoid the "bullwhip" effect. The article briefly reviews the related intelligent agent and supply chain literature and the technological gap between fields. It articulates a demand-driven, sense-and-response system for sustaining e-collaboration and e-business operations as well as monitoring products and processes. As a proof of concept, this research aimed a test solution at a single supply chain partner within one stage of the process.

INTRODUCTION: FROM E-BOTS TO E-SENSORS

As e-business and e-commerce has grown, so has the need to focus attention on the: (1) Electronic communications between e-partners; (2) operational transactions (e.g., sales, purchasing, communications, inventory, customer service, ordering, submitting, checking-status, and sourcing, among others); and (3) monitoring improvements in the supply (supply, demand, value) chain of products, systems, and services (Gaither & Fraizer, 2002).

Integrating continuous communication protocols and operational and supply chain management (SCM) considerations, early on in the enterprise design process, would greatly improve the successful implementation of the e-collaboration technologies in the enterprise. It is particularly important to examine the resources and systems that support the electronic communications, and relationships among partners, in the supply chain.

In addition, there is a need for obtaining (sensing) real time data for managing (anticipating, responding) throughout the supply chain. Typically companies need to synchronize orders considering type, quantity, location, and timing of the delivery in order to reduce waste in the production and delivery process. The data collection and availability provided by the e-sensing infrastructure/architecture discussed later in this article will allow for a collaborative environment, improve forecast accuracy, and increase cross-enterprise integration among partners in the supply chain.

Current supply chain information technologies (IT) allow managers to track and gather intelligence about the customers purchasing habits. In addition to point-of-sale Universal Product Code (UPC) barcode devices, the current IT infrastructure may include retail radio frequency identification (RFID) devices and electronic tagging to identify and track product flow. These technologies aid mainly in the marketing and resupply efforts. But, how about tracking partners' behaviors throughout the chain in real time?

Artificial intelligent agents (or e-bots) can be deployed throughout the supply chain to seek data and information about competitive pricing, for instance, e-bots can search for the cheapest supplier for a given product and even compare characteristics and functionality. For this reason, the concept of an *agent* is important in both the Artificial Intelligence (AI) and the e-operations fields.

The term "intelligent agent" or "e-bot" denotes a software system that enjoys at least one of the following properties: (1) Autonomy; (2) "Social" ability; and (3) Reactivity (Wooldridge & Jennings, 1995). Normally, agents are thought to be autonomous because they are capable to operate without direct intervention of people and have some level of control over their own actions (Castelfranchi, 1995). In addition, agents may have the functionality to interact with other agents and automated systems via an agent-communication language (Genesereth & Ketchpel, 1994). This agent attribute is termed here *e-sociability* for its ability to interact with either people, or systems (software).

The next evolution of the intelligent agent concept is the development of integrated hardware/software systems that may be specifically designed to sense (perceive) and respond (act) within certain pre-defined operational constrains and factors, and respond in a real time fashion to changes (not a just-in-time fashion) occurring throughout the supply chain. These integrated hardware-software systems are termed *e-sensors*, in this article. Indeed, there is a real opportunity for process innovation and most likely organizations will need to create new business applications to put e-sensors at the centre of a process if they want to be competitive in this new supply chain environment. Aside from asset tracking, each industry will have specialized applications of e-sensors that cannot be generalized. Before getting into the e-sensors details, let us review some key supply chain management (SCM) issues relevant to this discussion.

SUPPLY CHAIN MANAGEMENT IN THE E-COLLABORATION CONTEXT

SCM is the art and science of creating and accentuating synergistic relationships among the trading partners in supply and distribution channels with the common shared objective of delivering products and services to the 'right customer' at the 'right time.' (Vakharia, 2002)

In the e-collaboration/e-business context, supply chain management (SCM) is the operations management discipline concerned with these synergistic communications, relationships, activities and operations in the competitive Internet enterprise. SCM involves studying the movement of physical materials and electronic information and communications—including transportation, logistics and information-flow management to improve operational efficiencies, effectiveness and profitability. SCM consists in the strategies and technologies for developing and integrating the operations, communications and relationships among the e-trading partners (producers, manufacturers, services providers, suppliers, sellers, wholesalers, distributors, purchasing agents, logisticians, consultants, shipping agents, deliverers, retailers, traders and customers) as well as improving their operations throughout the products' or services' chain.

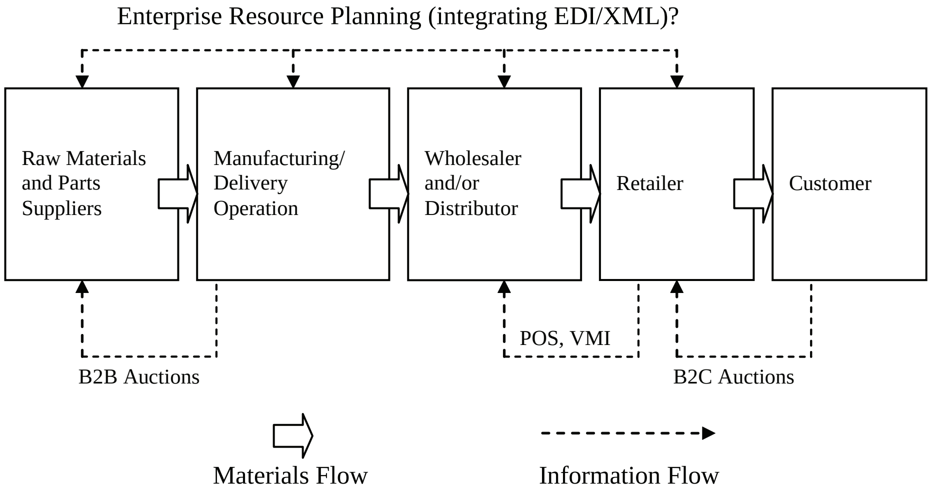
Integrated e-business SCM can enhance decision making by collecting real time information as well as assessing and analyzing data and information that facilitate collaboration among trading partners in the supply chain.

To achieve joint optimization of key SCM decisions, it is preferable that there be a free flow of all relevant information across the entire chain leading to a comprehensive analysis. (Vakharia, 2002)

As shown in Figure 1, IT systems, such as, enterprise resource planning (ERP), point of sale (POS), and vendor managed inventory (VMI) systems permit and, to some extend, automate information sharing.

The advent of reliable communication technologies has forced business partners throughout the supply chain to rethink their strategies as well as change the nature of the relationships with suppliers and customers. Companies that have made the shift have benefited from: "Re-

Figure 1. Information flow using electronic information technologies in the supply chain (after Burke & Vakharia, 2002; Vakharia, 2002)



duced operating expenses, increased revenue growth, and improved customer levels," according to IBM ERP/Supply Management Division (Cross, 2000). According to the same source, the companies that have implemented supply chain improvement projects have been able to increase forecast accuracy and inventory reduction (up to 50% in overall improvement!). Some of the newer activities being implemented include: Supply-and-demand auctions, integrated collaborative product design (CAD/CAM), cross-enterprise workflow processes, demand management collaboration. In addition, some companies are even deploying SCM as an offensive tactic to gain a competitive edge (Cross, 2000).

Meixell's "Collaborative Manufacturing for Mass Customization" (2006)site, at http://www.som.gmu.edu/faculty/profiles/mmeixell/collaborative%20Planning%20&%20Mass%20Customization.pdf, provides extensive information about the use of collaborative technologies in the supply chain. The same author recently compiled a literature review; particularly, on decision support models used for the design of global supply chains (Meixell & Gargeya, 2005). This, however, does not mean that there are no strategic and technological gaps in the supply chain.

PARADIGM SHIFT: FROM 'PUSH' (SCM) TO 'PULL' (SRS)

We are not smart enough to predict the future, so we have to get better at reacting to it more quickly. (GE saying quoted by Haeckel, 1999)

E-business forces have shifted both the enterprise landscape and the competitive power from the providers of goods and information (makers, suppliers, distributors and retailers) to the purchasers of goods and information (customers). For this reason, e-businesses must collaborate electronically and sense-and-respond very quickly to the individual customer's needs and wants. So, rather than considering SCM analysis from the "supply" perspective, some researchers and practitioners advocate analyzing the market operations from the "demand" perspective: Sensing-and-responding to the consumer changing needs and wants by quickly collaborating and communicating in real-time throughout the chain. Researchers argue that e-businesses should measure and track customers' demands for products and services, rather than relying solely on demand forecasting models.

Fisher (1997) studied the root cause of poor performance in supply chain management and the need to understand the demand for products in designing a supply chain. Functional products with stable, predictable demand and long life-cycle require a supply chain with a focus almost exclusively on minimizing physical costs—a crucial goal given the price sensitivity of most functional products. In this environment, firms employ enterprise resource planning systems (ERP) to coordinate production, scheduling, and delivery of products to enable the entire supply chain to minimize costs and maximize production efficiency. The crucial flow of information is internal within the supply chain. However, the uncertain market reaction to innovation increases the risk of shortages or excess supplies for innovative products. Furthermore, high profit margins and the importance of early sales in establishing market share for new products, the short product lifecycles increasing the risk of obsolescence, and the cost of excess supplies require that innovative products have a responsive supply chain that focuses on flexibility and speed of response of the supplier. The critical decision to be made about inventory and capacity is not about minimizing costs, but where in the chain to position inventory and available production capacity in order to hedge against uncertain demand. The crucial flow of information occurs not only within the chain, but also from the market place to the chain.

While Selen and Soliman (2002) advocate a demand-driven model, Vakharia (2002) argues that push (supply) and pull (demand) concepts apply in different settings. That is, since businesses offering mature products have developed accurate demand forecasts for products with predictable lifecycles, they may rely more heavily on forecasting models. While businesses offering new products, with unpredictable short cycles, are better off operating their chains as a pull (demand) system, because it's harder to develop accurate demand forecasts for these new (or fluctuating demand) products.

The difficulty in synchronizing a supply chain to deliver the right product at the right time is caused by the distortion of information traveling upstream the supply chain. One of the most discussed phenomena in the e-operations field is called the Forrester (1958) or "bullwhip" effect which portrays the supply chain's tendency to amplify or delay product demand information throughout the chain (Sahin & Robinson, 2002). For instance, a particular supplier may receive a large order for their product and then decide to replenish the products sold. This action provides the quantity to restock the depleted products, plus some additional inventory to compensate for potential variability in demand. The overstated order and adjustments are passed throughout the supply chain causing demand amplification. At some point, the supply chain partners loose track of the actual customer demand.

Lee et al., (1997) proved that demand variability can be amplified in the supply chain as orders are passed from retailers to distributors and producers. Because most retailers do not know their demand with certainty, they have to make their decisions based on demand forecast. When it is not very accurate, the errors in the retailers forecast are passed to the supplier in the form of distorted order. They found that sharing information alone would provide cost savings and inventory reduction. Other factors that contribute to the distortion of information is over reliance on price promotion, use of outdated inventory models, lack of sharing information with partners, and inadequate forecasting methods.

An important question in supply chain research is whether the bullwhip effect can be preventable. Chen et al., (2000) quantified the bullwhip effect for a multi-stage system and found that the bullwhip effect could be reduced but not completely eliminated, by sharing demand among all parties in the supply chain. Zhao et al., (2002) also studied the impact of the bullwhip effect and concluded that sharing information increases the economical efficiency of the supply chain. In a later study, Chen (2005) found that through forecast sharing the bullwhip effect can be further reduced by eliminating the need for the supplier to guess the retailer's underlying ordering policy.

The causes of uncertainty and variability of information leading to inefficiency and waste in the supply chain can be traced to demand forecasting methods, lead-time, batch ordering processes, price fluctuation, and inflated orders. One of the most common ways to increase synchronization among partners is to provide at each stage of the supply chain with complete information on the actual customer demand. Although this sharing of information will reduce the bullwhip effect, it will not completely eliminate it (Simchi-Levy et al., 2003). Lee et al., (1997a, 2004) suggests a framework for supply chain coordination initiatives which included using electronic data interchange (EDI), internet, computer assisted ordering (CAO), and sharing capacity and inventory data among other initiatives. Another important way to achieve this objective is to automate collection of Point of Sale data (POS) in a central database and share with all partners in a real time e-business environment. Therefore, efficient information acquisition and sharing is the key to creating value and reducing waste in many operations. A specially designed adaptive or sense-and-response system may help provide the correct information throughout the supply chain. The proposed system would have two important system functions—maintaining timely information sharing across the supply chain and facilitating the synchronization of the entire chain.

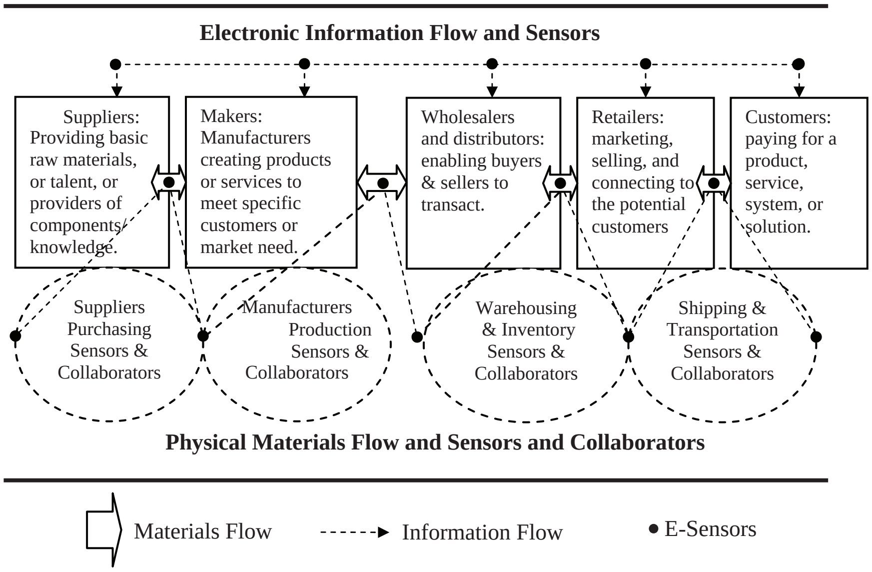
Haeckel (1999) indicates that “unpredictable, discontinuous change is an unavoidable consequence of doing business in the information age.” And, since this “intense turbulence demands fast—even instantaneous—response,” businesses must manage their operations as adaptive systems. Adaptive (sense-and-response) models may help companies systematically deal with the unexpected circumtances, particularly, e-businesses need to be able to anticipate and preempt sensed problems.

SENSE-AND-RESPONSE SYSTEM (SRS) MODEL AND FRAMEWORK

Figure 2 shows the proposed SRS model and framework for integrating real-time electronic communications, information sharing, and materials flow updating as well as monitoring the e-supply/demand/value chain—towards a new e-collaboration paradigm.

The “e-sensors” in the diagram are computer programs (software code) and its associated data and information collection devices (hardware), and communication interfaces. These sensors are designed for e-collaboration, data capturing (sensing), and information sharing, monitoring and evaluating data (input) throughout the value chain. Ultimately, this approach would result in semi-automated analysis and action (response) when a set of inputs are determined (sensed) without hindering human autonomy. That is, the sensors will gather the data, monitor, and evaluate the exchange in information between designated servers in the e-partners (suppliers and distribution channel) networks. Sensors will adjust plans and re-allocate resources and distribution routes when changes within established parameters are indicated. In addition, sensors will signal human monitors (operations or supply chain managers) when changes are outside the established parameters. The main advantage of this approach is that sensors will be capable of assessing huge amounts of data and information quickly to respond to changes in the chain environment (supply and demand) without hindering human autonomy. Particularly, e-sensors can provide

Figure 2. SRS framework for integrating communication, information and materials flow and monitoring the e-business supply/demand chain



the real-time information needed to prevent the bullwhip effect.

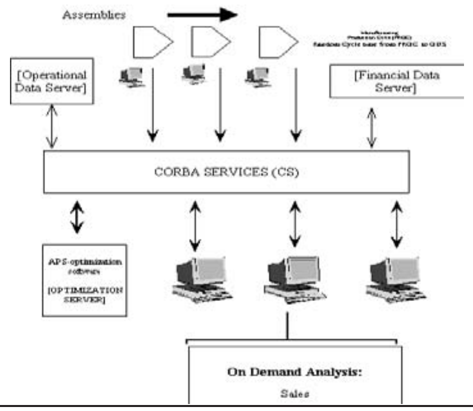
Companies like Cisco, Dell, IBM and Wal-Mart have led the development of responsive global supply chains. These companies and a few others have discovered the advantages of monitoring changes in near real-time. By doing so, they have been able to maintain low inventories, implement lean production and manufacturing operations, and even defer building and assembly resulting in lower costs and increase responsiveness to variable customer demands. This practice can be extended to incorporate e-sensors and human collaborators throughout the value chain and perceive and react to the demands.

SYSTEM ARCHITECTURE AND IMPLEMENTATION

To develop the implementation of the entire framework outlined in Figure 2 one faces involvement of multiple supply chain partners and months, if not years, of work just to develop a reliable communication infrastructure. In order to provide an immediate viable solution to test the concepts, in this research, the authors aimed at a single supply chain partner/company at only one stage illustrated in Figure 2, to provide interfaces to the immediate preceding and the immediate succeeding stage (Kirche et al., 2005). Choosing a wholesaler/distributor (the middle box in Figure 2) as the company to automate its information flows and material flows with e-sensors and e-controls interfacing to the manufacturers and retailers, as well as to internal storage and distribution centers, we developed the overall design architecture as illustrated in Figure 3.

The selected communication architecture is based on CORBA (Common Object Request Broker Architecture), a standard solution available from multiple vendors (Bolton, 2002). CORBA is an open system middleware with high scalability and potentially can serve an unlimited number of players and virtually any number of business processes and partners in the supply chain environment. As a communication infrastructure, it enables an integrated view of the production and distribution processes for an efficient demand management. Other benefits include continuous availability, business integration, resources availability on demand, and worldwide accessibility. The architecture presented in Figure 3 gives the wholesaler/distributor direct access to the assembly lines of the manufacturers and their shipping/transportation data via the operational

Figure 3. Architecture of distributed services for the wholesaler or distributor (after Kirche et al, 2005)



data server. Full communication with the retailers is available. The wholesaler/distributor company does have itself full control over their financial data server and optimization server. The detailed functions of this architecture are described in (Kirche et al., 2005).

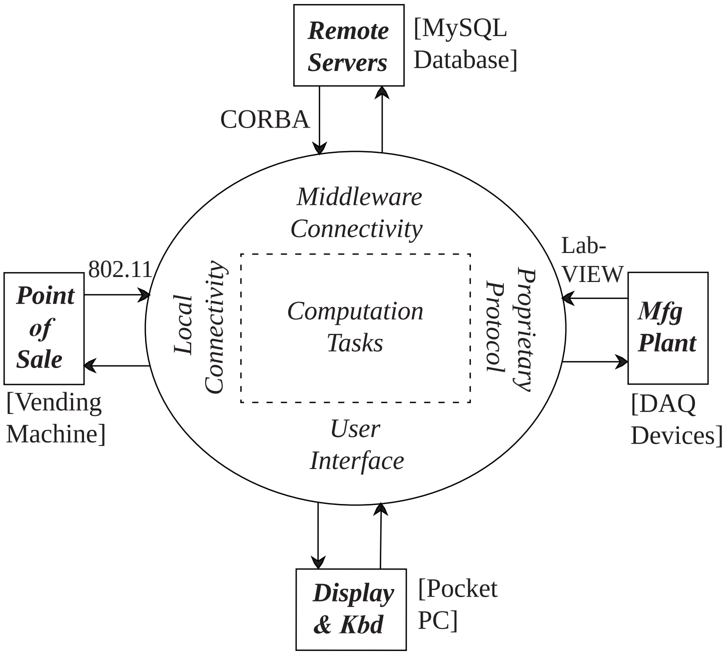
The goal of the real time system based on this architecture is to dynamically integrate end-to-end processes across the organization (key partners, manufacturers and retailers) to respond with speed to customer changes and market requirements. The real time CORBA framework enables employees to view current process capability and load on the system and provide immediate information to customers, by enabling tuning of resources and balancing workloads to maximize production efficiency and adapt to dynamically changing environment.

A sample implementation of the system architecture from Figure 3 is presented in the form of a context diagram in Figure 4. To achieve the project's objective, that is, remote data access to enterprise networks with e-sensors/e-controls, we provide the capability of accessing enterprise-wide systems from a remote location or a vehicle, for both customers and employees.

The overall view of the system is as follows:

- When access to manufacturers from Figure 2 is considered, the focus can be on *plant access* for immediate availability of data and functions of the system; in that case, a remote *e-sensor/e-control* application using LabVIEW data acquisition software (Sokoloff, 2004) comes into play, with graphical user interface capable of interacting with remote users connected via the Internet.
- When access to warehousing from Figure 2 is considered, the focus can be on *business integration* via a multi-purpose enterprise-wide network; in that case, a CORBA based framework is employed for a remote access

Figure 4. Context diagram of the system being implemented (DAQ stands for data acquisition and control, 802.11 stands for an IEEE Std 802.11 for wireless networks, SQL stands for standard query language)



to data objects identified as *e-sensors*, that can be stored on typical SQL database servers (Kirche et al., 2005).

From the network operation and connectivity perspective, e-sensors and e-controls provide business services, so they play the role of servers. Access to servers in this system is implemented via two general kinds of clients:

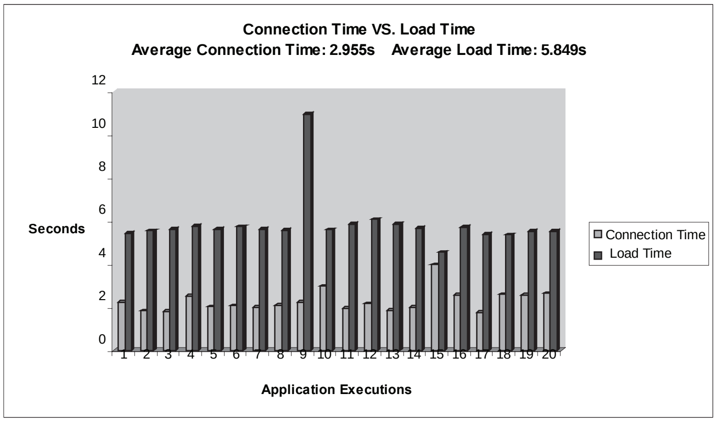
- When focus is on the *customer access* to obtain services, a cell phone location-aware application for business transactions has been developed, using order services as an example
- When focus is on the *employee access* to obtain services, such as conducting business on the road, a wireless PDA application for remote vending machine access has been developed, using the IEEE Std 802.11 wireless network protocol.

Several tests have been conducted to check behavior and performance of all four applications listed above and presented in Figure 4. For concision, it shows only a sample behavior of a PDA client via connectivity/performance test, in Figure 5. The graph shows how long it takes for the server to receive the connection request from the client application after the application was started. It is marked "Connection time." Another bar on the same chart shows how long the program itself took to load completely after being started (marked "Load time"). The connection graph was created to give an indication of how long, on average, one can expect for requests to be acknowledged and accepted by the server. Since all requests are handled the same way as the initial connection, this average connection time reflects sending and receiving of data to and from the client application. The load time is just a measure of performance for the application on the PDA itself. The data collected that way show the feasibility of all applications built within the SRS framework, as presented in Figure 2, for the architecture outlined in Figure 3.

CONCLUSION

This article briefly reviewed the current intelligent agent and supply chain paradigm and presented a conceptual framework for integrating e-collaboration tools in the operation and monitoring of products and services across value chain networks without hindering human autonomy. The demand-driven, sense-and-response framework model incorporates e-sensors and e-collaborators (humans using communication tools, computer software

Figure 5. PDA client connectivity/performance test



programs and its associated data-capturing hardware devices) throughout the supply chain. In practice, these e-sensors would be designed for data-capturing (sensing), monitoring and evaluating data (input) throughout the value chain, while humans collaborate and communicate in real-time, as tested in the above solution.

The implications of this new framework are that it contributes to the enhancement of the current SCM/DCM systems (such as Manugistics' demand planning system) that analyzes manufacturing, distribution and sales data against forecasted data. The addition of SRS sensors would signal human monitors (operations or supply chain managers) when changes are outside the established parameters. The main advantage of this approach is that sensors would be capable of assessing huge amounts of data and information quickly to respond to changes in the chain environment (supply and demand) without hindering human autonomy.

Ultimately, this approach would result in the semi-automated analysis and action (response) when a set of inputs are determined (sensed) without hindering human autonomy. That is, the e-sensors would gather the data and monitor and evaluate the exchange in information between designated servers in the e-partners (suppliers and distribution channel) networks. E-sensors would adjust plans and re-allocate resources and distribution routes when changes within established parameters are indicated. Particularly, the new approach will aid managers in the prevention of the bullwhip effect.

Having real time data is critical in managing supply chain efficiently. Typically companies need to synchronize orders considering type, quantity, location and timing of the delivery in order to reduce waste in the production and delivery process. The data collection and availability provided by the e-sensing infrastructure/architecture will allow for a collaborative environment, improve forecast accuracy and increase cross-enterprise integration among partners in the supply chain. E-sensors will also offer a more proactive solution to current ERP systems by giving them the ability to process in real time relevant constraints and simultaneously order the necessary material type and quantities from multiple sources.

This e-sensor concept opens additional research opportunities within the boundaries of the operations management and information technology fields, particularly in the development of new software-hardware interfaces, real-time data capturing devices and other associated technologies. Finally, it leads to future 'automated decision-making' where IT/operations managers can "embed decision-making capabilities in the normal flow of work" (Davenport and Harris, 2005).

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Chapter 3.6

An Ontology-Based Intelligent System Model for Semantic Information Processing

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ABSTRACT

In the context of increasing usage of intelligent agent and ontology technologies in business, this study explores the ways of adopting these technologies to revitalize current executive information systems (EIS) with a focus on semantic information scanning, filtering, and reporting/alerting. Executives' perceptions on an agent-based EIS are investigated through a focus group study in the UK, and the results are used to inform the design of such a system. A visualization prototype has been developed to demonstrate the main features of the system. This study presents a specific business domain for which ontology and intelligent agent technology could be applied to advance information processing for executives.

INTRODUCTION

Many executive information systems (EIS) failed to provide strategic significant and meaningful information to executives (Bussen & Myres, 1997; Rainer & Watson, 1995; Xu, Kaye, & Duan, 2003) despite enormous efforts to make EIS easy to use for executives. This is due to the nature of strategic information for executives and technological weakness in semantically scanning and processing information. On the one hand, information needed by executives is primarily about the external environmental changes, which is often diverse, dynamic, and usually scattered in locations and not readily available (Xu & Kaye, 1995); in addition, making sense of emerging events and signals from the environment relies on executive's interpretation and knowledge, which is subtle and tacit in nature (Choo, 1998). Moreover, an individual manager has limited capacity to notice and process all the information needed from the external environments, which results in limiting the scope of input coverage and the stretch of the output delivery (Martinsons, 1994; Xu & Kaye, 2002). On the other hand, semantic information processing technology, for example semantic indexing, ontology have the potential to advance future EIS design, however, they have not been applied to the domain of EIS. As suggested by Fensel, Harmelen, Klein, and Akkermans (2002), the main burden in information access, extraction, and interpretation, still rests with the human users. Current document management system on market exhibits the main weaknesses: (a) existing key-words-based search for information cannot avoid retrieving irrelevant information if a word has different meanings, or missing retrieving relevant information if different words have the same meaning; (b) current automatic agents do not possess the commonsense knowledge required to extract information from textual representations. Human browsing and reading are required to extract relevant information from various sources.

There are specific challenges to the domain of executive information processing. Data extraction from current EIS is usually based on key performance indicators (KPIs), which are drawn from existing databases or data warehouse. Information provided to executives is often internal and historical orientated (Xu et al., 2003a). Besides, information provided from EIS is often already existed in other forms (Koh & Watson, 1998). Moreover, information provision is reactive not proactive, that is executives need to initiate their information search. Automatic, systematic and proactive information scanning and provision for executives has yet been realized in practice. As a result, information can easily become stale in most current EIS due to static presentation of data and incapability of handling soft information semantically (Watson et al., 1997). Despite the over emphasis on easy of use, friendly interface and wireless access features, the usefulness of the information contents of EIS is often neglected (Xu et al., 2003). Although EIS has been enhanced with data manipulation and decision support tools, the key deficiency still remains, that is the lack of intelligent functionality (Liu, 1998a, b; Montgomery & Weinberg, 1998). For instance, very few EIS can systematically scan business environment, automatically and semantically filter information, and proactively report/alert significant information to executives.

With the emerging semantic Web and domain specific ontology, it is imperative to explore the possibilities and the potential of applying latest technologies in the domain of executive information systems. Within this context, a project was initiated to examine how intelligent agent and ontology-based semantic information processing could be applied to revitalize information processing for executives. This study reports the perceptions of executives towards an agent-based EIS, based on which an ontology driven EIS visualization prototype has been developed. The following sections will present a review of the intelligent and ontology technology, a brief introduction to the methodology, the main findings of executives' perception on agent-based EIS and the main features of an ontology driven intelligent EIS through the visualisation prototype.

LITERATURE REVIEW

Intelligent Agent Technology

Agent technology has contributed to intelligent systems development (Klusch, 2001). Intelligent agents are "*software entities that carry out some set of operations on behalf of a user or another program with some degree of independence or autonomy, and in doing so, employ some knowledge or representation of the user's goals or desires*"

(Maes, 1994). Demazeau and Muller (1990) elaborate that the word "agent" is used in a broad sense to describe an intelligent entity, acting rationally and intentionally with respect to its own goals. By "autonomous" agent, it means that each agent has its own existence, which is not justified by the existence of other agents. Several autonomous intelligent agents can coexist and can collaborate with other agents in a common world. Each agent may accomplish its own tasks, or cooperate with other agents to perform a personal or a global task. Research in artificial intelligence (AI) suggests that to design an agent which has full capability to control its environment appears a difficult task. Because the agent has to deal with multiple, uncertain, contradictory sources of information, and to deal with multiple, contextual, conflicting goals. Therefore, multi-agents are necessary. This requires cooperation between agents. Each agent is assigned a particular task, it accomplishes its own task and submits a solution to other agents, for example, a data collecting agent forwards collected data to an interpreting agent who interprets and transfers the information to the decision makers. If the problem can be decomposed into several subproblems, several agents may synchronously perform its own functions and submit a solution synchronously with other agents to an electronic co-ordinator. Each agent has an associated work pattern; this can be either:

- Agents are controlled by time events, executing at time intervals.
- Agents are triggered by system events (e.g., system start up, system close sown).
- Agents are triggered by other agents (e.g., information arrival).
- Agents are triggered by a combination of certain times dependent on certain conditions.

An agent is empowered to act on behalf of a user. It works according to encapsulated knowledge of rules, assumptions, and samples which either are predefined by systems developers, users, or learnt by the agent themselves. Maes (1994) describes how an agent learns from three different sources:

- By continuously "looking over the shoulder" of the user as the user is performing actions
- From direct and indirect user feedback, coaching
- From examples given explicitly by the user

Information Agent

Research on software agents are looking into ways to improve current information acquisition and processing activities from distributed information sources. Information agents are emerged as a major domain in intelligent software agent technology. The goal of an information agent is to perform the role of managing, manipulating, or collating information from one or many different information sources through advanced information acquisition and retrieval (Klusch 2001; Nwana 1996). Klusch (2001) defines an information agent as one that can satisfy one or more of the following requirements:

- **Information acquisition and management:** The agent is capable of providing transparent access to one or many heterogeneous information sources. It extracts, monitors, filters, analyzes and updates relevant information on behalf of its users or other agents. The acquisition of information includes advanced information retrieval from both internal and external distributed information.
- **Information synthesis and presentation:** The agent is able to filter and refine heterogeneous data and to provide unified, multidimensional views on relevant information to the user.

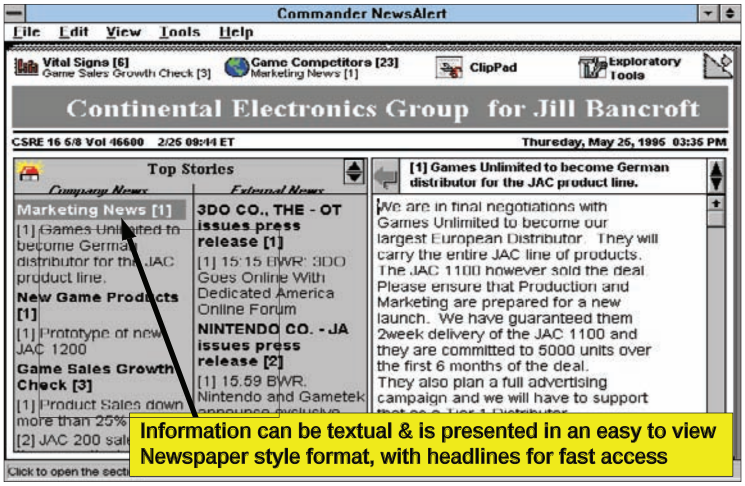
- **Intelligent user assistance:** The agent can dynamically adapt to changes in user preferences, the information and network environment.

It is envisaged that information agents can assist users in information scanning and monitoring, extracting and filtering, manipulating and interpreting, recommendation and notification. However, not many information agents have been developed and deployed to support executive information processing (Nwana, 1996; Wooldridge & Jennings, 1995; Wooldridge & Ciancarini, 2001). Most of information agents are currently under development in research labs (Liebermann, 1995, 1997; Liebermann, Fry & Weitzman, 2001; Moukas & Maes, 1998), or remain as conceptual models (Liu, 1998a, b). One exception is Comshare—an intelligent agent software for information detecting and alerting, which is named as Comshare Detect and Alert. The core component of the agent is a robot that is trained to watch targeted databases for changes, trends, and other patterns that are known to be of potential interest to a user. Like an electronic personal assistant, the robot continually watches the data sources, and re-evaluates the rules every time the data changes. The system comprises of a set of products, these include:

- **Robot for Dow Jones:** Monitors NewsFeeds and stock quotes from Dow Jones News/Retrieval
- **Robot for Reuters:** Monitors news and stock quotes provided by Reuters Business Alert server.
- **Robot for Lotus Notes:** Monitors Lotus Notes databases for keywords and phrases.
- **Robot for OLAP:** Monitors Commander OLAP Server data sets for complex numerical patterns or trends.
- **Comshare's News Alert:** Works as a personalized electronic newspaper as shown in Figure 1.

The agent sends out alert to the desktops of interested users. The alert is displayed in a personalized electronic newspaper, along with the background information and tools needed for detailed analysis. Many alerts are created, each with a different set of recipients. E-mail system provides a capable backbone for the delivery of alerts. Alerts can be deposited into the e-mail system by the software robot. A software agent, running on the desktop of each user, can be programmed to look for incoming alerts, pull them out of the e-mail system, and insert them into the electronic newspapers. Each edition of

Figure 1. Comshare's news alert: Electronic newspaper



Marketing News [1]
[1] Games Unlimited to become German distributor for the JAC product line.
New Game Products [1]
[1] Prototype of new JAC 1200
Game Sales Growth Check [3]
[1] Product Sales down more than 25%
[2] JAC 200 sal

3DO CO., THE - OT issues press release [1]
[1] 15:15 BWR: 3DO Goes Online With Dedicated America Online Forum
NINTENDO CO. - JA issues press release [2]
[1] 15.59 BWR. Nintendo and Gametek

[1] Games Unlimited to become German distributor for the JAC product line.

We are in final negotiations with Games Unlimited to become our largest European Distributor. They will carry the entire JAC line of products. The JAC 1100 however sold the deal. Please ensure that Production and Marketing are prepared for a new launch. We have guaranteed them 2week delivery of the JAC 1100 and they are committed to 5000 units over the first 6 months of the deal. They also plan a full advertising campaign and we will have to support

Information can be textual & is presented in an easy to view Newspaper style format, with headlines for fast access the newspaper is personalised for the individual reader and consists of a front page for the most important news stories followed by a series of individual news sections. Each user determines which sections appear in their personal newspaper and which types of alerts will appear. NewsAlert can also be used to broadcast news, where every user sees the same news, regardless of their individual interests. With the NewsAlert, there is a ClipPad which is a standard application serves as the electronic equivalent of a pair of scissors and a file box, which the newspaper reader uses to snip, save, and add commentary to articles or segments of articles from the news paper. The ClipPad also provides ready access to e-mail and Fax. Exploratory tools are available, so that readers can investigate any story and drill-down to the source data.

Although most information agents have been conceptualized to support automatic information scanning, processing, and reporting, a bottleneck for realizing their full potential is the lack of semantic data processing capability, which make current agent-based EIS attempts less appearing to executives.

The Challenge: Semantic Data Processing and Ontology

Heterogeneous sources and types of external information pose challenges to effective information scanning and processing, mainly because most of the information is textual and disseminated in various formats. Human knowledge is needed to browse and identify the most relevant information contained in the text file. Most of the current text retrieval systems are keywords matching based application programs that discover word or phrases encountered in the text. Keywords-based scanning could lead to information irrelevant, as indicated earlier, one word could have several different meanings in different context, or several terms may designate to the same concept. As a result, keywords based information retrieval system can hardly determine the correct meaning of the word encountered in different context, which can significantly degrade a query's precision and recall (Lu, Dong, & Fotouhi, 2003).

Another approach to retrieve text data is syntactic analysis. Syntactic based text retrieval system attempts to overcome the problem of keywords based scanning (Silverster, Genuardi, & Klingbiel, 1994). This system uses a recognition dictionary to assign syntax to each word encountered in the text, and to use Machine Phrase Selection program to string words together according to specified grammar rules. However, such a system requires large rules to handle different meanings of context sensitive words, and also needs enormous amount of information to disambiguate words. This makes the system's use impracticable. Problem also exists in understanding the meaning of the text, as the attention of the syntactic system is to form rather than content (Dorr, 1988). Only limited semantics can be derived from syntactic content of the Web pages (Lu, Dong, & Fotouhi, 2003).

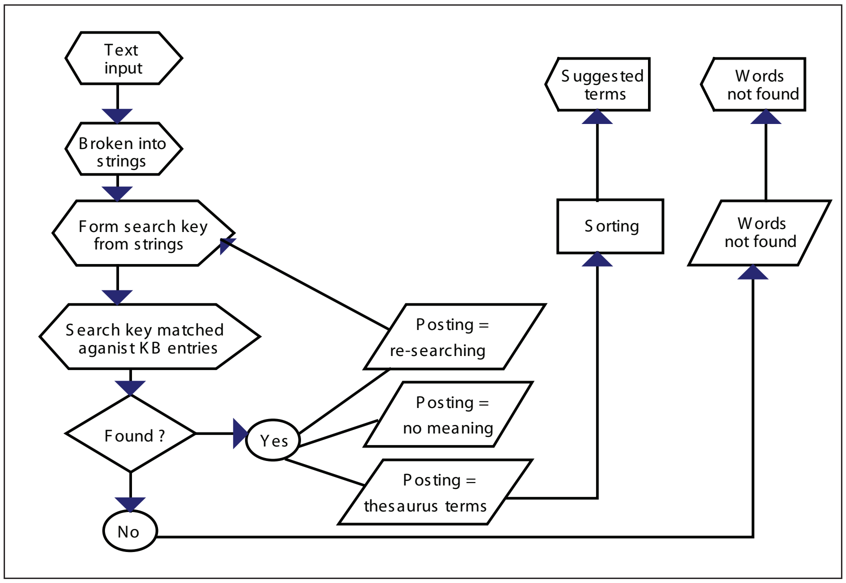
The above approaches pose challenge to transform distributed information into a semantically enriched information. Semantic data processing may offer a better solution to assign meaning to information and thus retrieve potentially relevant information. Several systems have been built to overcome the problems based on the idea of annotating Web pages with special HTML tags to represent semantics, including simple HTML ontology extensions system (SHOE) (Luke, Spector, Rager, & Hendler, 1997). The limitation is that they can only process Web pages that are annotated with these HTML tags, and there is no agreement upon a universally acceptable set of HTML tags. XML is another mark-up language that provides a text-based means to describe many different kinds of data. XML is a much more adequate means for knowledge representation, however, it can represent only some semantic properties through its syntactic structure.

Semantic-based text retrieval system has advantages over keywords based, and syntactic-based text scanning system. Silvester et al. (1994) introduced a machine aided indexing (MAI) system used by National Aeronautics and Space Administration (NASA) Centre for AeroSpace Information, which is a semantic-based indexing system. The MAI system is based on the use of "domain-specific terminology" as suggested by Melby (1990). This refers to words and phrases that are not broad in their meanings but that have domain-specific, semantically unambiguous, indexable concepts. These text words and phrases are matched against a list of text words and phrases that are generally synonymous to NASA's thesaurus terms. This system automatically suggests a set of candidate terms from NASA's controlled vocabulary for any designated natural language text input. Figure 2 depicts the procedure of the system.

The system consists of: (a) a text processor, the main function of this program is to identify the source of the text to be processed, to break the text into word strings, to delineate word strings found in natural language text; (b) a knowledge base (KB) which contains the Key field (Phrase Matching File) with more than 115,000 entries, and the Posting term field (NASA's thesaurus terms)—this is the dataset that provides the translations from natural language to NASA's thesaurus terms; (c) modular programs, this is to construct the search key in the string, look up the search key in the knowledge base, and return the output of the search to the index viewer or to the text processor. Although the system is mainly used for text indexing purpose, it allows limited semantics to be described by the controlled thesaurus terms. Using domain specific terminologies to automate machine indexing is akin to the ontology approach.

Ontology is key technology used to describe the semantics of information exchange. Berners-Lee (2001) suggests that an ontology is a document that describes a vocabulary of terms for communication between humans and automated agents. The most often cited definition for ontology is an explicit specification of a conceptualisation (Gruber, 1993). Nelson and Nelson (2005) suggest that an ontology can be thought of as a vocabulary (a set of words), a grammar (the set of rules or combining words into larger structures), and semantics (the meanings of the words and the large structure) all

Figure 2. Overview of NASA's online machine aided indexing system (MAI)



defined within a specific domain. Ontologies are useful because they encourage the standardization of the terms used to represent knowledge about a domain. In the context of business information, it is possible to have an executive ontology by which standard terms and specific meaning are defined to guide machine scanning and filtering. In addition, source documents provided to executives can be annotated by using ontology-annotation tools. In this way, machines are able to understand the meanings—semantics of the documents. Various ontology tools have been developed for building semantic data on the Web (Barros, Goncalves & Santos, 1998; Erdmann & Studer, 2001), and for digital library (Shum, Motta, & Domingue, 2000), but ontology specific to the domain of executive information processing have yet been developed, except a recent proposal (Camponovo, Ondrus & Pigneur, 2005) of an ontology for environment scanning that sheds some lights on this yet exploited area.

In summary, it appears that intelligent agents and ontology have the potential to advance executive information processing through automatic, semantic information scanning, refining, and sense making of data. The methodological setting described in the Methodology section aims to empirically examine executives' perception towards an agent-based executive support system. The findings will inform the development of an agent-based ontology driven EIS system or prototype.

METHODOLOGY

The methodological design consists two phases: the first phase is to examine executives' perceptions on using agent based EIS through a focus group study. The second phase is to develop an agent-base EIS visualization prototype on the Web in order to demonstrate the main features of such a system. The first phase involves a focus group study with 41 middle towards top-level managers in the U.K. The size of the focus group is about 10 persons per group. Each session begins with a brief statement on the purpose of the focus group, the confidentiality and ground rules for the discussion, that is, one participant talks at a time. The discussion questions, the related concepts and the use of software agents are also introduced prior to the discussion. Each focus group session took between 45 minutes to 1 hour to complete. Data is initially organized into meaningful themes according to predefined or newly emerging themes and categories. Thematic qualitative analysis (TQA) (Nicholas & Anderson, 2003) is used to conduct a detailed interpretive conceptual analysis and mapping. Meanings were sought from the transcripts to identify consensus, dilemmas, and contradictions. Selected quotes are directly presented as evidence.

In the second phase, an ontology driven intelligent system model and a visualisation prototype is designed to demonstrate the main features of the system for semantic information processing. The visualization prototype serves as a demonstration tool, rather than a tool for technological testing or implementation.

Findings

1. **Agent-based EIS scenarios:** Managers seem well perceived the importance of agent based EIS, and expect such a system to work for them by giving the following scenarios:

   Scenario 1: *"… you set up to run (the agent-based EIS) overnight, or whatever, and when I come in the morning, there will be something to look at …" "If the agent hasn't searched for a while, it could actually suggest to the user."*

   Scenario 2: *"You want to actually have the agent to be aware of that daily change. Today, priority for me is one thing. Tomor-*

row, it's something completely different. Now if I define within the agent, this is what I need now, tomorrow could be something completely different."

Scenario 3: "*… you could say to the system, 'get me half of page of view', it will then search all sources and present them in half a page.*"

Some issues emerged from the focus group discussions that may shape the development of an agent based EIS. These issues are described below:

2. **Semantic information processing:** Participants recognize the importance of obtaining semantically enriched information due to the different meanings that can be applied to the same word. As a result, they are concerned with the incomplete information processing caused by the lack of semantic information. Participants also express their frustration over the limitation of current search engine in natural language processing. Some managers perceive semantic information can be improved through better processing of natural language, in which the system is capable of categorizing natural language texts into predefined content categories. For example:

   "*If I am looking for something in my business, they might be in my head ten or eleven different words, which mean the same thing. But in various filter to get them, I have to put all those in. And then I might be missing something, because somebody else might call it something else.*"

   "*… is the frustration with natural language, like searching through the Internet. Conventional searching is giving you too much information, not the right information or whatever.*"

   "I think the challenge is to make sure that it conveys your meaning that (the EIS) provides needed information, and the way to improve is to understand the natural language."

3. **An executive controlled, personalized, adaptable learning system:** Participants raise the importance of adaptability and the learning capability of the agents, that is, the system should be flexible to adapt to changing situation and individual executive's managerial behavior through some kind of learning and user feedback. One manager suggests that the system *must* have a sort of flexibility within itself to retain (some of your interests and thoughts) as well as to develop. They further argue that the big mistake made is one usually driven by the software developer to drive what the rules are, for example, what we want to search, how you want to search, how you use it, and this has to be tailored into the context of the organization. The key to ensure EIS flexibility and adaptability is that the agent knows very clearly what the executive is looking for and what structure or format the executive would like to receive. Most managers suggest that great efforts are needed in order to coach the agent in order to enhance its learning capability, for example:

   "*I think the fact is that both systems would have learning curve. One is actually the programme itself, you wouldn't actually know what it's working on. And the people who are using it would actually go and say, 'oh, I did that last week and get the information or whatsoever'. From there, the system learns and how to turn and change.*" "*…it's the effort of coaching your agent*"; "*… more effort needed to train the agent.*"

   The finding suggests that the agent should understand the relevant characteristics of end-users. Hence, the setting of user profile and preferences, and domain specific ontology need to be established.

4. **Functionalities: Semantic scanning-filtering; categorizing-ranking-alerting, and analytical support:** Most managers tend to agree that data overload is a problem facing executives, thus filtering function is needed. One manager suggests that there is an immediate need for a filtering mechanism because of the volume of workload. For example:

   "*Conventional searching gives you too much information, but not the right information.*"

   "*I agree with the information overload, the quantity of information pouring into my consciousness*"; "*There's plenty of super fluid material that is going to me that there is no filter in between ...*"

In addition to semantic scanning and filtering function that enables systematically scan and retain relevant information, participants suggest a number of additional features of an agent based EIS. These features include information categorizing, ranking, alerting function, which will enable executives to manipulate information and to be informed proactively with new information. Managers comment that the system should have:

"*... the ability to filter and rank the importance of information … categorise the search results according to meaningful topics*"; "*…it should have different ways of organising information, for example, information of the day before, information of the day after.*"

"*Once the information comes in, the executive can get a rule of thumb, so the agent probably can give a flash, for example, about new information.*" "*… it will actually suggest things to you on what you are trying to look for.*"

Some managers expect an agent-based EIS to support decision analysis and decision-making in addition to strategic information provision. The key functions will include analytical tools such as data analysis, modeling, forecasting, comparison, drilling down, strategic mapping, and so forth. As generated from the group discussion, managers want the EIS:

"*to predict and forecast as well, but that will be the next level*"; " *to provide recommendation based on the information provided*";

However, not all executives agree on the filtering function of an EIS. The main concerns are the risk of filtering out potentially useful and important information, as expressed by a manager as follows:

"*There's a great possibility, very high risk, you are actually filtering out fringe of information that could be probably more beneficial to you than the initial information that you are looking for in the first place.*"

Although one participant expressed that "*… the raw data needs to be processed in a meaningful way*", most executives are sceptical to the interpreting function of the EIS. Most executives tend to agree that interpretation should be done by the manager.

"*I have extreme concern about that interpretation function*"; "*I believe interpretation should be done by executive … I think it has to be a low level interpretation first*"; "*…certainly for me, I interpret the data myself.*"

5. **Executives need a small amount of information that is manageable:** Participants were very concerned with the time needed

in processing information. Managers express that the key issue is to have the right balance of the amount of information. It is evident from the following statements:

"*It's about time constraints. We are talking about using executive time effectively and efficiently*"; "*Due to the lack of time, it should be manageable, with a small amount of information*"; "*The key driver is time, because the time you need to spend on the system. You only spend that time if it's key information that you need firstly according to your role*."

It suggests that the amount of information provided must be manageable and the time spent on processing the information must be kept to a minimum.

6. **Executives are concerned with the impact of using an agent based system:** Executives are concerned with the possible impact of the agent-based EIS on their information processing behavior. Some participants feared that their managerial roles could be changed or replaced by the system. The concerns are "*the system could actually force me to look at thing I don't want to look at …*"; "*Would it replace executive when it learns too much?*" and "*could it lead to the redundancy of managers?*"

    The main impact perceived by executives is over-dependent on the system, which will limit executives' personal development, as well as creativity as a senior manager. They express that:

    "*this system would actually limit the development of senior executives.*"; "*…the concern is this limiting development kept coming back to me.*"; "*…becoming more and more dependent on the software and not thinking for themselves, reducing creativity.*"; "*My another concern is probably people would completely start depending on the system rather than using their own brain.*";"*…sitting in front of computer, limit the creativity, losing the skills …*"

    An agent-based EIS may play limited role in directly support managerial decision making. Executives treated EIS as a complimentary tool that supports executive information processing activities rather than in any way to replace it. The main reason explained by the participants is intuitive nature of management decisions that require human intelligent instinct. However, the system has been perceived useful in the way that "*senior executives would use it more as gaining background knowledge and keeping up-to-date*", and "*It could be a useful source to back up some of your tacit knowledge*."

7. **Other Issues:**
    Ease of Use: It is believed that executive information system (EIS) should be easy to use, incorporate standards for good user interfaces, and allow quick access to vast amount of data by combining graphic, tabular and textual information on a single screen. Participants in this study suggest that the intelligent agent based EIS should be accessible, manageable and simple for users to use. A manager states, "*I think it should be simple for recipient to utilise the information*."

    Security: Information and system security have been highlighted as another concern for developing an agent-based EIS, particularly the confidentiality in the process of analyzing and interpreting information. As expressed by the manager that the software agent needs to have the real confidence in analyzing information, and be confidential if we ask software agents to interpret.

Cost Saving and Culture Change: One manager comments that his concern is the cost, and it has to be a cost-effective way particularly for information filtering. Change is inevitable for implementing agent based EIS, this may include not only the system itself, but also the vision, process, and culture. A manager comments that it might be more of a cultural challenge to get the system to work for them.

In summary, the criteria for an agent-based EIS from executive's perspective is self evident as disclosed above. Although some of the concerns are not subject to technological solutions, for example the concerns of the impact, the cost, and culture issues, their views on how an agent-based EIS will work for them shed light on how such a system shall be developed. The section titled "An Ontology Driven Intelligent EIS Model and Prototype" presents our initial efforts to turn executives' views into a system model and a visible prototype, which demonstrates the key features of the functionality of an ontology driven intelligent system for semantic information processing.

AN ONTOLOGY DRIVEN INTELLIGENT EIS MODEL AND PROTOTYPE

The key features of an ontology driven intelligent EIS can be summarised as below:

- Systematic scanning of information from multiple internal and external sources. The scanning engine incorporates executive ontology, and/or semantic indexing to ensure relevant information being widely scanned.
- Semantically filtering information to the level that the executives like to receive. The filter shall be driven by learning agents that filter out irrelevant information according to user profile, criteria defined by the user, user feedback, case based reasoning, and knowledge base.
- Automatic categorizing, ranking, prioritizing items according to its significance, and alerting significant news/unsolicited/unexpected information to the executives. Limited interpretation and recommendation can be offered as an advanced function. Intelligent agents perform these tasks according to user profile, user feedback and coaching, and agents learn from cases and examples.
- The system will integrate tools that support intelligence disseminating and sharing, allowing executives to manipulate information—drill down, track original information sources, and to support decision analysis.

The main agents and the bases underpinning agents' activity are depicted in Figure 3.

A visualization prototype of this model has been developed on the Web using Active Server Pages (ASP) and MySQL database. It is beyond the scope of this study to use the prototype in an online setting with live data stream. Hence, the prototype is not built for technological testing or as a technological solution. Figure 4 shows one of the interface windows of an ontology driven intelligent system for executives.

The left-hand window is an environment for executives to browse or search for both internal and external information. This window also serves as a personalized electronic newspaper and has a function to alert executives when unexpected (unsolicited) information has been detected. This is a workspace that integrates, aggregates, and presents strategic significant information from multiple sources, including the Internet, newsfeeds (press, subordinate, employee, customers, etc.), internal systems (ERP, CRM), internal reports, data warehouses, images, and file server. This is different from an enterprise information portal (EIP) in that the process behind the window

Figure 3. Model of an ontology driven intelligent system

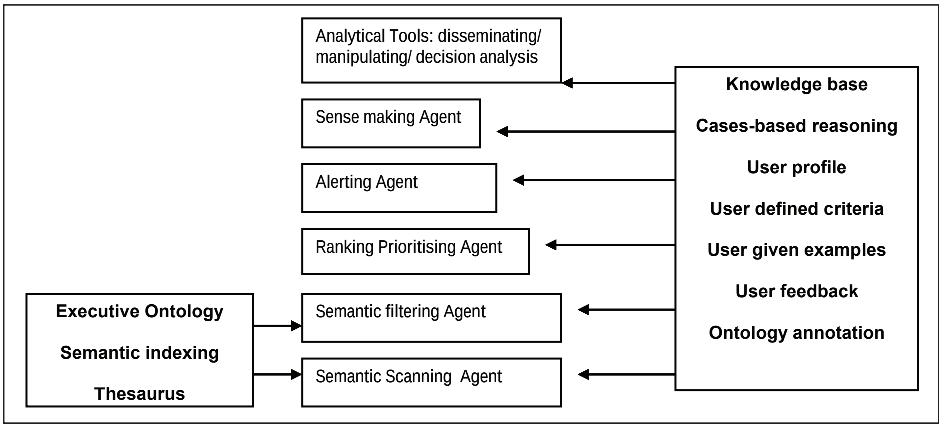
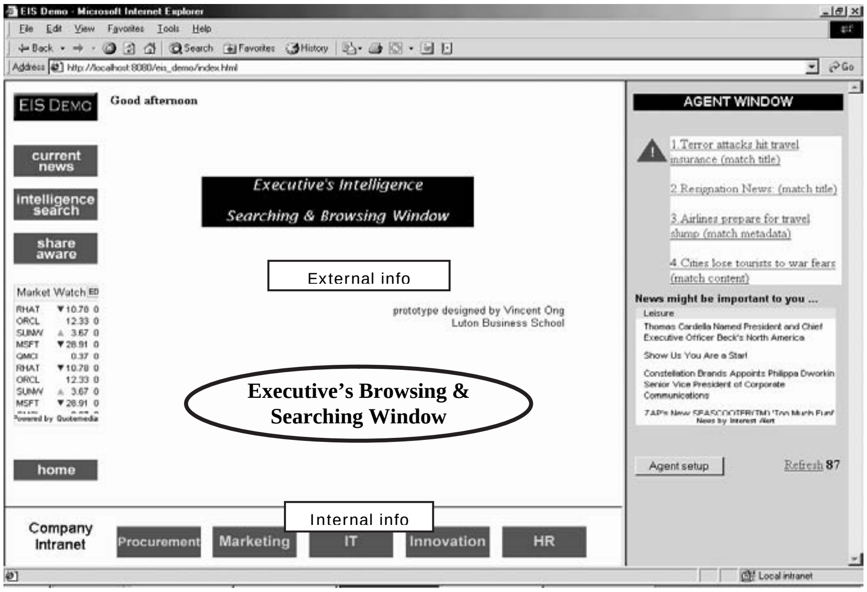


Figure 4. Strategic intelligence browsing, searching, and alerting



1. Terror attacks hit travel insurance (match title)

2. Resignation News: (match title)

3. Airlines prepare for travel slump (match metadata)

4. Cities lose tourists to war fears (match content)

News might be important to you ...

Leisure

Thomas Cardella Named President and Chief Executive Officer Beck's North America

Show Us You Are a Star!

Constellation Brands Appoints Philippa Dworkin Senior Vice President of Corporate Communications

ZAP's New SEASCOOTER(TM) 'Too Much Fun'

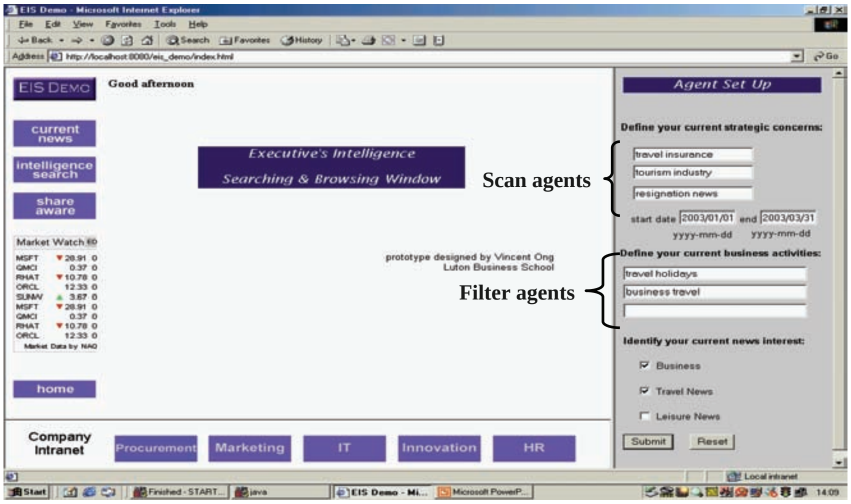
News by Interest Alert

is driven by intelligent agent and ontology that is specific to the individual executive. Hence, the information reported/alerted here has been semantically processed for relevancy and significance, and has been personalized for individual executive's managerial role and preferences.

The agent set-up window is shown in Figure 5. The agents could comprise past information search activities and predefined information needs in "*user profiles*", which is generated by a learning agent, or defined by the user. The user profile can consist of executive's personal profile, executive's information needs and interests, executive roles, and organizational environment profile, which enable software agents to perform domain-specific acquisition and filtering of information. As a result, information processing becomes more personalized to the executive.

The "agent setup" function allows executives to coach the agents by using natural language to define information needs and changes. In order for the agents to understand semantic meaning

Figure 5. Agent set up for semantic information processing using ontology



Address: http://localhost:8080/eis_demo/index.html

Define your current strategic concerns:
travel insurance
tourism industry
resignation news
start date 2003/01/01 end 2003/03/31

Define your current business activities:
travel holidays
business travel

Identify your current news interest:
☑ Business
☑ Travel News
☐ Leisure News

Market Watch		
MSFT	▼28.91	0
QMCI	0.37	0
RHAT	▼10.78	0
ORCL	12.33	0
SUNW	▲3.67	0
MSFT	▼28.91	0
QMCI	0.37	0
RHAT	▼10.78	0
ORCL	12.33	0

of executives' requests and enquiry, executive ontology shall be configured to the search engines for semantic scanning and refining. Different ontologies may be needed, for example, an environmental scanning ontology, and an information refining ontology. For example, the term "*Business*", "*Travel news*", "*Leisure News*" displayed on the right-hand window shall be the concepts defined with agreed meaning for a specific industry or an individual executive. The semantic meaning and coverage of word "business" in travel industry will be different from that of chemical industry. Thus, even using the same word, different ontologies will result in different information being scanned and processed. The ontology will define its domain specific concepts and a scheme showing relationship with other related concepts. The ontology-driven configuration will ensure only relevant information is scanned and filtered. Semantic indexing system using domain specific thesaurus may be an alternative solution. For example, synonymous terms related to "business" that is specific to the industry are defined in a controlled thesaurus. It is expected that executives can also use ontology-annotation tools to annotate items/signals to assist agent's learning and knowledge sharing.

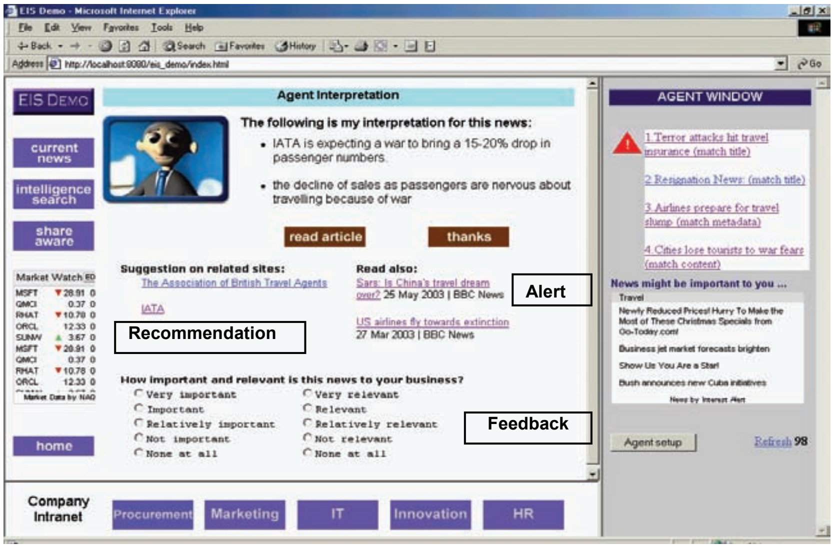
In addition to the information provided by the alert agents, an interpretation agent may analyze the information using AI techniques, such as case base reasoning, production rules, and machine learning. Figure 6 shows a sample of agent interpretation.

It is essential that executives give explicit feedback to the information agents through a rating system or using ontology annotation tools. Whenever the executive finds that the agents fail to provide relevant and less significant information, the executive can always give comments to the agents in order to improve his user profiles. Figure 7 shows an example of user giving feedback to agents.

IMPLICATION

The applications of software agents and ontology for semantic information processing are still in its infantry, particularly in the domain of executive information processing. The implications of this study are: firstly, the domain specific issues concerning executive information processing are revealed, which shed light on future development of agent-based EIS and other systems related to

Figure 6. Agent supported interpretation and alerting



The following is my interpretation for this news:

- IATA is expecting a war to bring a 15-20% drop in passenger numbers.
- the decline of sales as passengers are nervous about travelling because of war

Suggestion on related sites:

The Association of British Travel Agents

IATA

Read also:

Sars: Is China's travel dream over? 25 May 2003 | BBC News

US airlines fly towards extinction 27 Mar 2003 | BBC News

How important and relevant is this news to your business?

○ Very important	○ Very relevant
○ Important	○ Relevant
○ Relatively important	○ Relatively relevant
○ Not important	○ Not relevant
○ None at all	○ None at all

1 Terror attacks hit travel insurance (match title)

2 Resignation News: (match title)

3 Airlines prepare for travel slump (match metadata)

4 Cities lose tourists to war fears (match content)

News might be important to you ...

Travel

Newly Reduced Prices! Hurry To Make the Most of These Christmas Specials from Go-Today.com!

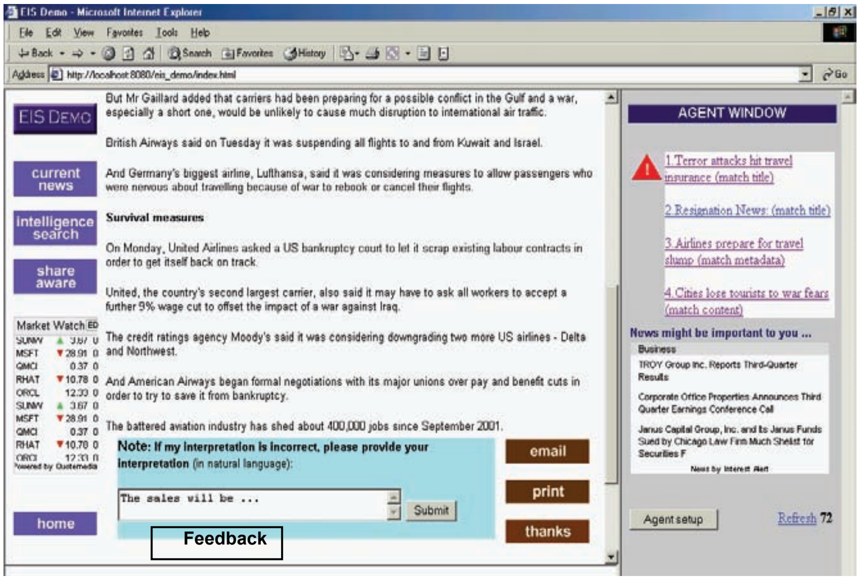
Business jet market forecasts brighten

Show Us You Are a Star!

Bush announces new Cuba initiatives

News by Interest Alert

Figure 7. User's explicit feedback to agent



But Mr Gaillard added that carriers had been preparing for a possible conflict in the Gulf and a war, especially a short one, would be unlikely to cause much disruption to international air traffic.

British Airways said on Tuesday it was suspending all flights to and from Kuwait and Israel.

And Germany's biggest airline, Lufthansa, said it was considering measures to allow passengers who were nervous about travelling because of war to rebook or cancel their flights.

Survival measures

On Monday, United Airlines asked a US bankruptcy court to let it scrap existing labour contracts in order to get itself back on track.

United, the country's second largest carrier, also said it may have to ask all workers to accept a further 9% wage cut to offset the impact of a war against Iraq.

The credit ratings agency Moody's said it was considering downgrading two more US airlines - Delta and Northwest.

And American Airways began formal negotiations with its major unions over pay and benefit cuts in order to try to save it from bankruptcy.

The battered aviation industry has shed about 400,000 jobs since September 2001.

Note: If my interpretation is incorrect, please provide your interpretation (in natural language):

`The sales will be ...`

1.Terror attacks hit travel insurance (match title)

2.Resignation News: (match title)

3.Airlines prepare for travel slump (match metadata)

4.Cities lose tourists to war fears (match content)

News might be important to you ...

Business

TROY Group Inc. Reports Third-Quarter Results

Corporate Office Properties Announces Third Quarter Earnings Conference Call

Janus Capital Group, Inc. and Its Janus Funds Sued by Chicago Law Firm Much Shelist for Securities F

News by Interest Alert

executives' information acquisition and processing. Secondly, this study takes an innovative step to explore the possibility of applying ontologies to agent-based EIS for the purpose of semantic information scanning and processing. Although such an executive ontology has not yet been developed within this study, the novelty of this exploration is expected to generate more interests and efforts in developing and applying ontology in the domain of executive support system. Thirdly, the Web-based interface prototype sets an example that could stimulate ontology and intelligent system developers to develop system solutions related to the work of executive information processing. Lastly, developing and implementing an agent-based EIS and executive ontology need executives' participation and support, for example executives annotate information received and give feedback. Considerations also need to be given to nontechnical issues such as cost, impact on managerial work, culture changes, and security of information.

CONCLUSION

Our study explored the opportunities of applying agent and ontology technologies in the domain of executive information processing, and revealed executives' perceptions towards developing an ontology-driven intelligent executive information system. Many executives perceive such a system useful by particularly using the system for semantic information scanning, filtering, and alerting as well as advanced executive decision analysis and support. However, the capability of this type of system shall not be exaggerated, as executives see it as only a useful supplementary tool. Executives tend to make sense of data (interpretation) and make intuitive decisions themselves. Executives also need a manageable amount of significant information from EIS. This implies that an agent-based EIS shall be able to selectively and semantically scan and filter information and report only significant information to executives.

The technological challenges rest on machine learning for semantic information scanning and processing. A range of tools for semantic information processing are available, but these tools are not yet used for executive information processing. In particular, executive ontology has not yet been considered as a potential tool to advance EIS design. The integration of intelligent and ontology offers great potential to revitalize EIS. Its realization however, relies on the development of functionality of the information agents, the executive ontology, and an environment that can facilitate agent learning.

Future studies can be carried out to address some of the limitations of this study in three directions, firstly, to develop executive ontology that is specific to industry sector and individual executive. Secondly, to continue developing a fully functional Web-based prototype/system that incorporates intelligent information agent and executive ontology with an emphasis on semantic strategic information scanning, filtering, and alerting and thirdly, to explore suitable ways of the interaction between executives and the agents through coaching and learning. It is hoped that this study will attract more research into this yet being exploited, but significant arena.

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Chapter 3.7

Intelligent Design Advisor:
A Knowledge-Based Information System Approach for Product Development and Design

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ABSTRACT

The rapid development of computing technology has facilitated its use in engineering design and manufacturing at an increasing rate. To deliver high quality, low cost products with reduced lead times, companies are focusing their efforts on leveraging this technology through the development of knowledge-based systems such as an IDA. An IDA, which can also be referred to as a design information system, is a part of the overall enterprise information system framework, and plays an important role in improving competitiveness in product development oriented companies. Not only must such a system utilize human expertise and address CE issues in decision making, it must also lead to the preservation and transfer of technical knowledge to minimize the knowledge loss from organizational moves such as personnel retirements and company relocation. The emphasis in CE is to consider downstream aspects of different phases in the product life cycle as early as possible in the design stage. These aspects include production process planning and realization, manufacturing and assembly resources, maintainability, costing and other factors. Both human expertise and downstream aspects predominantly consist of information that is descriptive. This paper discusses the structure and development of a knowledge-based design information system that can convert this descriptive information into forms that are suitable for embedding within decision-making algorithms. Information in such a system is sorted in terms of its nature into three groups: input data infor-

mation, constraint information, and objective information, all having different representations. Information is also mapped to the relevant design objectives and ranked in importance to facilitate the trade-off analysis.

INTRODUCTION

Concurrent Engineering (CE) has become a very attractive and enthusiastically discussed product development approach in recent times. To realize the concurrent design process, a key demand is to find an appropriate way to present life cycle information to the design stage. On the other hand, designs are normally required to achieve a set of objectives. Generally, these objectives are correlated to each other with either positive or negative dependencies. Therefore, solving a design problem always involves numerous trade-off decisions. It is a big challenge even for an expert to find an optimal compromising point and almost an impossible task for a less experienced designer. Thus, designers need a computer system to support the design course by providing them with the right advice at the right time (Reidsema, 2001). The rapid development in computer science and information technology has given birth to many new software tools for product development. Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), Computer-Aided Engineering (CAE), Computer-Aided Process Planning (CAPP), Design for Manufacturing (DFM), and Design for Assembly (DFA) are quite commonly-used tools in today's product development practice. To a large or less extent, these tools adopt some aspects of the concurrent approach through the inclusion of product data management and collaborative work tool functionalities. Quality Function Deployment (QFD) is another successful product development technique which is also compatible with the idea of CE as it provides a systematic methodology for ensuring that constraints and objectives identified in the client specification phase are maintained through the entire development phase. Although these systems may provide the designer with very good support at specific points, they lack the ability to observe the design problem from an overall point of view.

Knowledge Based Engineering (KBE) represents potentially the most significant product development technique to date. It provides a new strategic approach for realizing the concurrent product development process to improve effectiveness in design and manufacturing. It also facilitates the preservation and transfer of knowledge in companies that operate in a physically-distributed environment. Not only does it utilize traditional elements in the design process such as geometric models, it also captures other underlying attributes of design such as experience and expertise. In our research, an Intelligent Design Advisor (IDA) is proposed based on this approach in an integrated, concurrent engineering environment. On the one hand, it addresses the "life cycle" design challenges by incorporating multi-disciplinary knowledge resources into the system to achieve design and manufacturing intent, and other subsequent requirements generated through the product's distribution, use, and disposal. On the other hand, it utilizes an expert's knowledge in the course of product development to guide less experienced designers. The system can also suggest design alternatives in terms of cost, time, equipment availability, or other critical requirements to enable the creation of a fully-engineered design by acquiring, representing, planning, reasoning and then communicating the intent of the design process. Thus, it can provide the necessary degree of intelligent interaction that enhances the designers own inherent skills and creativity (Cooper, Fan, & Li, 2001).

To implement the IDA, all related product information, including raw numerical input data, physical design and manufacturing constraints, design objectives and various other life cycle requirements, as well as human expertise, must be stored in a design information system. The information must be attained and saved in a structured and reusable manner to emulate expert-like problem-solving styles (Yang & Reidsema, 2004), which can improve overall efficiency and solution accuracy, and reduce development costs. With such an information system, the generation and evaluation of new design alternatives can occur quickly and easily by changing and analyzing only the relevant parts of the system within the IDA. This frees the engineer from time-intensive, detailed engineering tasks such as repetitive and unnecessary calculations and allows more time for creative design work. An IDA also provides a proprietary intellectual base to avoid the loss of knowledge within a company, and can guide new designers towards a solution which represents "best practice" according to company requirements.

As a part of the whole Enterprise Information System (EIS), an IDA plays an important role in a product-development-oriented company. Unlike other earlier information systems such as Material Requirement Planning (MRP) and Manufacturing Resource Planning (MRPII), which focus on manufacturing aspects, an IDA is concerned with the product development and the design function of an organization. It may also interact with other information systems, such as Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM), to increase functional integration within a company and to perform information verification, characterization, development and distribution in the overall perspective of the company.

In this paper, a brief literature review is first carried out, and the basic requirements for a KBE system are summarized. Then, a matrix-based approach to represent design information within a concurrent product development environment is explained including its configuration, working principle and failure recovery mechanism.

LITERATURE REVIEW

KBE has found a large number of applications in product and process design. Chau and Albermani (2002) have developed a system prototype to assist in the preliminary design of liquid retaining structures by providing expert advice to the designer in selection of design criteria, design parameters and optimum structural section based on the minimum cost. Kwong, Smith, and Lau (1997) presented a blackboard-based system for concurrent process design of injection molding to obtain process solutions quickly and easily. Both systems are focused on the particular products. They are difficult to extend to the other applications because they do not have a general implementation frame. Reidsema and Szczerbicki (2001) discussed the development of a general knowledge-based system for the design planning process in concurrent engineering by utilizing the Blackboard Database Architecture (BBDA). However, this system is mainly concerned with process planning rather than specific design parameter selection. There are also some commercial KBE systems; among them, ICAD is one of the first developed and most commercially successful system. It consists of two interfaces: the CAD interface handles the geometric model and the knowledge interface deals with the programming of rules (KTI, ICAD). Although ICAD provides a connection between the actual geometry and the associated knowledge, the design process is still a repetitive loop, and thus efficiency is compromised. Moreover, knowledge preservation in ICAD is not emphasized. Studer, Benjamins, and Fensel (1998) pointed out that reuse of knowledge is advantageous in reducing development costs of knowledge-based systems because such a system can be constructed from ready-made modules instead of being developed from scratch. Recent research on KBE has concentrated on the knowledge preservation and utilization within companies and institutions. A useful approach is the case-based reasoning approach (Pokojski, Okapiec, & Witkowski, 2002; Pokojski, Strzelecki, & Sledziona, 2002) which involves solving new design problems on the basis of similar solutions from previous problems. The stored cases are previously solved problems that include not only the final solutions but also the project evolution history. Gardan and Gardan (2003) proposed to record knowledge from experts that can be invoked within CAD software in the form of scripts. The purpose of using such design scripts is to separate the knowledge from the implementation, and then to bridge the gap between design and knowledge management. Though knowledge storage is achieved more or less in these methods, it is not easy to maintain, structure, and re-process the preserved knowledge.

In summary, a KBE system must be easy to access, maintain and be documented, and most importantly, is able to solve a design problem correctly and efficiently. Some basic requirements include:

- Correctness and efficiency: It must ensure that a design problem can be solved efficiently and accurately.
- Maintainability: The model must be flexible so that it is easy to add/remove or modify knowledge.
- Compatibility: The model must be easily associated with other commercial software tools to improve its accuracy and efficiency, and broaden its use.
- Communicability: It should be easy for a designer to access and communicate with the model, and monitor and intervene in its progress.
- Reusability: It must be structured in a reusable manner so that it can be retained as generic design knowledge.

Our proposed IDA can be referred to as a matrix-based design information system since information in this system is presented as a matrix pattern and involves activities of acquisition, structuring, and processing. It has the ability to take comprehensive consideration of all design objectives and also utilizes an objective-oriented approach by mapping design parameters to the relevant design objectives. The IDA can also be used as a product development frame. It can generate, or at least suggest, a new design automatically based on a previous example and new design objectives through structuring and characterizing the design information

The matrix-based design information system meets most of these requirements. Organizing all information in a matrix promotes maintainability as any information can be included in the matrix, and it is easy to add/remove and modify information. Matrices are a simple, straightforward yet powerful representation pattern. It is easy for people to accept, understand and handle, and therefore improves communicability. The matrix is also able to record a large amount of knowledge and leads to the preservation of technical knowledge to minimize the loss from organizational moves such as personnel retirements and company relocation. Once a design project is finished, the information matrices, including characterized sub-matrices and the detailed problem-solving process, can be saved in design history storage for future use. In this system, information processing is finished before making decisions in the selection of design parameters. The information processing results can also be stored for future re-use. Thus, solving a new design problem becomes relatively easy, and the time and cost can be saved because of reduced and simplified computations.

CONFIGURATION OF THE INTELLIGENT DESIGN ADVISOR

The configuration of our proposed matrix-based IDA can be shown in Figure 1. Within such a system, we assume that a project library has been established in a company. The library contains all existing products that a company has developed, and is saved in an information model that contains such attributes as geometry, decomposition scheme, information matrices, characterization results, and decision tables. For a new design, a new information matrix can be established based on previous similar design examples and new design inputs, then after a series of processing stages, a decision-making algorithm will provide solutions or present suggestions to the new design objectives.

The configuration of the IDA also indicates that such an information system can be summarized into four typical stages from the sequential point of view. As described in Figure 2, after the first step of information acquisition, the information is prepared for introduction to the processing stage. Then, processed information is integrated to facilitate the decision-making process.

Information Acquisition

In the information acquisition stage, all information that is relevant to the design problem, such as attributes, requirements, constraints, and objectives, is collected. This is a particularly difficult stage as it requires manual inputs from designers. This stage also involves searching for previous similar examples from the design project library in order to develop a new or adapted design based on the previous product. The design project library can be thought as part of the information system used as long-term memory (Yang & Reidsema, 2004). It should be well-organized and indexed to enable efficient searching.

When a finished design is saved into the project library, it will be allocated to an appropriate family domain from a list of existing domains under which it can be saved. Alternatively, a new family domain can be created. Once a new family domain is created, it will then appear in

Figure 1. Configuration of the IDA

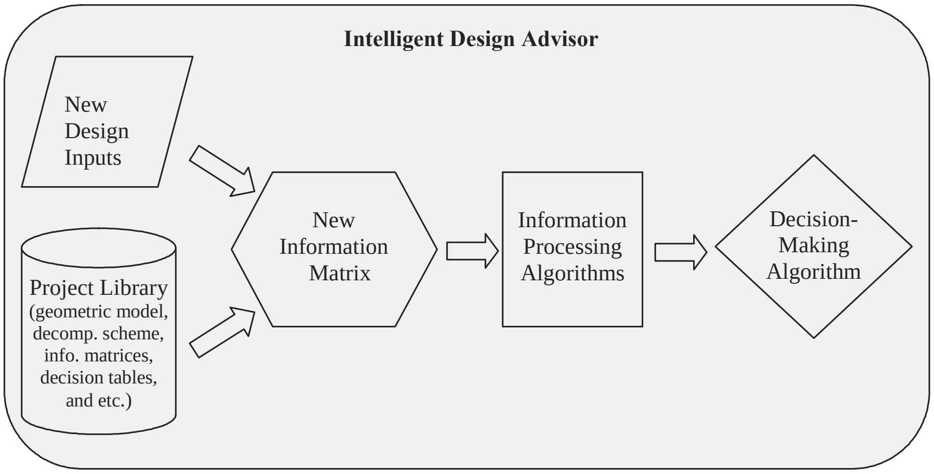
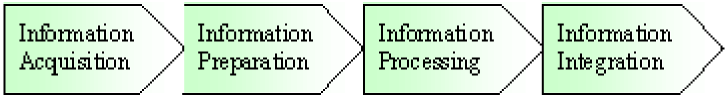
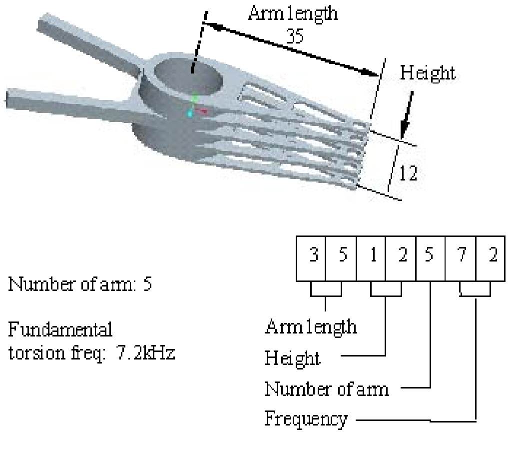


Figure 2. Information handling in IDA



the option list in future saving and searching processes. The name of the family domain must be meaningful and descriptive to describe the nature of the model clearly. After choosing the appropriate family domain, critical factors must be selected from a list, and their relevant values entered to be saved together. Newly identified critical factors, which are associated with this family domain, can be added to the list. In general, the designer will be given information such as key design specifications and design targets at the beginning of the design process. Therefore, to facilitate the searching process, these key design specifications and targets are normally chosen as the critical factors. For example, in the design of an actuator arm for a hard disk drive as shown in Figure 3, the height, arm length, and the number of arms can be thought as the critical factors, as well as the fundamental torsion frequency which is a key design target for actuator arms in general. These critical factors can serve as a searching index. During searching, the process is quite similar to that describe earlier. First, the designer is asked to choose a family domain, and then must provide preferred target critical factors and their desired values. Based on these values, it would be relatively easy to obtain one (or even more) close design example upon which the new design can be developed.

Figure 3. An actuator arm and its name code

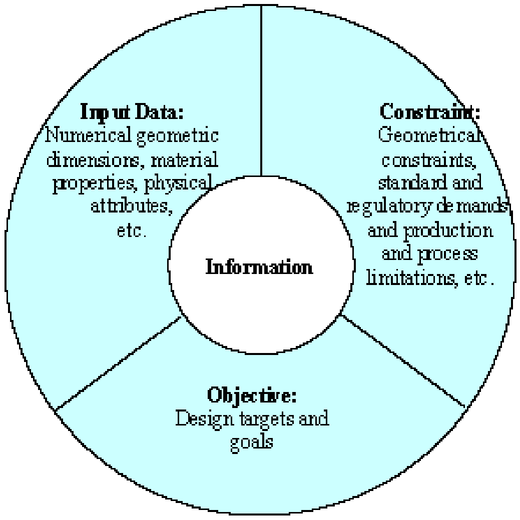


Alternatively, instead of setting critical factors, we may develop a name code system to label the critical parameters and their respective values (or value ranges) for a particular product. As shown in the actuator arm, its name can be coded as 3112572 in which the first two digits indicate the length, the third and fourth indicates the height, the fifth suggests how many arms it has, and the last two indicate the fundamental frequency. However, this method may not be as flexible as the first method since it prevents the designer from freely adding new codes.

Information Preparation

The second phase of information preparation includes elimination of duplicated or unnecessary items and the sorting of these items. This must be done manually by the designer. The aim of doing this is to cross-check the gathered information so that it is suitable to be introduced into the next processing stage. Normally, the gathered initial information is unstructured and needs to be cleared up. The designer can answer questions regarding the redundancy or necessity of the information in order to discard all unnecessary information. This sorting is also very important

Figure 4. Information wheel



in order to classify the information in terms of its nature. All information items can be sorted in terms of their nature into three groups: input data information, constraint information and objective information, as shown in the information wheel in Figure 4. Input data are in numerical form and include geometric dimensions, material properties, physical attributes and characteristics, as well as production and process data. Constraint information includes geometrical constraints, standard and regulatory demands, and production and process limitations. There are two types of geometrical constraints: numerical constraints such as distance and angle, and symbolic constraints such as coincidence and parallel (Wang, 2003). For instance, in the design of a slot, it is required that its width should not be less than a certain value, and its two edges must be parallel. Hence, the width requirement is a numerical constraint while the parallel condition is a symbolic constraint. Constraints are normally expressed either in declarative forms, "if-then" rules, or as mathematical equations. Constraint information is extremely important in a knowledge-based system as constitutes a critical component of the knowledge and can allow for constraint relaxation methods to be employed when possible solutions become overly constrained. Objective information includes certain targets and goals that the design is expected to achieve. These should be clearly stated and uncomplicated. An ambiguous or ill-defined design objective can easily result in either a failure to arrive at a solution or an excellent but incorrect recommendation. Some objectives may be uncertain, such as minimum cost and mass for a design. In such a case, certain levels can be set for them based on the previous example.

It should be pointed out that it may not draw a clear line to distinguish the objective and the constraint information. Constraints are something that must be followed in the design process and are used to guide parameter selection. The objectives can be thought of as indications that a design has been finished successfully. Objectives can also be used to evaluate the performance of a design. In the previous example of an actuator arm, an engineer may be asked to design an arm for which the fundamental torsion frequency is not lower than 7 kHz and the length of the arm is between 33 mm and 37 mm. The first requirement is a design objective and the latter is a constraint.

The preparation stage may also involve the preliminary analysis of information. First, the previous similar design example(s) need to be modified based on the new design requirements, in order to remove any conflicting elements. For instance, the overall length of the selected design case may be a little less than required. Thus, it can be identified as a parameter that must be modified to form the new design. In other cases, analyses such as FEA might be carried out on the initial model to obtain preliminary physical and structural characteristics. These preliminary analytical results are introduced into the information processing model as well to give a measure of the initial performance of the design based on the new design objectives.

Information Processing and Integration

The third phase of information processing is a core part in an IDA. The main processing activities in a matrix-based IDA system involve the following steps:

- Identification of relationships between information items,
- Problem decomposition by grouping input information items into families towards objectives,
- Quantification of relationship strength, and
- Measurement of factor priorities.

The design problem may be decomposed into smaller more tractable sub-problems in the information processing stage. However, each sub-problem may involve only specific points, and therefore, all sub-problems need to be integrated again after the information processing phase in order to solve the overall design problem. Based on the integrated information processing results and the constraint information, a decision table can be established, and the decision-making algorithm in the IDA can then provide design solutions in terms of new design requirements.

Suitability of the IDA System

In solving a design problem, the four main phases involved are (Dixon & Poli, 1995):

- Engineering conceptual design,
- Configuration design,
- Parametric design, and
- Detail design.

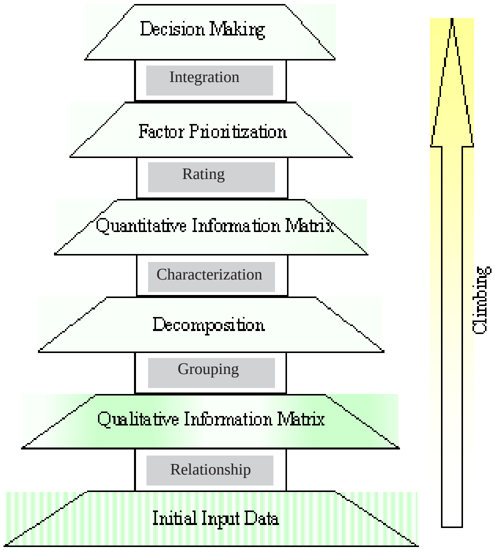
The first two phases of this process are to establish the function structures and define the geometric features. This requires a significant amount of creative work for the designer and is very difficult to enable through the use of a computer-based system. The parametric and detail design phases mainly focus on identifying and classifying the specific design parameters. A computer system may provide help in the selection of suitable parameters to meet certain design goals. The IDA will focus on these two phases, aiming to guide the less-experienced designers to achieve multiple-design goals that satisfy both company objectives and general design requirements such as performance and manufacturability.

The computer-based generation of original or unique design concepts is a problem that has yet to be solved. The approach that is taken in this research is a case-based approach where the inputs to an information matrix are based on previous design cases. In industry, about 75% of design work is of either the adaptive or variant type (Singh, 1996). In adaptive or variant design, a new design is derived from an existing design case that has a high degree of similarity. Hence, the implementation of an IDA in this research will be based on proposing solutions based on variants to a designer.

WORKING PRINCIPLE OF MATRIX-BASED IDA INFORMATION SYSTEM

The working principle of this system can be described by the information processing tower in Figure 5. Climbing up to the top of the tower, the information processing is completed. All information items are listed in a matrix through which the information relationships can be identified, and then the problem can be decomposed by grouping interrelated information into families. Following that the characterization is carried out for each sub-problem to obtain the quantitative information matrix, and all input data information items are rated to show their effectiveness towards the objective information. Finally, all the sub-problems are integrated again to arrive at an overall solution.

Figure 5. Information processing tower



Problem Decomposition

In the first matrix, all collected initial information items are listed both across the top and down the left of the matrix. Their interdependencies are then qualitatively identified. This may be performed automatically by the system and then reviewed by the human designers. To illustrate this, consider a hypothetical design scenario involving eight input data information items, four constraint items and three objectives. The information matrix for this situation is shown in Figure 6. A star indicates that the two information items are interrelated to each other.

For a large and complex design problem, the divide-and-conquer strategy is often used. The problem is decomposed into smaller tractable sub-problems which can be solved separately and in parallel. A matrix-based method called a Design Structure Matrix (DSM) has been used to determine the process sequence of interrelated known subtasks of product development and manufacturing (Chen & Lin, 2003; Yassine, 2004). However, instead of focusing on the process sequence, the decomposition we discuss here aims to divide the design problem into subtasks by grouping the information to form sub-systems based on the qualitative matrix. It results in another matrix as shown in Figure 7. Different algorithms, such as the Similarity Coefficient Method (Kusiak & Cho, 1992), Branch and Bound algorithm (Kusiak & Wang, 1993), and Genetic Algorithm grouping technology (Falkenauer, 1998) may be employed in order to obtain appropriate decomposition schemes depending on the type of problem under consideration, The decomposition shown in Figure 7 is an ideal case in which all sub-systems are independent of each other (that is there is zero interaction density). Practically this may not be achieved. However, as it is pointed out by Yang and Reidsema (2004), independence can be achieved by allowing an information item to appear in different sub-problems if a link is introduced to maintain the equality. Figure 8 shows a decomposed matrix with shared items in which item 3 is included in both Sub-system 1 and 3, indicating they are related to each other.

An expected decomposition is that each sub-system has no more than one objective. Thus, all the information can be mapped to respective objectives after decomposition. In the case where a sub-system doesn't have objective information, it is still acceptable if it has shared items with other sub-systems which include objective information. In such a case a shared item can be treated as an objective. Otherwise, such an independent sub-

Figure 6. Information matrix with qualitative relationship

	Index	Input data Inf.								Const. inf.				Obj. Inf.		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Input data Inf.	1					*	*							*		
	2				*			*				*				*
	3										*		*		*	
	4		*									*				
	5	*					*			*				*		
	6	*				*				*				*		
	7		*		*											*
	8			*							*				*	
Const. Inf.	9					*	*									
	10			*					*				*			
	11		*		*											
	12			*							*					
Obj. Inf.	13	*				*	*									
	14			*					*							
	15		*					*								

Figure 7. Information matrix after grouping

	Index	Sub-system 1					Sub-system 2					Sub-system 3				
		1	5	6	9	13	2	4	7	11	15	3	8	10	12	14
Sub-system 1	1		*	*		*										
	5	*		*	*	*										
	6	*	*		*	*										
	9		*	*												
	13	*	*	*												
Sub-system 2	2							*	*	*	*					
	4						*			*						
	7						*	*			*					
	11						*	*								
	15						*		*							
Sub-system 3	3													*	*	*
	8											*		*		*
	10											*	*		*	
	12											*		*		
	14											*	*			

Figure 8. Decomposed information matrix with shared item

	Index	Sub-system 1						Sub-system 2					Sub-system 3				
		1	5	6	9	13	3	2	4	7	11	15	3	8	10	12	14
Sub-system 1	1		*	*		*											
	5	*		*	*	*	*										
	6	*	*		*	*	*										
	9		*	*													
	13	*	*	*			*										
	3		*	*		*											
Sub-system 2	2								*	*	*	*					
	4							*			*						
	7							*	*			*					
	11							*	*								
	15							*		*							
Sub-system 3	3														*	*	*
	8												*		*		*
	10												*	*		*	
	12												*		*		
	14												*	*			

system without an objective can be deleted since it does not affect any objectives.

Relationship Characterization

After decomposition, problem solving can then be carried out on each sub-system separately. A particular concern is to determine the strength of relationships. That is, how much it affects the others, especially the objective information, when one information item is varied. For a hypothetical case with continuous linear relationships, a rearranged quantitative information matrix of Sub-system 1 can be shown in Figure 9. It must be noted that two rows, (Constraint Information item 9 and Objective Information item 13) are deleted, as these two items are defined as fixed parameters during the earlier stage of character-

Figure 9. Rearranged qualitative information matrix for Sub-system 1

Index	Input Information				C. I.	O. I
	1	3	5	6	9	13
1	1		0.3	-0.45		-0.9
3		1	-0.5	0.75		1.1
5	1.2	-0.9	1	-1.5	*	1.8
6	-0.8	0.6	-0.67	1	*	-1.2

ization. It can be seen that constraint information item 9 is related to input data information items 5 and 6, meaning it defines the physical relationship between these two items.

In order to compare the effect among different items, a normalized number is used in the matrix. The sign indicates a positive or negative effect. For example, if the value of item 1 is increased by 10%, this results in the value of item 5 increasing 3%, item 6 decreasing 4.5%, and objective information item 13 decreasing 9%. Therefore, the information matrix can be represented by $I_{1-5} = 3/10 = 0.3$, $I_{1-6} = -4.5/10 = -0.45$, and $I_{1-13} = -9/10 = -0.9$ (in which I denotes the information matrix). In this case, the row suggests the influence *on* the other items while the column indicates the influence *from* the other items. It is worth noting that the alterable range of an item can also be identified in the characterization.

Characterization also provides a chance to cross-check the information matrix. If two items have both the same row and column characterization results, they can be regarded as two identical items, and either one can be deleted from the matrix. On the other hand, extra attention must be payed to any two items with opposite results, such as item 5 and 6 in Figure 9. This may result from two different situations. First, there may be two conflicting items that have negative correlations. Normally, this conflict is of concern as it represents the condition in which trade-offs might occur. Second, there may be two complementary elements and one of them can be deleted. For example, in the design of a part such as a rod with varied diameter but fixed overall length, as shown in Figure 10, the length of two segments, *a* and *b*, are two complementary items since the increase of one means the decrease of another. From the characterization results, it can also be determined whether two items with negative correlations are complementary. As shown in this example, a 1% increase of item 5 will cause a 1.5% decrease of item 6. Moreover, in both row and column, all results of item 5 are -1.5 times of item 6. Thus, they are two complementary items, and either one can be deleted.

The earlier discussion is focused on the case with continuous linear relationships. However, for non-linear cases the characterization becomes much more complicated. For relatively simple cases, the characterization can be implemented by focusing on a smaller range. The correlations of items within the range can then be treated as approximately linear. This can be illustratively shown in Figure 11. For further complex problems, two methods can be used to measure the interdependencies of relationships. First, using the order notation (Big O) method can be used to characterize the algorithm efficiency of a program, where an order family can be established to indicate the strength of relationships. Second, the dependencies of relationships can be more accurately expressed by approximate polynomials.

Figure 10. A fixed-length rod with two complementing segments

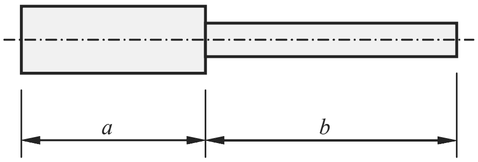


Figure 11. An illustrative multi-range qualitative information matrix of Sub-system 1

Index	Input Data Information				C. I.	O. I.
	1	3	5	6	9	13
1	1 1 1 1		0 0.25 0.4 0.5	-0.1 -0.2 -0.3 -0.3		-1.1 -1.0 -0.8 -0.6
3		1 1 1 1	-0.6 -0.6 -0.6 -0.8	0.8 0.6 0.4 0.2		0.5 0.5 0.5 0.5
5	1.1 1.1 1.3 1.5	-0.6 -0.6 -0.6 -0.8	1 1 1 1	1.5 1.5 1.5 1.5	*	1.2 1.2 1.5 1.5
6	-0.8 -0.8 -0.9 -1.0	0.4 0.4 0.4 0.5	-0.7 -0.7 -0.7 -0.7	1 1 1 1	*	-0.3 -0.5 -0.5 -0.7

Range key:

1 2
3 4

The coefficients and the order of power suggest the strength of influence. This is compatible with the concept of Principal Component Analysis (Matthews, Blessing, & Wallace, 2002).

In an IDA, the characterization may be associated with other software tools such as FEM packages. Characterization is a stage with heavy computations. It is necessary to select the most suitable algorithm for a certain sub-system. This selection is mainly based on the type of objective information within the sub-system, because the objective information is normally related to the domain concerned, such as engineering functional objectives and financial objectives. The motivation of characterization is to reduce repetitive computations to increase the computational efficiency. Since the strength of a relationship is characterized in advance, any subsequent changes of an event are very easy to compute by utilizing the quantitative relationships.

Factor Prioritization

The characterized information system provides a basis for calculating subsequent variations of an event. However, we may often need to select a parameter to work on among a number of candidates so that there is a greater probability of achieving an objective with the least compromise on other design requirements. It is, therefore, necessary to refine the matrix by prioritizing the input data information. All information items are first ranked in terms of their importance, and weight numbers are assigned to them; the priority index P_i can then be calculated for each input data information item using the formula:

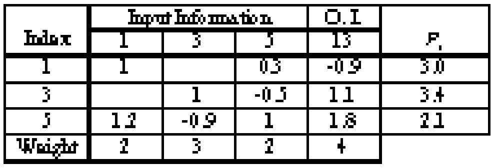
$$P_i = \sum W_o \left| I_o \right| - \sum_{j \neq i} W_j \left| I_j \right|$$

in which W_o and W_i are the weight numbers, I_o and I_j are the normalized values of objective and input data information respectively. For instance, for the sub-system shown in Figure 9 (where item 6 is deleted because it is a complement element of item 5), P_i of item 5 can be computed by 4*1.8-3*0.9-2*1.2 = 2.1, as shown in Figure 12. The formula is established based on the criterion of “most contributions and least side-effects” because its first term represents the contributions toward the objective information, and the second term suggests its side effects on other input data information. The priority index offers another quantitative measure to the input data information to facilitate the trade-off analysis.

Problem Integration and Decision Making

After characterization, the design problem can then be solved. In order to achieve the overall solution, all of the sub-problems must be considered as a whole since they are normally related to each other. Thus, they need to be integrated again. An initial plan must be first generated based on the analysis of the directional relationship among all sub-problems. The analysis should focus on the

Figure 12. Prioritization of input data information



Index	Input Information			O.I	P_i
	1	3	5	13	
1	1		0.3	-0.9	3.0
3		1	-0.5	1.1	3.4
5	1.2	-0.9	1	1.8	2.1
Weight	2	3	2	4	

shared items to distinguish the input and output parameters of sub-problems to establish a sequential order. Sub-problems that are independent of each other can be implemented concurrently, while sub-problems with unidirectional dependency have to be executed sequentially. For those interdependent sub-problems, an iteration plan needs to be developed. This plan would consist of determining the sub-problems to start the iteration process based on an initial guess or estimate of a missing piece of information and then revise the estimation after iteration (Yassine, 2004). The decision-making process will be performed by the IDA based on an appropriate framework, such as the Blackboard Database Architecture (BBDA) or Expert System (ES) (Corkill, 1991; Nii, 1986; Reidsema, 2001). A decision table can be established to facilitate this process. Constraint information plays a key role here as it controls and guides the decision making. The factor priority index offers a reasonable quantitative sense in the selection of appropriate design features and parameters to avoid a blind "trial and error" process. A more in-depth discussion of this aspect of decision making however is beyond the scope of this paper.

FAILURE RECOVERY

In cases where the desired solutions cannot be achieved, or where conflicts occur in the process preventing the problem-solving from continuing, the system is considered to have failed in its efforts to solve the problem. This necessitates consideration of a failure recovery strategy. Failure recovery can concentrate on the following four aspects in accordance with the information processing flow:

- Check where the failure occurs and then examine whether the corresponding sub-problems are correctly characterized.
- Verify the decomposition scheme to see if it is suitable. If necessary, try to decompose the problem using other algorithms.
- Inspect the initial information matrix to see if any relationships are not included. For those relationships which are unsure or unessential, they must be included in the matrix. Although this may complicate the decomposition and characterization stages, it can avoid failure occurring. In fact, the characterization can cross-check whether a pre-defined relationship exists or not. For example, a zero value may indicate no relationship exists between two pieces of information.
- Review the information gathering and preparation processes to see if any information is overlooked and whether constraint and objective information is adequately defined.

DISCUSSION AND CONCLUSION

In this research, we propose a matrix-based IDA system. As a part of the overall enterprise information system framework, an IDA is a knowledge-based design information system. It can utilise human expertise and address CE issues in decision making. It also leads to the preservation and transfer of technical knowledge to minimize the knowledge loss from organizational moves. It is easy to access, maintain, able to solve a design problem correctly and efficiently, and has the ability to take comprehensive consideration of all design objectives. This paper has discussed its configuration and working principle in detail based on the information handling process in such a system. The information is sorted in terms of its nature into three groups: input data, constraint and objective information, all having different representation strategies. After decomposing the problem into sub-problems, information is then mapped to the relevant design objectives and processed separately and in parallel to quantitatively characterize the strength of relationships. Following that, all information items are rated, according to their importance, with weight numbers assigned in order to measure their priorities towards the design objectives. Finally, all sub-systems are integrated again to achieve the final solutions through trade-offs between interdependent sub-systems.

At the problem level, our proposed IDA information system can be summarized as Generation, Decomposition, Distribution and Integration (GDDI) (Reidsema, 2001) where:

- Generation refers to defining the problem including collecting and classifying information to present to the information system.
- Decomposition entails applying the "divide and conquer" method to split the overall problem into smaller, more tractable sub-problems in terms of the interrelationships between gathered information pieces.
- Distribution involves handling sub-problems separately through characterizing them according to the nature or objective of the sub-problems.
- Integration requires all characterized sub-problems to be brought together and then solved in an integrated and collaborated environment.

The success of an IDA is determined by the accuracy of the identification of dependent relationships, and the characterization of relationship strength. In our proposed matrix-based information system, relationships are stressed because all the relationships are important elements of knowledge. This has been pointed out by Compton and Jansen (1990), where they state that knowledge only has meaning in relation to other knowledge and can be explored in terms of relationships. This system is also an objective-oriented model. By sorting all information, the design objectives are clarified. By decomposing the problem, related information is mapped to respective objectives. By characterizing the strength relationships, the priorities of input data information toward the objectives are quantitatively measured.

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Chapter 3.8

PROMISE:

Product Lifecycle Management and Information Tracking Using Smart Embedded Systems

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ABSTRACT

Product lifecycle management (PLM) processes can be greatly improved and extended if more information on the product and its use is available during the various lifecycle phases. The PROMISE project aims to close the information loop by employing product embedded information devices (PEIDs) in products. In this chapter, we present the goals and application scenarios of the project with special focus on the middleware that enables the communication between PEIDs and enterprise applications. Furthermore, we give details of the design and implementation of the middleware as well as the role of Universal Plug and Play (UPnP) as device-level protocol.

INTRODUCTION

The PROMISE project (PROMISE Consortium, 2006) aims at improving business processes of product lifecycle management (PLM) by using the information loop across the various stages in a product's lifecycle, from beginning-of-life (design, production) to middle-of-life (use, maintenance) and end-of-life (recycling, disposal). The technological approach of the project is to use smart networked devices that are embedded into products to gather data on the product's status, properties, and working environment. The data is then made available to back-end systems to perform data analysis for decision support. Moreover, the information acquired is exchanged between the various interested parties, for example, manufacturer, customers, service and recycling companies.

The vision of closing the information loop for PLM has attracted the interest of a number of large companies, like *Infineon* (Germany), *Bombardier Transportation* (France), *Fiat/Iveco* (Italy), and *Caterpillar* (France/USA), in addition to SAP, to take part in the project. This emphasizes the relevance of the idea and also the commitment of industry in realizing it. In particular, *Infineon* is developing the hardware for PEIDs (product embedded information devices) to be installed in physical products.

PROJECT GOALS

The goals of PROMISE fall into the categories of technical, business, and research goals:

Technical Goals

- **Product Embedded Information Devices (PEIDs):** Suitable PEIDs have to be developed which turn products into smart items. PEIDs will provide data about the product to external applications. Using PEIDs will enable automatic data acquisition of high accuracy, which is less error-prone and more efficient than manual collection and entry of the data.
- **Integration of PEIDs with Backend Systems:** To enable the communication between PEIDs and backend applications, a middleware providing abstraction from device-level protocols and data transformation is required.
- **Product Data and Knowledge Management (PDKM):** Product-related data from PEIDs, field databases, and other sources have to be integrated to allow for sophisticated data analysis.
- **Decision Support:** Data from the PDKM has to be analyzed to transform the data into actionable knowledge for PLM decision support.
- **Cross-Company Information Flows**: A major hurdle for today's PLM applications is the inaccessibility of product-related data in other organizations. To overcome this, methods and software that allow sharing of data, information and knowledge among certified actors of the system have to be developed.

Business Goals

- **Enable New Business Models:** Using technology developed in PROMISE, new business models, for example in the areas of product service and recycling, will be developed to increase the economic impact of results from applied research.
- **Improve Existing Business Processes:** Business processes related to PLM will be improved and extended, for example, by achieving lower operational cost, better quality and safety, reduction of errors, and better informed decisions.

Research Goals

- **Generic PLM Models:** The consolidated requirements of many PLM application scenarios are to be integrated into domain-specific and generic models of PLM information flow and PLM workflow.
- **Information and Knowledge Management Methodologies:** To turn the collected product data into useful knowledge for decision support, methods and concepts for information enrichment and transformation of information into knowledge have to be developed.

INNOVATIONS IN PLM BUSINESS PROCESSES

In the following, three application scenarios are presented to show how PROMISE technology can be applied to a PLM business process in beginning-of-life (BOL), middle-of-life (MOL), and end-of-life (EOL).

Improved Product Design: Bombardier (BOL)

Bombardier is a provider of rail equipment and servicing. Based on a component platform, Bombardier designs and produces a large number (over 400) of different locomotives. Applying the PROMISE idea, Bombardier aims at closing the information loop between the experience in service (field data) and the knowledge needed in order to develop improved locomotives for specific criteria, such as design for reliability, availability & maintainability/life cycle costs, product safety, environment, and so forth. For these purposes, field data is recorded on the locomotives and transferred to a field database using GSM (Global System for Mobile Communication). The data is then analyzed for information on the performance of components compared to their expected behavior. Based on that, the engineers can evaluate the suitability of their designs and improve them accordingly.

Flexible Maintenance Planning: Fiat (MOL)

Fiat focuses on predictive maintenance of trucks. To improve the effectiveness of fleet management, FIAT seeks new ways to better understand the product usage and the mission profile of Iveco commercial vehicles. The objective is to provide customers with flexible maintenance planning, which is based on the actual degradation of vehicle components instead of fixed intervals. With this approach, costly breakdowns are avoided, while preventing the replacement of parts that are still in good condition. The correct timing for maintenance is determined by measuring the wear-out of selected critical components with sensors that are integrated into the vehicle. Furthermore, the mission profiles of trucks are determined in order to predict the wear-out for components depending on the respective mission profile. For each truck, the output of the decision support system is a calendar containing the time and the type of planned interventions. The maintenance crew is provided with a consolidated view on all interventions of the fleet.

Effective Recycling: Caterpillar (EOL)

Caterpillar is a manufacturer of construction and mining equipment. Using PROMISE technology, Caterpillar aims to support decommissioning of heavy-load machinery at the end of its life. More specifically, the value of the vehicle’s components has to be evaluated to identify those that can be reused. Previously, end of life decision-making was based on inspection in order to determine whether a component could be remanufactured. Now, a PEID monitors the product’s status and systematically collects data during the machine’s operation. Using a smart item middleware, this data can be accessed from the PEID and stored in a database. When the machine is decommissioned, the data associated with the built-in parts is retrieved from the databases and serves as input to a decision support system (DSS), where it is combined with data on economic demand. Thus, the appropriate handling of the various components is determined, for example, deciding whether to dispose of, recycle, reuse or remanufacture components in order to increase the re-use of components.

TECHNICAL SOLUTION OVERVIEW

Overall PROMISE Architecture

The technical solution of PROMISE consists of different layers, which are consolidated into the overall PROMISE architecture (see Figure 1).

Business processes from various application areas are supported by applications for decision support and product data and knowledge management (PDKM). These applications access PEID data through a middleware, which provides functionality for reading and writing of PEID data, as well as notifications on data updates, and PEID management. On the PEID level, mechanisms for detection of devices and invocation of services are offered.

Brief Overview of the PROMISE Middleware

A key part of the PROMISE architecture is the middleware, which was co-developed by SAP. Its purpose is to connect PEIDs with backend applications to facilitate data exchange between them (see Figure 2). One of the main challenges in the design of the middleware was to support mobility of products. As products can be mobile (e.g., trucks, locomotives), they might not be permanently connected to the network. To handle this, the communication between backend applications has to be asynchronous. Furthermore, the presence of devices has to be detected automatically in order to trigger the execution of pending requests.

The middleware is divided into three logical layers, which are described here briefly:

- **Device Handling Layer:** The DHL provides mechanisms for device discovery and invocation of services on the PEID to access data. In the PROMISE middleware, this was achieved by using Universal Plug and Play (UPnP Forum, 2006). All PEIDs implement a unified UPnP interface called

Figure 1. PROMISE architecture

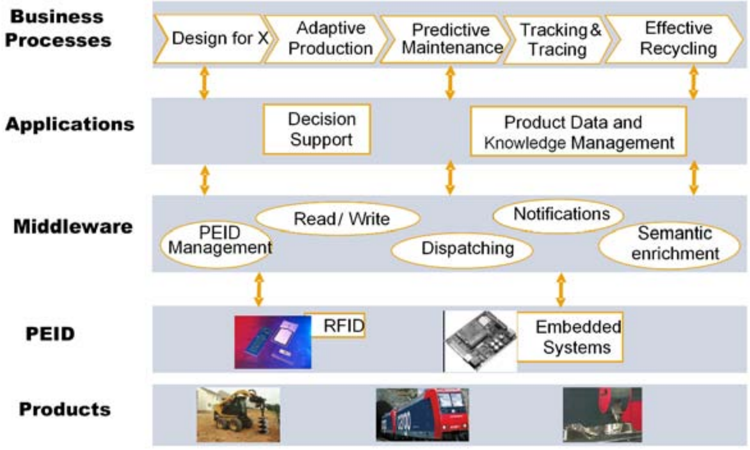
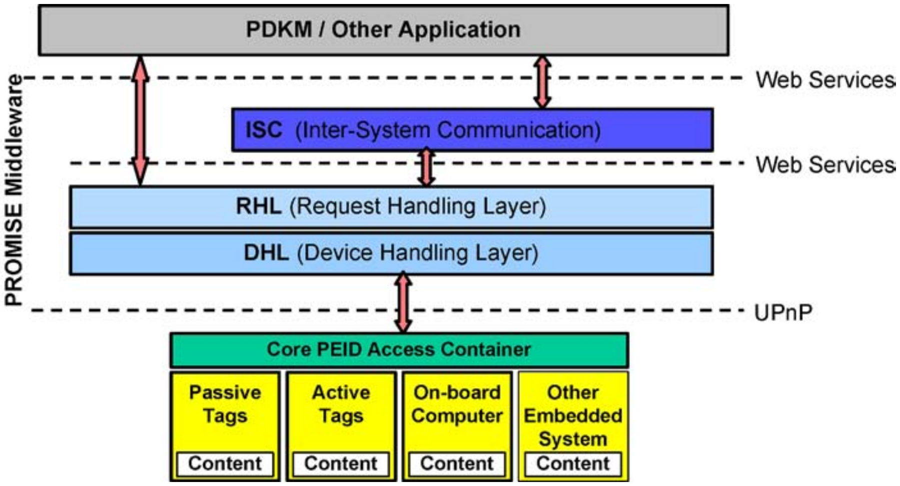


Figure 2. Logical components of the PROMISE middleware



"Core PAC" (Core PEID Access Container). When a PEID is detected, the DHL connects to it and sends a notification to upper layers of the middleware. Additionally, it translates incoming requests into UPnP services invocations to read or write PEID data.

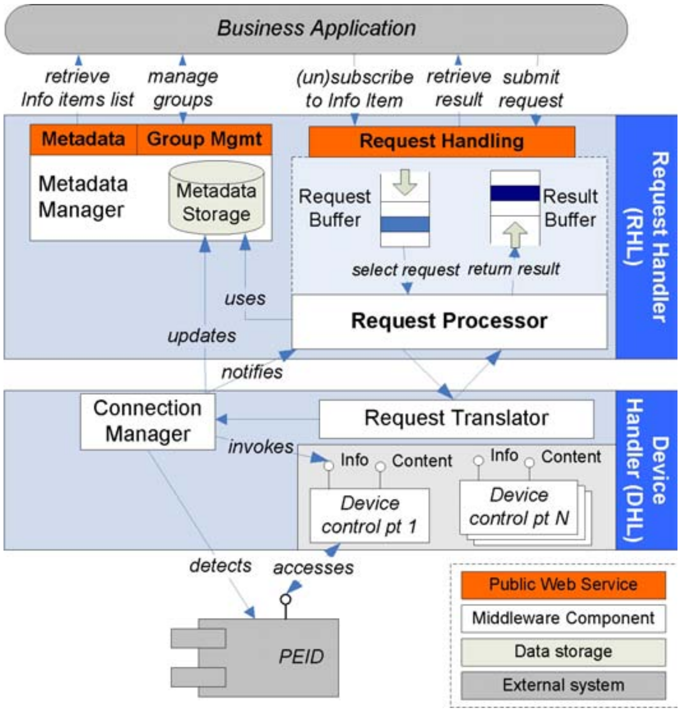
- **Request Handling Layer:** The RHL provides Web services to interface with back-end applications, which can place requests for PEID data at the RHL. If the required PEID is currently connected, the request is directly forwarded to the DHL. Otherwise, it is buffered until a connection notification is received from the DHL, which triggers the forwarding of the request. In a large-scale deployment, a RHL node can be connected to multiple DHL nodes, which can be installed in different physical locations to provide PEID connectivity.
- **Inter-System Communication:** To provide cross-organizational communication, the ISC was developed. It is an optional part of the middleware stack for scenarios where external parties are to access PEID data. In these scenarios, each organization has at least one Inter-System Communication (ISC) node installed, which then connects to other ISC nodes in a peer-to-peer fashion. Back-end applications place their request at an ISC node, which then forwards the request to the correct RHL, PDKM or third-party system. Companies can thus gather product-related information from other organizations.

IMPLEMENTATION

We have implemented the lower layers (RHL and DHL) of the middleware, which was introduced in the previous section. Figure 3 shows the detailed design of these two layers. Here we give some details of the chosen technologies and elaborate on some of the notification mechanisms developed.

The connection manager in the DHL implements an UPnP control point (Institute of Information Science and Technologies, 2006; Konno, 2006) that can read and write information on PEIDs once they have been discovered in the network. The DHL is realized as an application consisting of a set of bundles running on an OSGi (OSGi Alliance, 2007) service platform, in our case the open source distribution Oscar (Hall, 2006).

Figure 3. Detailed design of RHL and DHL layers



The RHL is implemented as a Java 2 Enterprise Edition (J2EE) application, with its functional components being Enterprise Java Beans (EJB) (SUN, 2006). For deployment, a J2EE 1.3 (SUN, 2002) compliant application server (SAP Help, 2007) was used. Container-managed entity beans are implemented to represent the business objects such as targetIds and infoItemIds. They are mapped to tables, which are then automatically deployed on the server. Web services to be invoked from back-end applications are also automatically generated from the beans. A timing service was required for the management of subscriptions to RHL requests. To compensate for the lack of an EJB Timer service in J2EE 1.3, the Open Symphony Quartz (Open Symphony, 2006) was used as a powerful library for scheduling.

Communication between RHL and DHL is established using Java Messaging Service (JMS), which provides reliable asynchronous messaging. The JMS Provider manages three queues to exchange messages between the two layers. A request queue and a response queue are dedicated to receiving requests from the back-end applications via the RHL and the corresponding responses from the DHL respectively. A third queue is used for the delivery of notification messages for PEIDs discovered as well as metadata about those PEIDs.

For the processing of messages on the DHL, a JMS MessageListener is implemented to listen on the request queue for incoming requests. To enable the DHL to retrieve the factories required for JMS communication, a J2EE client library (Opgenorth, 2005) has been included as an application bundle. On the RHL, the request processor contains message-driven beans (MDB), listening on the response queue and notification queue to process the messages, which are received on it.

When a device is discovered by the connection manager and permitted to connect by the device manager, a JMS notification message with the PEID and respective metadata is sent to the notification queue. The dedicated MDB within the request processor then performs the necessary processing to check for pending requests for that PEID. If there are requests buffered, they are sent via the request queue to the DHL as JMS messages. After performing the required operation (read/write), the result for each request is then sent back via the response queue to the RHL. The result messages are handled by the above-mentioned MDB, which places the results in a buffer to be retrieved by the back-end applications through a Web service interface. Incoming requests are forwarded to the request queue until the RHL is notified of the disconnection of the PEID.

When a back-end application has placed a subscription on the request handler, a trigger is created with a subscription interval and the subscription is then scheduled as a Quartz job. Whenever the RHL is notified of the disconnection of a PEID, all the subscriptions on that PEID are paused. When the PEID connects again, all the subscriptions placed on it are resumed. Whenever it is activated, the scheduled job sends a request according to the given interval, which is then handled as described above.

BENEFITS AND LIMITATIONS

The system presented allows back-end systems to acquire data from product embedded information systems, which can then be used to support business decisions. Using UPnP as standard technology for detection and invocation of services as well as a common data access scheme (“InfoItems” and their IDs), an abstraction from concrete products can be achieved. Thus, the middleware enables reading and writing of PEID data for a large number of heterogeneous products.

One of the major drawbacks is that all products not only have to be UPnP compatible, but also implement the UPnP interface which was defined in the PROMISE project. It remains to be seen to what extent this interface is used in real-world applications. However, our middleware architecture is designed with abstraction as a major goal. Therefore it is also possible to support other protocols and interfaces by implementing a designated DHL instance for it. Such an extension would not affect back-end applications and the RHL. Additionally, we have not yet conducted a thorough analysis of performance and scalability for the middleware.

SUMMARY

The PROMISE project shows how smart embedded systems can be employed for future generations of product lifecycle management applications. Real-world application scenarios not only give a proof-of-concept, but also show the variety of different business problems that can be addressed with the help of PROMISE technology. Transparency about product data and its exchange across company boundaries are the main drivers for these new capabilities. However, it also highlights the importance of standards for product identification, detection and data exchange. These standards have not only to be suitable for a technical problem, but also accepted in the industry to enable interoperability.

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Chapter 3.9

Mobile Batch Tracking:

A Breakthrough in Supply Chain Management

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INTRODUCTION AND BACKGROUND

Traditional problems of managing resources and the flow of material appear to have been solved by enterprise resource planning (ERP) systems as well supply chain management (SCM). This is true of the stationary case of an isolated factory and of the goods that form part of its inventory. However, with the increasing movement of goods, a new dimension of problems has arisen that makes it inevitable to consider transport status itself—particularly to improve the supply chain planning and the execution process. This chapter is an attempt to cope with the new challenges that result from a higher degree of mobility, a higher percentage of the mobility phase with respect to the total lifecycle, and a higher flexibility with respect to transport media and changes of the transport mode within one single transaction, such as conveying a pallet from A to B (where A and B may be located anywhere on the surface of the earth, thus indicating that also increasing distances have to be bridged).

Goods, spare parts, and assembly components are no longer kept in storage for long periods of time, but are fed in when needed. This is the effect of the popular just-in-time (JIT) approach to inventory management. Thus, managing the supply chain effectively means managing more and more of the transportation chain.

Successful attempts have been made to manage the internal transport at a factory site by means of new technologies, such as radio frequency identification (RFID) tagging or other auto ID technologies (ten Hompel & Lange, 2005). Within this context, a new class of middleware is emerging, acting as a platform for managing the data and routing them between tag readers and enterprise systems (Leaver, 2004). However, a huge gap of information exists for the increasing time of external transportation—either between two factory sites for a semi-product or between factory site and end user location for a final product.

THE CORE CHALLENGE IN SUPPLY CHAIN MANAGEMENT

In order to obtain an exact overview at any time, it is essential to track the flow of goods on batch level at least, if not on item level (for larger items). This requires acquiring knowledge about the geographical position whenever needed plus detailed information about the goods—that is, batch identification and batch description, including information about origin and destination, plus all intermediate agents involved in the process. Regulation (EC) No. 178/2002 of the European Parliament and of the Council of January 28, 2002, as an example, is laying down the general principles and requirements of food law and at the same time the procedures in matters of food safety. This includes strong implications with respect to downstream trackability (from origin to destination), as well as upstream traceability (from end user back to the production site). In the case of non-preservative food, it is of essential importance to monitor and to record the environmental data of the transport—for example, to ensure that the refrigerating chain has not been interrupted (or only for a very short period of time and within a certain temperature range). The big challenge therefore consists of getting all the required information while the goods are on their way on a transport medium in motion.

THE SOLUTION TO THE CHALLENGE

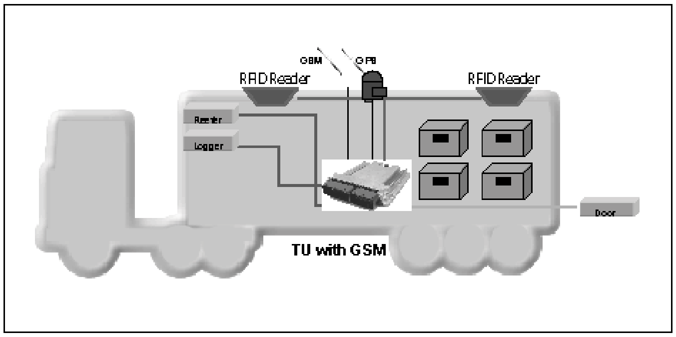
The requirements mentioned above directly lead to the way of finding an appropriate solution by a decomposition of the system into its two basic components:

a. Subsystem to determine the geographical position of the transport medium (container, lorry, trailer, wagon, ship, aircraft, etc.).
b. Subsystem to gain information about the goods transported by that medium—that is, batch identification and batch description (plus additional environmental parameters).

The first subsystem (a) preferably consists of a GPS antenna and a GPS receiver to obtain the geographical position. For the second subsystem (b), an advanced approach would be to use RFID technology—that is, RFID tags affixed to the packaging units and RFID readers installed on the transport medium to read the tags. An example is shown in Figure 1 (for the case of a trailer/lorry configuration).

The trailer contains the GPS equipment plus RFID reader(s) to identify and to read the tags which are fixed at the package units. A great advantage of RFID vs. other auto ID technologies is due to the fact that no direct geometrical line-of-sight between tag and reader is required—that is, the packages may be oriented in any arbitrary way and do not have to be aligned or rotated in a specific manner. Additional environmental parameters, such as temperature, acceleration (shock), door status, and so on (including intrusion alarm) are polled from adequate sensors by a so-called reefer and are stored locally on a data logger. All data are collected online by a telematic unit (TU) and are transmitted instantaneously or at given time intervals to a Transport Tracking Center (TTC), preferably by means of GSM or by using satellite communication (depending on the coverage and

Figure 1. Trailer equipment



the location of the transport medium on its route). This Transport Tracking Center, thus defining the third subsystem (c), collects the batch data from all connected transport units and makes them available to all subscribers and stakeholders being entitled to use them. The TTC itself will consist of a computer cluster with distributed tasks for I/O handling, central data storage, archiving, and data retrieval. Figure 2 shows an example for this network of information, again for the lorry/trailer configuration mentioned above:

Whenever a batch is leaving Factory A, a stationary tag reader identifies the batch, and the batch data are transmitted by an appropriate middleware to the ERP system of Factory A. The same procedure will take place when the batch arrives at Factory B (or at the site of final destination). The full information is available at any time by connecting the stationary ERP system to the Transport Tracking Center by means of a proprietary telecommunication link or via Internet. By those means, it is possible to obtain a more reliable estimate of the time of arrival for a specific good—thus allowing for a rearrangement of the production line at the destination site within due time (if necessary).

The eminent advantages of such a system become increasingly obvious if the transport is not a single point-to-point connection, but if a number of intermediate waypoints have to be covered, including unloading of some batches and loading of new batches, as illustrated in Figure 3, and whenever the transport medium is changed (e.g., from lorry to train) and a new batch configuration has to be assembled.

The system described here allows the user to gain an exact overview at any time and to track the flow of goods from the origin to the destination online and in real time. On the other hand, by means of archiving and retrieval, it allows for backward (upstream) traceability at batch level (or item level). In other words, by closing the mobility

Figure 2. Network of information

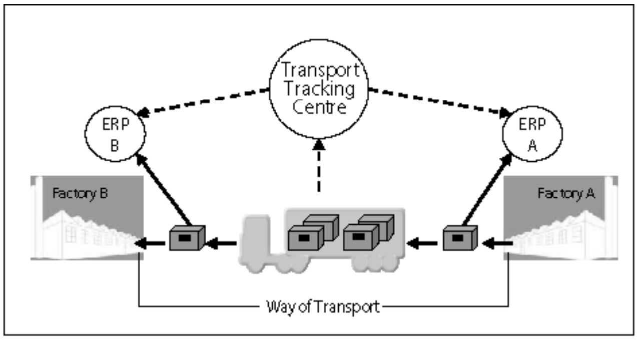
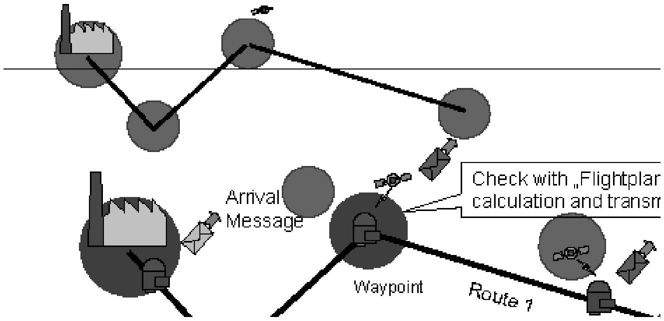


Figure 3. Intermediate waypoints



gap, this system is covering the full supply chain without any interruptions.

T-Systems has implemented such a system (called "eCargo") for RAILION, Europe's largest international logistics enterprise for railway-based transports, as described by Epple and Feuchtmüller (2005). More than 100,000 individual RAILION transports per day are crossing all over the continent, carrying a huge variety of goods. About 13,000 wagons are equipped with GPS and GSM devices at least, plus environmental sensors, reefers, and data loggers.

For a pilot installation and for operational use, a similar system (called "iTM"®—intelligent Tracking Management) has been developed by T-Systems for Schmitz CargoBull, one of Europe's leading trailer manufacturers. Reliability, safety, and security are top priority requirements for both systems.

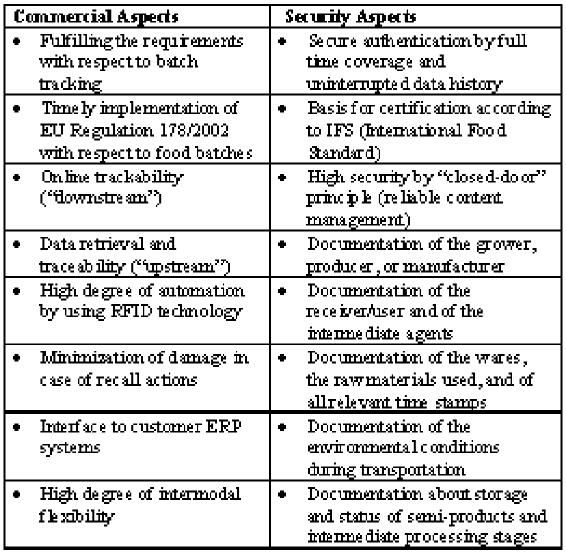
Table 1 provides a summary of the benefits and advantages of the described system solution.

LIMITATIONS AND CHALLENGES TO THE SOLUTION

Basically, there are no other limitations to a worldwide use of the system than those imposed by physics. Perturbations of the radio frequency (RF) may have to be faced if RFID is used in a ferro-metallic environment, or Faraday screening may prevent readers from identifying tags if they are "hidden" by a metallic foil. A further electromagnetic threat is encountered if the system is operated in environments with spark discharges or in cases of other events causing high-voltage electromagnetic pulses (EMPs). In those cases, the transponder chip may be completely damaged.

Besides these physical challenges and threats, a global use is rather endangered by incompatible or even competing systems with respect to the performance of readers and transponders, and with respect to the RF used. While in the U.S. the UHF

Table 1. Benefits and advantages of mobile batch tracking systems



Commercial Aspects	**Security Aspects**
Fulfilling the requirements with respect to batch tracking	Secure authentication by full time coverage and uninterrupted data history
Timely implementation of EU Regulation 178/2002 with respect to food batches	Basis for certification according to IFS (International Food Standard)
Online trackability ("downstream")	High security by "closed-door" principle (reliable content management)
Data retrieval and traceability ("upstream")	Documentation of the grower, producer, or manufacturer
High degree of automation by using RFID technology	Documentation of the receiver/user and of the intermediate agents
Minimization of damage in case of recall actions	Documentation of the wares, the raw materials used, and of all relevant time stamps
Interface to customer ERP systems	Documentation of the environmental conditions during transportation
High degree of intermodal flexibility	Documentation about storage and status of semi-products and intermediate processing stages

range between 868 and 915 MHz is favored, many developments in Germany prefer a frequency of 13.56 MHz (ten Hompel & Lange, 2005).

A different limitation to an increasing use of RFID-based systems may be given by a more commercial point of view. As for all new technologies in the beginning, the unit prices are relatively high (approximately 0.60 USD per transponder tag, depending on the storage capacity, ranging from a few bytes to several Kbytes). Drastic price reductions can be expected for the time to come when large numbers of tags will be produced.

Finally, like in many other cases, it has to be considered that the system is subject to some security risks and to the possibility of criminal attacks. Removing or destroying tags by brute force is the simplest way, followed by more sophisticated acts such as unauthorized reading of the tags, cloning of tags by means of electronic devices, and emulation of tags with any desired content (Oertel et al., 2005).

Here again, further development of the technology and international security standards will help to reduce the inherent risks.

CONCLUSION AND FUTURE DIRECTION

This chapter has shown that a system solution for mobile batch tracking is feasible that allows for online batch tracking during downstream transportation, as well as for upstream traceability. The system presented here bridges the information gap between the automated systems at the factory sites and the storage control systems at the destination sites. By using finest technology according to the state of the art, this mobility system can be considered to represent a breakthrough in supply chain management—especially when taking into account that an increasing number of goods will be “on the road” (on rails, on ship, in the air) for an appreciable percentage of the lifecycle, thus resulting in an urgent need to cover this mobility phase.

Nevertheless, a number of problems and difficulties still persist. Due to the international nature of the system, it is quite obvious that full functionality across borders will require international agreements, legal regulations, and standards. Technological standards will have to deal with reserved frequency ranges for the RFID equipment, the transmission speed, coding, protocols, and anti-collision procedures. Data standards will have to take care of a scheme for unique numbering (e.g., according to ISO/IEC Standard 15963), and application standards will have to consider new coding standards, such as the Electronic Product Code (EPC) replacing the UPC Barcode Standard (ten Hompel & Lange, 2005). Unique identification will require a well-elaborated coding standard based on a worldwide agreement, especially when thinking in terms of progressing from unit- and pallet-tagging down to item-tagging.

In parallel, sophisticated security measures will have to be developed in order to overcome the criminal risks inherent to each new technology.

Provided that these prerequisites are given, there is no doubt that mobile batch tracking systems based on RFID technology—like the one presented here—will result in a tremendous improvement of supply chain management.

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Chapter 3.10

Intelligent Supply Chain Management with Automatic Identification Technology

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ABSTRACT

RFID-enabled business models are proposed in this chapter to innovate supply chain management. The models demonstrated benefits from automatically captured real-time information in supply chain operations. The resulting visibility creates chances to operate businesses in more responsive, dynamic, and efficient scenarios. The actual initiative of such novel RFID enabled applications is therefore to encourage intelligent supply chain management to dynamically respond changes and events in real-time. As the RFID implementation costs are continuously decreasing, it is expected that more novel business models would be inspired by the technological advancement to foster more intelligent supply chains in the near future.

INTRODUCTION

Enterprises have been experiencing significant changes in the realms of technology, organization and management, due to increasing demands on the agility, flexibility, customization, and collaboration in supply chains. There is a pressing need to improve the process visibility and to facilitate supply chain wide decision-making through strategic business intelligence to sustain enterprise competitiveness (Krishnamurthy, 2002; Srinivasa & Swarup, 2002). One of the important enabling technologies to build up business intelligence is the identification and tracking technology, with which the product-centric information resources and associated decision-making systems can be established within and beyond enterprises (Davie, 2002). The information about product movements is crucial to the supply chain efficiency, agility, and product safety (Jakobs, Pils, & Wallbaum, 2001). Product identification and tracking technologies have been developed over time—from paper based manual recording systems to the "semi-automatic" barcode technology associated with optical-digital data processing systems. In recent years, a wireless identification technology, radio frequency identification (RFID), has attracted increasing attentions in supply chain management. Many trials have been implemented with recognized benefits including improved traceability, reduced labor costs, increased speed, greater responsiveness, and better product quality.

A networked RFID system integrates local identification and tracking data with a networked supply chain system through Internet. Unlike barcode systems, the RFID technology can remotely identify physical objects instead of visual alignment of each product with a scanner. It can communicate with multiple products simultaneously and dynamically update the data on RFID tags. The technology provides opportunities in automation of the data capture, item-level product visibility, and particularly in the business process transparency, integration and collaboratively decision making. Therefore, integrated RFID systems are of greater potential to enhance the intelligence of supply chain management than traditional identification technologies.

This chapter will focus on the RFID-enabled intelligence for innovation of the enterprise operations and supply chain management. The barcode and RFID based identification technologies are reviewed in the second section. The models which gain benefits from RFID applications are described in the third section. The conclusion is given at the end of this chapter.

IDENTIFICATION TECHNOLOGIES AND ASSOCIATED SYSTEMS

The RFID technology is one of the efficient identification technologies. Other technologies include one-dimension barcodes, two-dimension barcodes, DNA based bio-barcodes, and global positioning systems (GPS). Although advantages of the RFID technology have been broadly recognized in the past few years, the (one dimension or linear) barcode system has been a dominant identification technology for the last two decades. In this section, we will review technical details of the RFID and linear barcode systems.

The Barcode Technology and Associated Systems

A barcode is a data carrier which stores data as a series of stripes with different widths and with different spaces between them as seen in Figure 1. The data can be captured by a scanner or reader which requires positioning closely in line with the printed stripes. The scanner uses a laser beam that is sensitive to the reflections from the image pattern on a barcode label. The scanner

Figure 1. An example of the barcode prints (Source: EAN International, 2003)

(01)04012365478912(10)8765101234

translates the light signal into digital data that is transferred to an associated computer system (Mallah, 2005). The barcode technology has been applied to industries for a variety of purposes, including consumer product identification at various packaging levels, tracking operational processes, traceability for safety and quality assurance, and so forth. (Osman & Furness, 2000).

There are several different barcode standards or symbology for various applications and used in different regions in the world. The widely accepted standards include Universal Product Code (UPC) from the Uniform Code Council in the U.S., and the European Article Numbering system (EAN) which is a UPS compatible system created by EAN International. The standard allows for a pair of extra digits along with the unique identification of a physical object to support customized coding for various internal uses in industrial operations (EAN International, 2003). On a barcode label, the relevant information can be printed for both scanning and human reading purposes. The human readable interpretations of a barcode provide flexibilities in the operations management when a human intervention is necessary.

The major contribution of the barcode technology is facilitating automatic or semiautomatic, fast and accurate acquisition of data. It dramatically improves the efficiency of information processing and avoids the error-prone manual data input into information systems. "*Previous studies have demonstrated that, while human data entry has an error rate around 1 in 300, the use of barcodes can reduce this to less than one in 2,000,000*" (Osman & Furness, 2000). The standardized coding and machine-reading technology facilitates information processing across industry and company boundaries in supply chains.

The limitations of the barcode technology are mainly in its data acquisition method and data carrier capacity. Firstly, to capture data on a barcode label, a reader must be closely positioned to the label. The reading has to be made for labels on each product or facility one by one. This procedure will apparently slow down operational processes with a large volume of product flows (Kärkkäinen & Holmström 2002). Data may also be missed due to human errors or misread due to unclean barcode labels. The second limitation of the barcode is its low data density which only allows a data capacity about 20 characters (Osman & Furness, 2000). The small data volume carried on the barcode label limits the flexibility of data transfers through supply chains, that is, a product or a logistic unit itself cannot provide enough details of themselves in many cases, and the information has to be accessed through centralized databases. Furthermore, data on a barcode label are static and cannot be changed. Therefore, the barcode cannot identify dynamic changes associated with a product and logistic unit.

The RFID Technology and the Associated Systems

Applications of the RFID technology in industries started more than two decades ago. However, the technology has not been widely adopted until late 1990s due to significantly decreased costs of the RFID hardware and software, although the development of barcode systems has significantly improved the efficiency and accuracy of data capture in supply chain operations against manual data recoding systems in 1980s. Researchers and practitioners in supply chain management are currently investigating the role of the RFID technology in another possible wave of revolutions in supply chain management technologies (Schwartz, 1997). In this section, we introduce the RFID technology, and compare it with the traditional barcode technology.

The Infrastructure of RFID Systems

A RFID system identifies products/assets or other objects via radio transmissions between data carrying devices (tags) and devices (readers) that are capable of receiving the radio transmission. It consists of three basic components, tags, readers, and the middleware which transfers the captured data into enterprise data sources with appropriate formats.

A RFID tag consists of a microchip as the memory-based data carrier and antenna to transmit encoded information through wireless interrogation with different radio frequencies. The encoded data is used to uniquely identify items (e.g., pallets, cases, or individual products) to which the tags are attached. The capacity of a tag can be 512 bytes for passive tags and up to 32Kb for active tags (Furness, 2005).

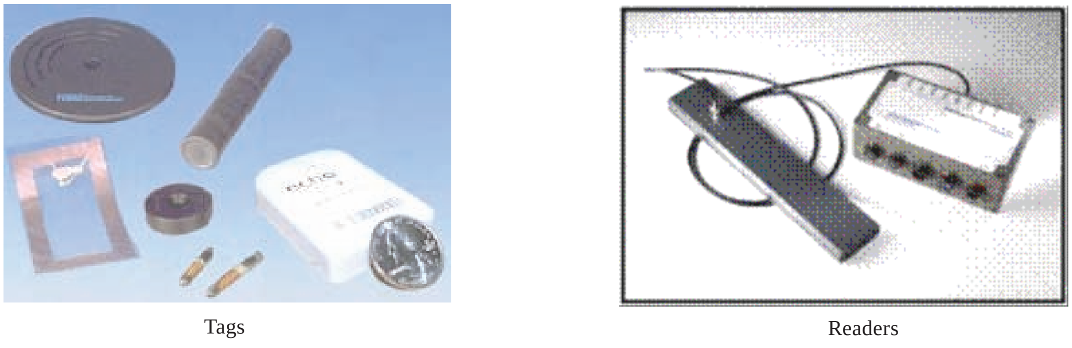
The reader as an interrogator of a RFID system automatically communicates with the tags when they enter a reader's reading field. The reader converts the radio wave into digital data and transmits the data to RFID middleware, which is a bridge of the communication between RFID systems and enterprise applications. Communications between RFID readers and tags may cause interference or collision when multiple readers or tags send signals simultaneously. Anticollision methods have been designed in RFID communication standards or protocols to solve such problems (Sarma Weis, & Engels, 2003). When a RFID tag receives overlapped signals from multiple readers, the problem is known as reader collision. On the other hand, when multiple tags send signals to a RFID reader at the same time, the problem of tag collisions will arise (de Jonge, 2004). While RFID communication protocols offer different solutions to these problems, additional software functions may also be required in associated applications to enable unique identifications and support relevant business operations.

According to communication powering features, RFID tags can be classified as active tags and passive tags. An active tag is powered by an internal battery. The power is continuous available within the battery lifetime. Active tags transmit the stored data at regular intervals. Active tags have a greater communication range than passive tags; better noise immunity and higher data transmission transfer rates as they have the greater response strength then passive tags (Furness, 2005). A passive tag is powered by an electromagnetic field generated by a reader signal and is without the internal battery. It therefore has virtually unlimited operational lifetime. However, passive tags have weaker response and shorter communication ranges compared with active tags. Passive tags cost less and may have smaller sizes (Furness, 2005).

According to the data adaptability, the tags can also be classified as read-only or read/write types. The data carried on read-write tags can be adapted through the air interface commands from readers as seen in Figure 3. On the other hand, the data on read-only tags cannot be changed (Furness, 2005).

According to the frequencies used for the communication between RFID tags and readers, RFID tags can be classified as low frequency (LF),

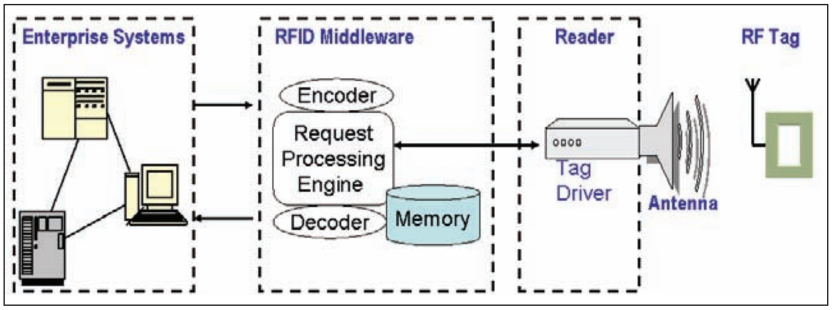
Figure 2. RFID plastic tag, paper tags, and reader systems (Source: Microlise, 2003)



Tags

Readers

Figure 3. Structure of a RFID system (Adapted from Chartier, 2005)



high frequency (HF), ultra high frequency tags (UHF). In Table 1, the communication features with different frequencies are described.

The middleware of a RFID system associates the unique identifier stored on a specific tag with the information about the product. After the middleware processes the information received from readers, it filters the data to the company's supply chain execution software, which updates its inventory data accordingly.

Networked RFID Systems and Supply Chains

Figure 4 shows a networked RFID system which includes a local RFID system and the service to integrate the local product identification information with the networked supply chain system through Internet.

To globally share the product identification information, the output from the RFID middleware is described in a subset of XML language, physical mark-up language (PML) which enables standard data communication with Web services. The data about a product in a standard format, electronic product code (EPC), can be captured through the particularly designed on-line directory, object name services (ONS), on the Internet. This Internet-enabled object name registration and discovery service facilitates the real-time location of individual products or logistic units with their relevant information throughout supply chains.

The EPC, as a RFID coding standard which is not based on the existing ISO standard, was originally developed by the AutoID Centre at MIT (de Jonge, 2004). It has been further developed towards a worldwide standard by EPCglobal which is a nonprofit organization and was set up by the Uniform Code Council and EAN International (UCC.EAN) (EAN International, 2003). The EPC stored in a RFID tag is a number with a header and three sets of data as depicted in Figure 5. The header of the code represents the version number. The three sets of data represent the manufacturer of the product (the EPC manager), the type of the product (object class), and the item unique serial number respectively.

Table 1. Communication features of RFID systems with different frequencies (Source: de Jonge, 2004)

Frequency	Shot Description	Read range (meter)	Data speed (tag/sec)
125-134 kHz	LF	0.45	1-10
13.56 MHz	HF	<1	10-40
868-870 902-928 MHz	UHF	2-5	10-50

Figure 4. Internet-enabled RFID systems

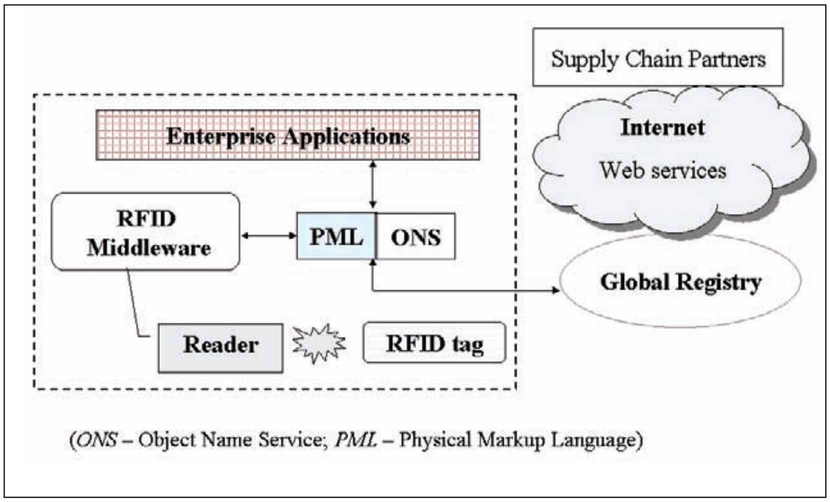
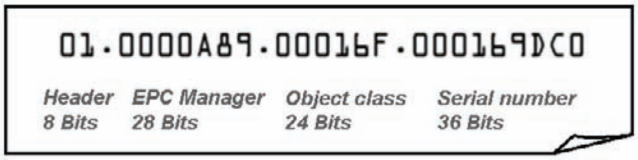


Figure 5. The electronic product code (Source: RFID Gazette, 2005)



With the networked RFID systems and the standard product code, all relevant supply chain members can share the information of physical product movements and associated status (quality, processing stage, and contamination risk, etc.) in real time. This enables automatic tracking and tracing of products without human intervention.

Limitations of RFID Systems

The current limitations of the RFID technology are mainly in several aspects—high costs, barriers in standardization, concerns in data security and privacy, immaturity of necessary technologies, and technical shortcomings of the RFID technology (de Jonge, 2004; Microlise, 2003; Sarma et al., 2003; Smart Manufacturing Forum, 2003).

The investment of a RFID application depends on the scale of an application and the nature of a business. A RFID application is usually much more expensive than a barcode application due to the technical complexity of electronic tags and readers. Although RFID applications may bring significant benefits to businesses, in general the investment cannot be covered by potential profit increases in a very short term (Chadbourne, 2005). Relevant case studies for cost benefit analysis will be reviewed in the next section.

Different standards for the RFID technology have been developed such as EPC and ISO, and so forth. (de Jonge, 2004; Microlise, 2003). To apply the technology in supply chain operations, it is important to employ open standards in all business processes so that the RFID tags can communicate with all systems in the supply chain. The RFID systems with different standards are difficult to share the critical information in real time. This poor interoperability would also lead to high costs in manufacturing and operations of the incompatible RFID equipments. As the technology becomes more mature, it is expected that the RFID technology would be more standardized.

As a RFID system does not need contact or line-of-sight reading for data capture, it is difficult to prevent unauthorized users from accessing the data on a RFID tag. This exposes security and privacy threats (Sarma, et al., 2003). For instance, unauthorised RFID readers may read RFID tags on a container. As the information on a RFID tag may store valuable information for products or users, it is important to protect the data on RFID tags. For this purpose, various approaches are under development such as encryptions, data locks, and authentication keys, and so forth. (Sarma et al., 2003). However, such solutions may increase the costs of RFID technologies.

A RFID reader communicates with RFID tags through different radio frequencies as seen in Table 1. The communication will be significantly affected when the tags are placed with metal and liquid. Radio signals in high frequencies are easily absorbed by liquid and low frequency signals are strongly affected by metal (de Jonge, 2004). Therefore, in RFID applications with such environment, solutions need to be particularly designed to reduce impacts on the RFID system performance from the environment.

Benefits of RFID Over Barcode Systems

As a summary, advantages of the RFID technology over the barcode technology mainly include:

- **Automatic data capture without visual alignment with a scanner:** This reduces labor costs, improves accuracy and speed of data acquisition. More importantly, the real time information can be captured to support in-depth management functions, for example agile logistic operations control. Such information is too costly to be obtained through manual scans (Microlise, 2003).
- **Greater data storage capacity:** The enriched information from RFID tags facilitate agile and flexible supply chain operations due to reduced reliance on centralised data sources. This portable data source is particularly beneficial to distributed operations, for example construction projects and distributed manufacturing, when centralized databases are not easy to access (Marsh & Finch, 1999).
- **Durable tags which can work in harsh environments:** Barcode labels are easy to be contaminated and damaged in harsh environments (e.g., dust and high temperature). The RFID tags are much more durable to such conditions (de Jonge, 2004)
- **Rewritable tags for dynamic data modification:** This capability facilitates dynamic operational control based on the variance of product or environmental attributes, for example, temperature, pressure, and so forth. With integration of various sensing technologies with the RFID systems, product safety, and quality can be improved (Li, Tang & O'Brien, 2005).
- **Simultaneous communication with multiple tags and data reading with longer distance:** Together with the first feature, the data capture power enables efficient monitoring a large volume of physical objects in a large area without human intervention.

With these advantages, the RFID technology is generally more efficient than traditional barcode systems for supply chain management. Benefits of the RFID technology has been extensively reported from industrial trials. However, costs in the implementation of RFID projects have been a major concern and barrier in adoption of the technology. In this section, we review some cases of RFID trials which reveal major cost/benefit features of RFID applications.

Reported case studies have shown that investment returns on appropriately implemented

RFID applications would cover the costs in a limited period (Chadbourne, 2005; de Jonge, 2004). A RFID solution provider, Intellident, reported the RFID application case of Marks and Spenser (M&S Foods) with a cost benefit analysis (Chadbourne, 2005). M&S Foods uses 300 million labels per year. Cost of the barcode system, including labels, scanners, labor, and data management, is estimated at €3 million per annum. Comparing the barcode system solution, the RFID system at the company had an initial investment of £50,000. The cost of reusable tags (on crates, boxes, pallets) is €1 each and at the total of €3 million. With the estimated RFID life as ten years, the depreciation cost of RFID tags will be one-tenth of the barcode label cost per annum. With the supply chain of 200 suppliers, six distribution centers and 350 stores, the payback period of the initial investment (£50,000) on the RFID system is estimated less than 12 months based on savings (estimated as £600,000 per annum) from reduced goods intake speed (from 22 minutes to 3.6 minutes), savings (estimated as £22 million per annum) from improved delivery accuracy, improved shelf availability, and reduced store administration, and savings (£3 million labels to £300,0000 tag depreciation per annum) from removing tray labels.

In a RFID benchmark study reported by LogicaCMG (de Jonge, 2004), a detailed cost/benefit calculation framework was proposed. A RFID tag is estimated at €0.50. Its life is estimated as 7 years. The system installation cost is € 30,000 per reader. The investigated supply chain has 15 stores, 25 dock doors with one reader each door, 10,000 returnable transport items (RTI) per day. The payback period for the investments in RFID technology is between two and three years in the case. In year one, the net cost is €3.71 million. Then, from year two to year five, the net benefits will be €3.56 million, €2.91 million, €2.91 million, and €2.91 million respectively. The benefits are derived from savings mainly in the RTI handling cost reduction (€0.52 each), efficiency increase (8.5%), and stock level decrease (10%).

The evidence reported above shows that RFID-enabled supply chain systems are more efficient than those with the barcode technology. More cost benefit analyses of RFID applications can be found in various technical reports (BT Auto-ID Services, 2005; Fitzek, 2003;). While industrial RFID applications are exploring the potential of the technology as a new identification technology to improve existing operations performance, we focus on the investigation on the value adding potential of the RFID technology to innovate supply chain operations with new business scenarios. In the following sections, we will present some inspiring thinking on the supply chain innovation based on RFID enabled systems. It should be noticed that technical and economic details of the RFID system implementation are beyond the scope of this chapter.

RFID ENABLED INTELLIGENT BUSINESS MODELS

With the recognised benefits and decreasing hardware costs of the RFID enabled automatic tracking technology, numerous industrial trials and technical developments on the RFID systems have been reported such as cases at WalMart, Sainsbury, Marks and Spencer, Finnair, Ford Motor Co., BT and many others. The applications have mainly focused on improvement of the business efficiency by replacing barcode or manual tracking systems with the RFID technology.

Although promising outcomes have been obtained as evidence, using the enriched automatic tracking information as a source of strategic intelligence for business innovation still remains a challenge. Some research has reported in the literature for investigating such opportunities in different industries (Karkkainen Holmstrom, Framling, & Artto, 2003; Li, Kehoe, & Drake, 2006; Liu, Zhang, Ni, & Tseng, 2004; McFarlane, Sarmab, Chirna, Wonga, & Ashton, 2003). The RFID related research has proposed novel concepts, business processes, and information systems, which improve the efficiency, agility and flexibility of business processes through restructured business scenarios. McFarlane et al. (2003) proposed an intelligent product concept which integrates the product information content permanently with its material content. With intelligent products, the RFID technology are integrated with agent based systems to enable individual products to participate in decision making processes intelligently according to the information embedded with themselves. Karkkainen et al. (2003) developed a prototype system which controls a large number of individualized deliveries in international projects to arrive at destinations just in time. They proposed a product-centric, so called "inside-out," delivery control approach with which products themselves provide delivery requirements to the control systems through RFID tags attached to the products. The planning and control of the deliveries are relatively independent from the centralized information storage, and are flexible to uncertain supply routes and partners. The supply chain network is highly responsive to dynamic changes in the delivery processes. Liu, et al. (2004) proposed a decentralized production control system with the RFID technology applied to a manufacturing shop floor context. Intelligent agents are integrated with the system to communicate with the products that carry the information about their own destiny on RFID tags. Through a simulation of different control rules, the research concluded that, with the real-time information linked to products the agent-based model outperforms traditional control rules. Such efforts on the opportunities from the technology driven innovation of the operations management are still at the concept-proving stage (McCartney, 2006; Sullivan, 2006).

The following sections of this chapter will introduce three research cases on intelligent operations and supply chain management through utilising the RFID enabled automatic tracking technology for innovative business models.

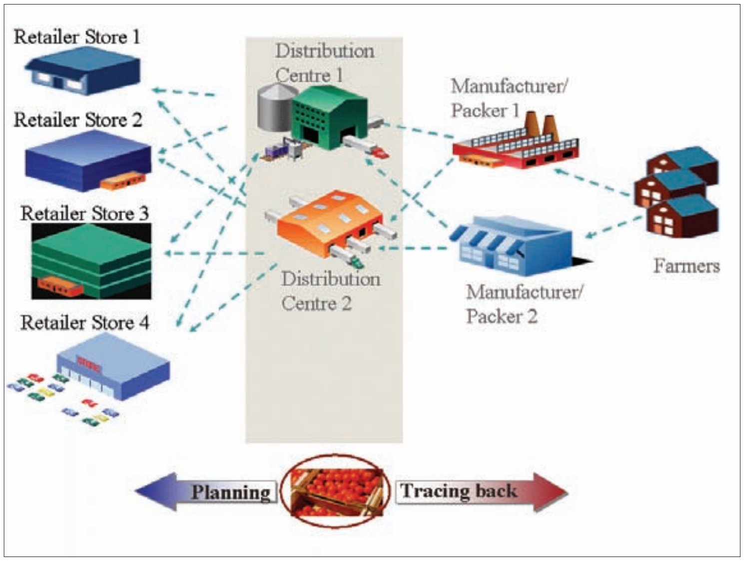
Dynamic Product Quality Tracing of Perishable Foods

It is important to maintain suitable environment to protect the quality of perishable foods. Therefore, the accuracy of the dynamic product tracking information and the technology to capture such information in food manufacturing and supply processes are crucial to the food quality control. In the industry, the RFID-sensor technology is now under investigations for the accurate estimation of product quality characteristics thorough continuously detecting changes of key environment parameters (Sullivan, 2006). In this section, a dynamic product quality tracing model which utilizes the automatically captured product data through RFID sensor systems is proposed. The quality in this model is represented by the "product value" which intends to indicate the consumers' perception of the product quality in the form of "usefulness" (in this case, edibleness). The concept of product value is derived from the research of Blackburn and Scudder (2003) in which the concept is used to abstract the consumer perceived product quality and its impact of the product value on demands. The model in this section is based on a perishable food retail supply chain context as shown in Figure 6. With the integrated RFID sensor network, the product movements and the environment changes in a supply chain can be continuously monitored or tracked with a greater accuracy comparing with traditional manual or barcode enabled control systems (Sullivan, 2006). This provides the possibility of qualitatively modelling the continuous food value or shelf life variations.

The Value: Tracing Model for Perishable Foods

To quantitatively measure the food quality deterioration, we adopt the model in Blackburn and Scudder's research (2003) which evaluates the fresh food value by an exponential function of the

Figure 6. A case of dynamic product value tracing in a food supply chain (Adapted from Li et al., 2005)



time period T and an environment parameter λ (see equation (1)). The exponential function indicates the fact that the consumer perceived product value decrease quickly over time in a nonlinear form given the environment condition. The parameter λ in our research represents the influence of the temperature on the product quality. The maximum value of a product is 100 (%) at the time of delivering from a farmer.

Present product value = *Original Value* •*EXP*(-λ•*T*) (1)

To describe the product quality (value) tracking process with the RFID sensor networks, a value tracking model is developed in equations (2).

$$V_{m,k*g} = b_{k*g} \cdot V_{f-m,g} \cdot e^{-(\lambda_{f-m,k*g} \cdot t_{f-m,k*g})}$$
$$V_{m-d,k} = b_{k*g} \cdot V_{m,k*g} \cdot e^{-(\lambda_{m,k} \cdot t_{m,k})}$$
$$V_{d,j*k} = b_{j*k} \cdot V_{m-d,k} \cdot e^{-(\lambda_{m-d,j*k} \cdot t_{m-d,j*k})}$$
$$V_{d-r,j} = b_{j*k} \cdot V_{d,j*k} \cdot e^{-(\lambda_{d,j} \cdot t_{d,j})}$$
$$V_{r,i*j} = b_{i*j} \cdot V_{d-r,j} \cdot e^{-(\lambda_{d-r,i*j} \cdot t_{d-r,i*j})}$$
$$i = 1,2,3,4; \quad j = 1,2; \quad k = 1,2; \quad g = 1,2.$$
$$b_{k*g},\ b_{j*k},\ b_{i*j}$$
$$= \begin{cases} 1, & \textit{Delivery was paased throug the route} \\ 0, & \textit{Otherwise} \end{cases} \tag{2}$$

The model is derived from the concept of product value (Blackburn & Scudder, 2003). The concept is based on the assumption that a value function can be properly structured with the key parameter λ, through quantitative approaches such as experiments and statistical analyses to represent the impacts of the production and delivery processes on the product deterioration feature and the consumers' perception of the product quality. However, such research is beyond the scope of this chapter.

In equation (2), the value deterioration parameter λ reflects the magnitude of the environmental impacts on the product quality/value per unit time. An exponential value deterioration rule (Blackburn & Scudder, 2003) is adopted, that is, with a given impact from the environment, the product quality deteriorate exponentially over time. In equation (2), *i*, *j*, *k* and *g* denote the supply chain tiers, that is, the retailer (*r*), distributor (*d*), manufacturer (*m*) and grower (*f*) respectively as seen in figure 6. *i*j*, *j*k* and *k*g* denote the immediate preceding transit routes of a supply chain node at a tier. V_r, V_d, and V_m are the product value at a supply chain node at the time of entering tiers of the retailers, distributors, and growers respectively. $V_{f\text{-}m}$, $V_{m\text{-}d}$, and $V_{d\text{-}r}$ are the initial product value in a transit process between tiers. With this model, given the initial product quality/value, the status of the product quality at any place and at any time can be quantitatively identified dynamically through RFID sensor network.

To trace the product quality changes, data dynamically stored in the RFID system would include product identifications, the manufacturer, packaging codes of the processes (manufacturing, packaging, delivery, storing, etc.), codes for preceding and succeeding processes, dates and the time of entering and leaving a process, the temperature (and other necessary quality parameters) in a time period. Readers of a RFID system is installed at key control points of each supply chain process to capture both the product and process details. The sensors in an integrated RFID sensor network should be connected to the readers to synchronize the product data reading and the environment parameter reading. This will enable the system to capture the accurate impact of the environment on the product quality while the products are moving through a supply chain. The EPC service and object naming service of a RFID system enable the supply chain partners to access the accurate information of an individual product unit (e.g., palette, case, box, etc.) or even an individual product (e.g., a bottle of milk) in a supply chain through Internet. Without the automatic product identification technology and the integration of the sensor systems with RFID systems, the accurate quality status of an individual product/product unit in bulky and fast product flows would be very difficult to capture through current Internet based information sharing applications (Li, Kehoe, & Drake, 2006).

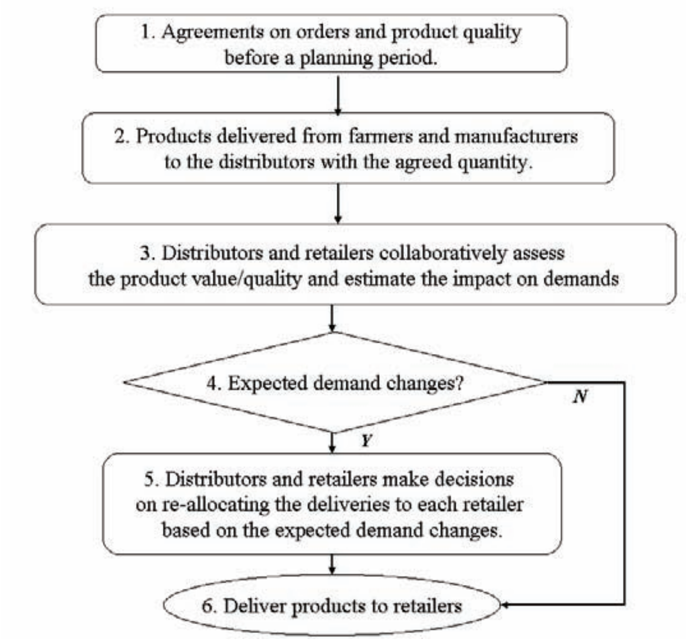
Applications of the Dynamic Product Tracking

One potential application of the above product tracking approach is dynamic planning and pricing in perishable food supply chain operations. With the context given in last section, we assume that distribution centres in the retail supply chain dynamically plan their perishable food deliveries to retail stores according to the decision on differentiated food pricing policies and estimated demands at the retailers. These dynamic planning and pricing decisions require the accurate product quality information which enables effective estimation on product demands and consequently pricing based on the potential demands. A centralized pricing decision structure is proposed in Figure 7.

Before a planning period, retailers place orders based on estimated demands and the agreed product quality. The actual demand delivered to each retail store is determined dynamically based on the product tracing information during the selling period. Variations of the actual delivery against the orders placed in agreements will incur supply rearrangements and excess stocks. It therefore leads to penalties. The objective of such an application would be maximizing the aggregated profits of the retail stores in the supply chain.

The relationship between a product sales price and demands can be represented by widely adopted price-dependent demand descriptions in the economic research literature. The form of the demand description can be either determinative in a linear or nonlinear form, or with a stochastic function. As the perishable foods deteriorate over time, given accurately captured data for the product value variations through the RFID sensor network, a dynamic pricing decision can be made against potential consumer responses to the value variation. A price marking down policy can be consequently developed to dynamically match demand changes with proper price levels.

Figure 7. Procedure of the dynamic pricing approach



The benefits identified from the product tracing approach are likely to vary with the consumer buying behavior. The more important the product quality or value that is perceived by consumers, the more benefits the dynamic product value tracing approach would generate.

Dynamic pricing models have been intensively studied in the literature. Many RFID applications have been reported. The above RFID enabled application has proposed an innovative product value tracing and dynamic pricing scenario by utilising real-time product quality information from RFID enabled sensor networks. The RFID technology underlies the implementation of such a dynamic pricing approach, because the real-time and traceable product information is a prerequisite for accurately evaluating the product value or quality. With the large volume and variety of product flows, this is very difficult, if not impossible, to be achieved by traditional product identification technologies. When consumers are able to dynamically perceive the quantitative product quality evaluation, it is particularly crucial to dynamically plan the deliveries and price the perishable food, so that better services to consumers and good profits can be achieved.

The proposed product tracing application in this section has only focused on the optimisation of retailer's profits. A supply chain wide dynamic planning and pricing scenario based on such a technology driven approach may be analysed for a wider view of the benefits. More insights into the relationships between the perceived product value and the demand in the demand function would be also beneficial to improve the applicability of the model.

Product Centric Manufacturing Scheduling

Based on the RFID and agent technologies, the concept of the Intelligent Product (IP) has been proposed (McFarlane et al., 2003). The products, with RFID tags and presented by intelligent agents, have unique identities and are capable of communicating effectively with its environment. An intelligent product can describe itself with self-retained data, and can make decisions for its own activities (McFarlane et al., 2003).

With the IP approach, the information system becomes product centric and the decision-making tends to be driven by the products themselves. This approach enables the manufacturing to be more flexible and agile when dealing with a large number of product varieties, and more efficient with given manufacturing constraints. An IP-driven agile manufacturing approach is proposed in this section to demonstrate the benefits of the IP approach in the manufacturing operations with a mass customisation context.

The Concept of Intelligent Product

The Intelligent Product has been defined as a commercial product that works with a RFID system and has part or all of the following five characteristics (Zaharudin et al., 2002):

- Possesses a unique identity
- Is capable of communicating effectively with its environment
- Can retain or store data about itself
- Deploys a language to display its features, production requirements, and so forth.
- Is capable of participating in or making decisions relevant to its own destiny.

Every IP has two components—a physical entity and informational presentation. The physical entity is the physical product which is equipped with RFID technology. The informational presentation of an IP can be an individual software agent that owns some product-related data (e.g., unique ID) and acts (e.g., negotiate with other agents, make decisions) on behalf of the product's interest (e.g., short lead-time and low costs, etc.). An IP retains data about itself. The informational part of the IP retrieves the data through the RFID technology. The IP may also keep dynamic data regarding product's movements and processing requirements, and so forth. The IP system can access networked data sources (local databases or ONS registered network sources) that stores product data such as production requirements, historical records, and so forth. The local manufacturing unit, IP systems and enterprise systems, can be integrated with such networked sources so that the data are visible and updatable by different cooperative parties. This allows manufacturing activities to be responsive to the dynamic environment.

The Intelligent Product Driven Control Approach

The use of autonomous product agent to represent the informational part of products has been reported in some recent research (Kim, Song, & Wang, 1997; Krothapalli & Deshmukh, 1999; Lim & Zhang, 2004; Reaidy, Massotte, & Diep, 2006). The research has proposed approaches with product agents to provide product information, negotiate for production control, and communicate ERP systems. The research articles did not provide details of the linkage between physical items and agents. The proposed system in this section will describe the architecture which links the physical product with the agent systems. The proposed system aims to copes with a large number of product varieties and late changes of production requirements more efficiently in manufacturing processes through the IP enabled intelligent scheduling system.

In the mass customization context, with an extreme case, every production order may be one batch itself. The traditional centralized decision-making approaches are not so scalable when dealing with such complexity in scheduling. With the IP approach, a product can make decisions about its destiny with less or without centralized management. Since each product has a duty of making decisions about itself, and the RFID technology is applied to enable agents to quickly respond to physical products, the system is potentially more scalable to the number of product varieties. In other words, the manufacturing performance becomes less affected by the complexity originating from the product variety issues.

In addition to the product variety issues, customers may request to change the requirements of an ordered product before it is produced. The requests lead to changes of a production process. Consequently, manufacturers need increased visibility to the latest updates in order to conform to the customer needs. To cope with this, the IP approach may be adopted to track individual product items in real time and responsively make decisions for updating a manufacturing process.

The IP Enabled Scheduling System

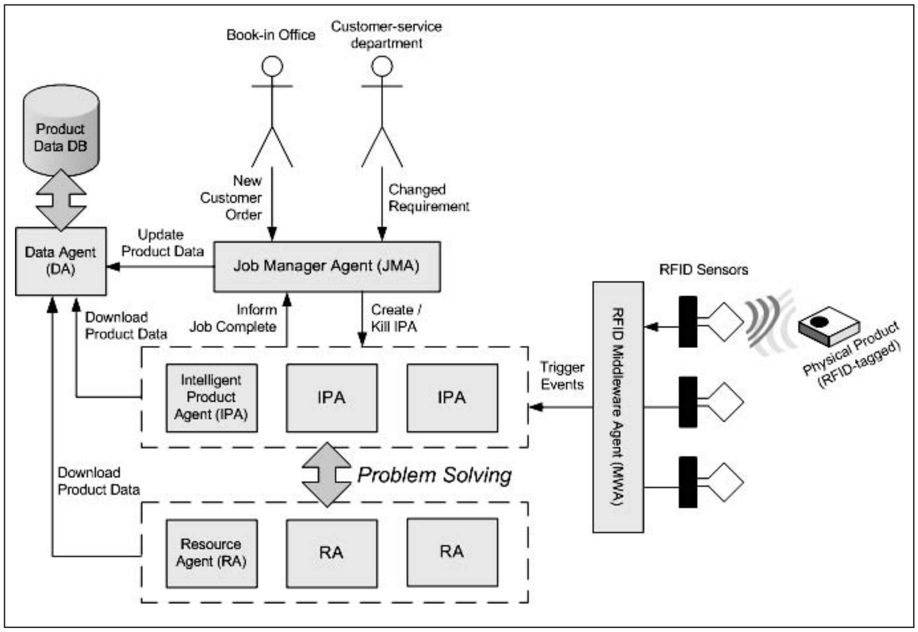
We firstly introduce a proposed MAS architecture which enables the communications between physical products and the production systems as seen in Figure 8.

The architecture includes a job manager agent (JMA), a data agent (DA), intelligent product agents (IPA), resource agents (RA), and an RFID middleware agent (MWA). The DA is in charge of receiving data transaction requests from other agents and fulfilling the data transactions to a database before giving feedback to agents about their requests. An *IPA* is the information presentation of the intelligent product. It actively drives the scheduling process and makes decisions within a negotiation process. A *JMA* receives new production orders and requests for changing production orders from other parties. It creates and removes *IPA* from MAS when a job is created and completed respectively. A *RA* is the informational presentation of resources. Based on the generalized case in the last section, a *RA* can represent a workstation. The *MWA* manages the sensor devices, receives raw data from sensors, filters and interprets the data, and finally informs the corresponding *IPA* about the status of the physical part. In other words, *MWA* and sensors are the communicational link between the physical part and informational part of an IP.

Detailed workflows of the approach can be described by the life cycle of jobs and negotiation protocols. A job life cycle is described below:

- Production orders are received randomly. After a new production order is received by the *JMA*, it will create a new *IPA* and submit

Figure 8. Proposed IP-driven scheduling system architecture (Adapted from Liu, Li, & Kehoe, 2006)



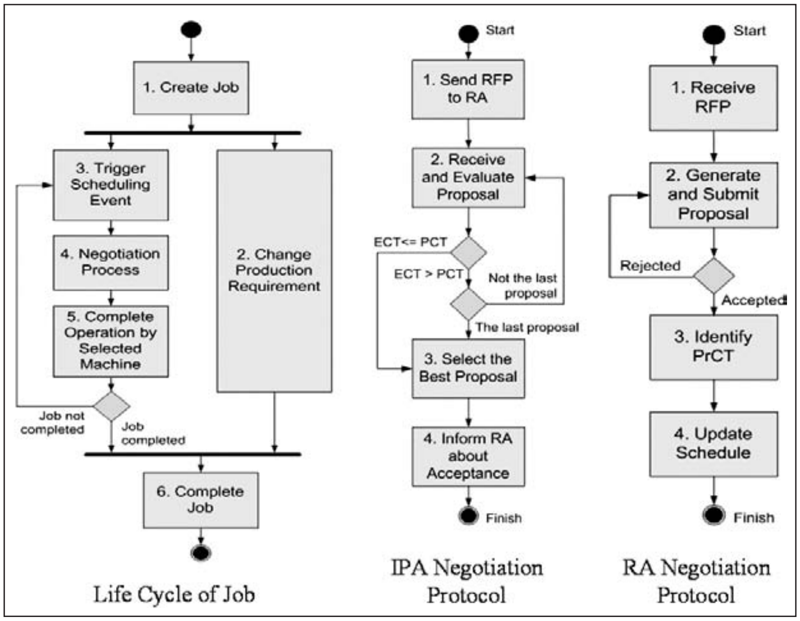
the product data to a *DA* which stores the data in a database. The physical product equipped with a RFID tag carries unique ID and necessary static data.

- When production requirements need to be altered during a manufacturing process, the changes are received by the *JMA* which checks if the process needs update.
- At checkpoints, the products with RFID tags are physically allocated to the routes of processing stations. When a process is completed and the product is leaving the station, the *MWA* retrieves the unique product ID and other relevant data from the RFID tag and informs of the *IPA* that the product has completed. Then the *IPA* will trigger the negotiation process with the *RA* for a scheduling decision of the next route.
- The *RA* will consequently add the new jobs to its schedule according to the agreement. It downloads the production requirements from centralized database through the *DA*. Finally, the workstation finishes the whole process.

The negotiation process takes the interests of both the *IPA* and *RA* into account. The *IPA* and the *RA* work cooperatively to address the production lead-time and workstation resource optimization issues respectively. Figure 9 explains the negotiation protocols. With the negotiation protocols, *IPA* initializes the negotiation process, and has the power to evaluate, accept and reject *RA*'s proposals.

Through the proposed approach, the problem of the product variety and dynamic requirement changes would be dealt in a more scalable and responsive manner. A MAS architecture is proposed to support the IP enabled scheduling approach. The architecture integrates the IP's physical and informational attributes, as well as the links between them. In order to illustrate the idea, prototype negotiation protocols are developed to implement the architecture. Further research is being performed to simulate the approach with some manufacturing cases.

Figure 9. The workflows of the proposed IP-driven scheduling system (Adapted from Liu et al., 2006)



Intelligent Traceability Systems

The traceability of product data, globalized data sharing, and risk analysis within and beyond business networks is a key capability to maintain food quality and safety. The research on traceability systems has been reported in the literature, including RFID tagging and DNA profile auditing solutions Caja (2002). A number of traceability systems and approaches (Bertolini, Bevilacqua, & Massini, 2006; EU FoodTrace 2004; Mouseavi, Bevilacqua & Massini, 2002; Sasazaki et al., 2004; Wilson & Clarke, 1998) have been developed to deliver the supply chain traceability and internal traceability for achieving different business objectives. These systems vary in complexity from simple paper recording systems, complex computer-based information technology methods, to the most sophisticated systems including biological technologies.

The traceability is defined as: "the possibility to find and follow the trace, throughout all the stages of production, processing and distribution of a foodstuff, feedstuff, and an animal destined for food production or a substance destined to be incorporated in foodstuff or feedstuff or with a probability of being used as such" (The European Parliament and the Council, 2002). According to TRACE-I Guideline (EAN International, 2003), both tracking and tracing must be in place for the effective traceability. The tracking and tracing capability of a traceability system has been used as tools for achieving a number of different objectives. Golan, Krissoff, Kuchler, Calvin, Nelson, & Price (2004) indicated that firms have three primary objectives in using traceability systems: facilitate trace-back for food safety and quality; differentiate and market foods with subtle or undetectable quality attributes; and improve supply chain management.

Although, food traceability becomes an essential issue for the food industry, companies are reluctant to invest on these systems as many food organizations acknowledge their main motivation of adopting traceability is complying with the regulations. For many businesses, implementations of traceability are still seen as a daunting task without any obvious benefits to a business in financial terms. Traceability is frequently mentally separated from other supply chain activities (EU FoodTrace, 2004). Therefore, enhancing and understanding the value of the food traceability becomes increasingly crucial for the food industry. In this section, we particularly demonstrate the potential benefits of the RFID technology for the integrated traceability-supply chain management—not only for tracing product origins, but also support the strategic and operational supply chain decision-making.

RFID Based Traceability System

A traceability system requires capabilities of identifying any items deemed necessary for traceability, and facilitating data capture, storage, management, and communication. RFID based traceability systems have the potential to improve such capabilities. Although paper based and barcode based traceability systems can deliver both internal and chain traceability with basic traceability functions, the RFID traceability system changes the way in which data are recorded, processed and transmitted across a supply chain, to manage the traceability processes innovatively and more efficiently. Wilson and Clarke (1998) indicated that the data structure used in traceability system must meet two conflicting criteria: firstly, it should be as small as possible to enhance speed and efficiency; secondly, it must be of sufficient capacity to meet the needs of large data volumes. RFID technology itself offers the speed, automation, and data capacity with a distributed data management scenario (every individual product attends the data storage and processing),which limits the complexity of the centralized traceability data management. Table 2 shows the advantages of RFID enabled traceability systems over barcode based traceability systems.

Table 2. Advantages of RFID based traceability system over barcode system

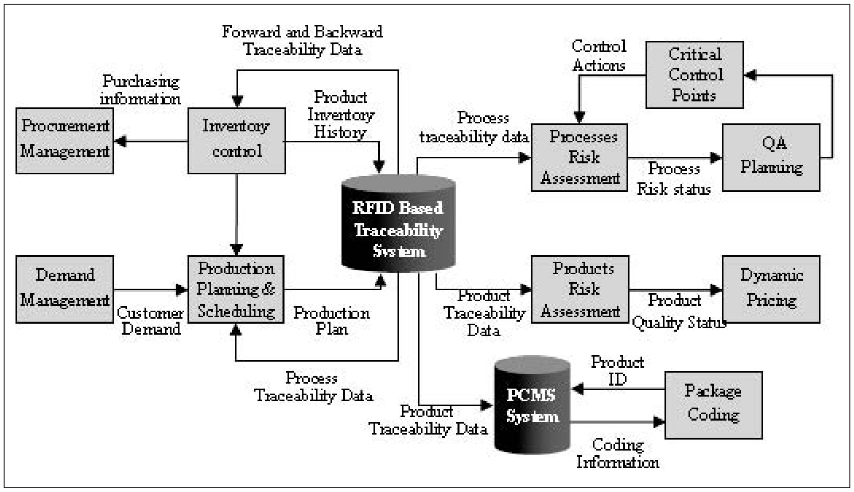
	Advantages of RFID Based Traceability System Over Barcode System
Data Feature	Capacity: More data (6bit~64kbit) can be stored in tags.
	Unique identifier: A serial number or unique identity can be assigned to specific item
Data Capture	Efficiency: Many tags can be read simultaneously
	Convenience: Data can be captured within certain range
	Location: Readers can provide location information when products being scanned
Automation	Up-to-date data: Data can be obtained continuously
	Accuracy and cost-effectiveness: Without human involvement in data scanning

Traceability System Integration

With RFID based traceability systems, a product can be tracked and traced in a more efficient way to provide accurate real time data of food and ingredients as they move through supply chains. To maximize the benefits from such systems, traceability systems need to be integrated with enterprise systems and supply chain management processes so that the traceability systems can contribute to the operations and supply chain management with the benefits beyond the contingency management. A framework of integrating the traceability system with operations management processes is proposed as seen in Figure 10 in a food manufacturing context. The investigated case is based on a British meat manufacturer. The current paper based traceability system records batch numbers and time of processing for all products. The business is experiencing problems such as low production efficiency due to long production lead time, high inventory and large batch size, high quality maintenance costs due to long storage time; and lack of real time tracking/tracing capability for production and quality control, and so forth.

With the proposed traceability-operations integration, the RFID enabled system is expected to provide the real time traceability data of production process and raw materials, such as production

Figure 10. A framework of the integrated traceability-operations management solution. (PCMS: package coding management system)



facility, processing history, supplier information of raw materials, and its storage period and quality status for production planning and inventory control processes. On one hand, the integrated solution provides the real time information that enables to optimize production plan and a better quality control for lower costs and better product quality. On the other hand, the optimised production decision as an input of the traceability system would improve both tracking and tracing capabilities through reduced unnecessary batch mix and reduced numbers of products that may be potentially recalled.

With a RFID enabled solution, enriched traceability data can be retrieved such as process environmental parameters, real time positions, product composition, packaging, and storage conditions. The information would improve customer satisfaction and more accurate and responsive risk assessment. The dynamic evaluation results in food safety risk consequently support dynamic planning for production and supply chain operations (e.g., dynamic pricing and supplier selection) and critical control points (e.g., control actions at required points according to risk alert level). With an extension to the supply chain management, Table 3 summarizes potential benefits of the integration in different domains within and beyond a food manufacturing enterprise.

To achieve these benefits, the RFID enabled traceability system must be properly designed to ensure that the right data is collected and managed effectively. The business process needs to be re-engineered to integrate the RFID based traceability system with enterprise systems.

The above research concludes that, when a traceability system is integrated with operations and supply chain management, more competitive advantages can be potentially obtained. The RFID enabled traceability system is promising in facilitating such integration. A key issue to achieve the maximum potential value of integrated traceability systems is how to utilize the traceability data for business innovation. Future research would be beneficial to such applications by identifying the benefits of the integrated traceability solution through quantitative analyses.

CONCLUDING REMARKS

The proposed business models in the third section, utilize the RFID technology to improve the visibility of products and their relevant attributes in logistic or manufacturing operations. The visibility consequently creates chances to operate the businesses in more responsive, dynamic, and efficient scenarios. In such proposed RFID

Table 3. Potential benefits of integrating traceability system with operations and supply chain management

Processes	Impact of integrated RFID based traceability systems
Production Planning & Scheduling	Optimal production planning; avoid uneconomic raw material mixture, reduce the production lead time.
Inventory Control	Inventory visibility; efficient and accurate picking and packing operations.
Quality Control	Better quality and process control; efficient and accurate risk assessment, dynamic product quality and safety evaluation.
Package Coding Management	Coding automation; accurate and efficient coding process; additional traceability data on the package.
Shelf Management	Improve on-shelf availability; effective shelf replenishment; dynamic pricing.
Reverse Supply Chain management	Quick response; efficient product recalls and returns.
Supply and Logistic/Distribution Management	Efficient and effective information flow; instantaneous decision-making responses to supply chain variations.

applications, the technology is not only used as a replacement for barcode systems. The actual initiative is to encourage the “sense and respond” management strategy which enables more agile and intelligent supply chains to respond changes and events dynamically (Ferrari, 2006). The development of advanced identification and tracking technologies, including RFID, GPS and other sensing technologies (e.g., for temperature, pressure, humidity, shock, and weight, etc.) are key enablers of the intelligent supply chains as they provide the “sense” to management systems throughout a supply chain. Therefore, integrations of the identification and tracking technologies into a business intelligence platform are required, so that the real time information at different levels (e.g., product attributes, product items, stock units, containers, vehicles, etc.) can be available for various decision-making purposes.

To achieve the potentials of the technology driven innovation, supply chain partners must be cooperative in investments of the technologies, information sharing, risk and profit sharing, and standardisation of the technologies, and so forth. Without the cooperation, the sensing information would be restrained within organization boundaries, and would not add values to supply chain operations. Lack of cooperation may simply stop supply chain partners to join in RFID applications projects (e.g., manufacturers may refuse to pay for RFID tags, when increased profits are only related to retailers). Furthermore, associated technologies also need to be mature so that the sensing data can be processed into valuable information for decision support. For instance, the software which integrates RFID systems with various enterprise applications is still under development. This has limited the potential benefits of RFID applications, and also affected the technology adoption (Microlise, 2003). Therefore, both organizational and technical supports are essential for the success of RFID technology applications.

In summary, the RFID-enabled business intelligence which improves the process visibility and facilitates decision making are increasingly important to sustain competitiveness. As the implementation costs of the RFID technology are continuously decreasing, the technology is expected to play more important roles in the innovation of supply chain management. Although this chapter focuses on the RFID enabled intelligence for innovative enterprise operations and supply chain management, it is apparently that the RFID technology is not the only player in the technology driven business innovation. Applications of the grid computing technology, agent based systems, global positioning system, wireless mobile networks, personal data assistant, and many others in the industry have generated promising outcomes in providing strategically important information sources. Such information sources would be increasingly used as business intelligence to improve business performance. We are expecting that novel business models would be inspired by such technological advancement to foster more intelligent supply chains in the near future. This, we believe, would demonstrate both the benefits and challenges of the “visibility,” not only in the industry, but also in everyone’s daily life.

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Chapter 3.11

RFID and Wireless Personal Area Networks for Supply Chain Management

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INTRODUCTION

Efficient supply chain management relies on knowing where products in the supply chain are located. The ability to track items from manufacturing plant to warehouse to distribution center to wholesaler to retailer is currently provided by RFID, radio frequency identification (Weinstein, 2005). Case examples of commercial applications of RFID in supply chain management are evaluated by Jones et al. (2004). A recent development, low power wireless personal area networking, WPAN, can offer advantages over RFID in certain circumstances. It is the purpose of this article to evaluate RFID and wireless personal area networks with respect to each other and to identify the features that give one an advantage over the other. We first describe the two technologies.

RADIO FREQUENCY IDENTIFICATION (RFID)

RFID tags are of two types: passive and active. A passive RFID tag is a chip incorporating memory and a microwave transmitter that is embedded in a product or in the product's packaging. The memory contains the identification number of the tag and may also contain physical specifications of the product using PML, Physical Markup Language (York, 2003). In order to read the tag an RFID reader sends out a burst of microwave energy, which is picked up by the tag and is sufficient to allow the tag to transmit the contents of its memory, which is received by the reader. Since the tag receives power from the reader, it does not need to have its own battery, and is called a passive RFID tag for that reason. Passive tags cost about US$0.20 in large volumes, and are used much more widely than active tags.

Active RFID tags incorporate a battery, cost more than passive tags and can be used to track more expensive products. The price of tags is continuously dropping and increasing usage of active tags can be expected over time.

Some tags are read-only in which case the ID is burnt into the tag at time of manufacture. Others are read/write in which case the memory contains not only the fixed identification number of the tag, but may also contain other information such as a physical description of the product (color, size, etc., in PML format), which is added when the product is manufactured.

Standardization of the identification number, so that it can be read by the many different readers used by organizations in different parts of the supply chain, started at the Auto-ID Center at MIT, and is now being pursued by EPCglobal Inc, an industry consortium that aims to standardize the format of the EPC, electronic product code for use in RFID tags. The current proposal is illustrated in Figure 1 and consists of three parts:

- A 28-bit EPC manager allowing 268 million manufacturers,
- A 24-bit object class allowing 16.8 million products for each manufacturer
- A 36-bit serial number allowing 68.7 billion copies of each product

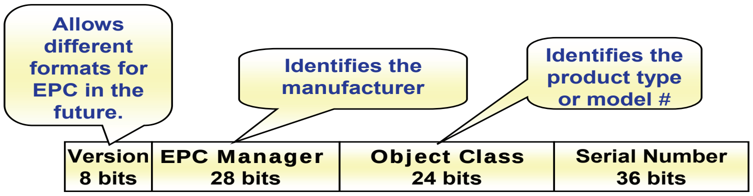
The specification of the air interface is given by the International Standards Organization (2004). Taken together, the EPC and the air interface are the main standards for RFID.

Automated input of RFID information into a supply chain management system requires RFID readers to be located on shelves in warehouses, distributions centers, and possibly also in retail stores and in delivery trucks. Readers have a range of about one meter so that multiple readers are required. Readers can input information to the supply chain management database via wired connections, for example, using Ethernet, or using a wireless technology such as WiFi or WiMAX (Wright, 2007a, 2007b). The total cost of the system consists of the cost of the tags on each item flowing through the supply chain plus the cost of the readers. Although passive tags cost only US$0.20, readers cost approximately US$250.00.

WIRELESS PERSONAL AREA NETWORKS (WPANs)

An alternative to RFID for supply chain management is a wireless personal area network or WPAN, consisting of devices that communicate with each other instead of with a reader. The word "personal" in the title does not mean that there is always a human user, instead it refers to the limited range of the wireless communications: approximately 1 meter from one device to another. WPANs are of various types and here we focus on the low power version that is standardized by IEEE (2003), and is being commercialized by the industry consortium, the Zigbee Alliance, which has developed a specification for wireless personal area network applications (Zigbee, 2006). WPANs require each device to be powered, typically with a battery, but they transmit low data rates at low power so that battery life can exceed a year. Methods for

Figure 1. 96 bit Standard Electronic Product Code, EPC



reducing power requirements are described by Liang (2003) and Rajendran et al.(2006); and the system's performance is analyzed by Chin et al. (2003). Initially applications of low power wireless personal area networks include interactive toys and industrial control, in which sensors measure temperature, humidity and position of items in a production facility and use the WPAN to communicate this information to a production control system (Egan, 2005). Supply chain applications include embedding WPAN devices with EPCs in products or their packaging and could also include sensors for measuring temperature and humidity, which are important for perishable items such as produce. WPAN devices can be designed as small as a coin, so as to be easily embedded in products and packaging (Choi, 2003).

The network architecture of a WPAN is illustrated in Figure 2, and is built up of clusters of devices. Each cluster has one device designated as a "cluster head," and one of these cluster heads is the WPAN coordinator. Although the communications range between one device and another is limited to about one meter, networks of clusters can communicate over a much longer distance. Each device uses wireless communications to communicate with its neighbors, and one device can communicate with a supply chain management system using Ethernet, WiFi or WiMAX. This "upload device" is more costly than the others, however only one is required per WPAN. Actual $ costs are not available at the time of writing (1Q06) since WPAN devices are at an early stage of commercialization. Practical methods for designing WPAN networks are described by Minami (2004).

In supply chain management, WPAN devices can be embedded in products or in packaging and can communicate with each other in warehouses and delivery vehicles. As items are added to or removed from a stack of shelves in a warehouse, the clusters reconfigure dynamically, and information about the new products is distributed to the upload device. Each stack of shelves in a warehouse needs an upload device connected to the supply chain management system to forward information it receives from all the other devices on the products stored on those shelves.

COMPARATIVE EVALUATION

A comparative evaluation of RFID and WPANs for supply chain management is summarized in Table 1.

Both RFID and WPANs have a limited communications range of about 1 meter, however the extent of a WPAN can be much greater end to

Figure 2. Wireless personal area network

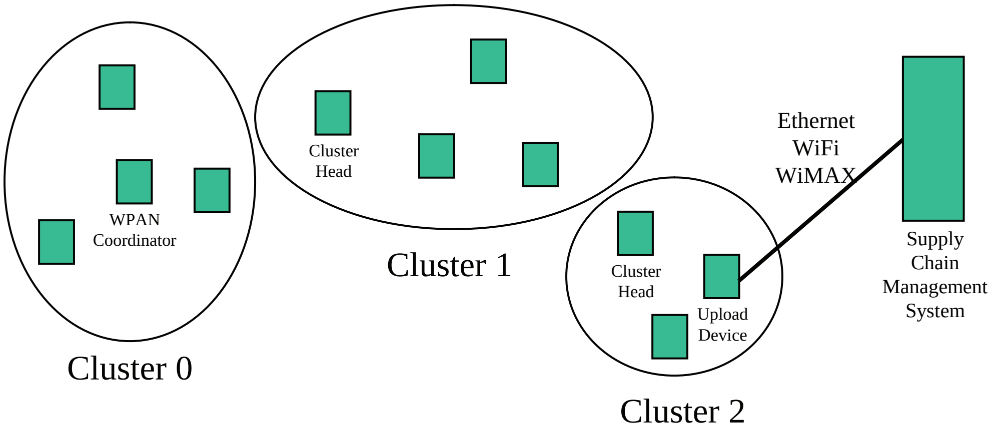


Table 1. Comparative evaluation of RFID and WPANs for supply chain management

	RFID	**WPAN**
Communications range	~ 1 meter: tag to reader.	~ 1 meter: device to device.
Networking	N/A	A network can consist of hundreds of devices.
Number of devices needed	One tag per product or package. One reader within a meter of each product or package connected to the SCM system.	One device per product or package. One upload device per WPAN, connected to the SCM system.
Cost	Very low cost per tag. Higher cost per reader.	Low cost per device. Higher cost per upload device.
Environmental monitoring	No standard integration with sensor technology.	WPAN sensors commercially available.
Reliability	< 100% reading ratio.	Error control protocol enhances reliability.
Stage of development	Established technology.	New technology at early stage of commercialization.
Power	Tags derive power from reader.	Devices need batteries or mains power.

end. In warehousing applications, this allows a WPAN to span an entire stack of shelves, using only a single upload device, whereas multiple RFID readers are required, each having an upload capability. Upload devices and RFID readers cost more than regular WPAN devices and RFID tags, so that using less of them gives a potential cost advantage to WPAN over RFID. Another advantage of WPAN is that additional sensor devices can be added to monitor temperature and humidity, which is important in the case of perishable products. This can be done in a standardized way with WPAN sensors; however sensors interfaced to RFID tags require a proprietary interface (Philipose et al., 2005). The final advantage of WPAN is improved reliability, due to the use of an error control protocol. Any low power wireless communication can be unreliable in the presence of metal, for example, in warehouse shelving and in the products themselves, and read ratios on RFID readers are often <100%. The downside to WPANs is the additional cost of the devices, first due to the fact that it is a relatively new technology, and second due to the requirement for each device to have a battery or mains power supply.

CONCLUSION

RFID is a mature technology that is currently seeing widespread deployment to provide information for supply chain management. WPAN is a more recent development which could provide similar and, in the case of perishable products, improved functionality. As WPAN technology is commercialized and unit prices drop, we can expect cost advantages compared to RFID, since the cost of multiple upload devices can be eliminated in the case of WPANs. In addition WPAN is a more reliable technology than RFID since it incorporates error control.

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KEY TERMS

Electronic Product Code (EPC): A code that can uniquely identify each item in the supply chain, by specifying the manufacturer, the product code and the serial number of each item.

Physical Markup Language (PML): A language for describing the physical characteristics of items, including the dimensions, weight and operating specifications of products in the supply chain.

Radio Frequency Identification (RFID): A system consisting of tags containing identification numbers, which can be transmitted to readers over a distance of about 1 meter.

WiFi: A commercial implementation of the IEEE 802.11 standard for wireless communications up to about 100 meters, in which the equipment has been certified by the WiFi Alliance, an industry consortium.

WiMAX: A commercial implementation of the IEEE 802.16 standard for wireless communications with a range of 2-5 Km, in which the equipment has been certified by the WiMAX Forum, an industry consortium.

Wireless Personal Area Network (WPAN): A network consisting of multiple devices communicating using wireless, each within about 1 meter of its neighbor, following standards developed by IEEE 802.15.

Zigbee Alliance: An alliance of companies commercializing WPAN technology by developing specifications for its efficient application in a number of areas of business, home and industry.

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Chapter 3.12

Integrating Mobile Technologies in Enterprise Architecture with a Focus on Global Supply Chain Management Systems

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ABSTRACT

This chapter investigates opportunities to integrate mobile technologies within an organization's enterprise architecture (EA), with an emphasis on supply chain management (SCM) systems. These SCM systems exist within the overall EA of the business. SCM systems are further influenced by the increasing modern-day need for information and communications technologies (ICTs) within a business, to bring together all of its disparate applications. The resultant enterprise application integration (EAI) also stands to benefit immensely from the incorporation of mobile technologies within it. Traditionally, supply chain management systems have involved management of the flows of material, information, and finances in a complex web of networks that include suppliers, manufacturers, distributors, retailers, and customers. Thus, these traditional supply chain management systems have a great need for integration under the umbrella of EAI. Mobile technologies can provide time and location independence to these EAIs in terms of information in the supply chain systems,

creating the possibility of multiple business processes that traverse diverse geographical regions. This chapter, based on the research conducted by the authors at the University of Western Sydney, discusses the opportunities that arise in supply chain management systems due to the time and location independence offered by mobility, and the resultant advantages and limitations of such integration to the business.

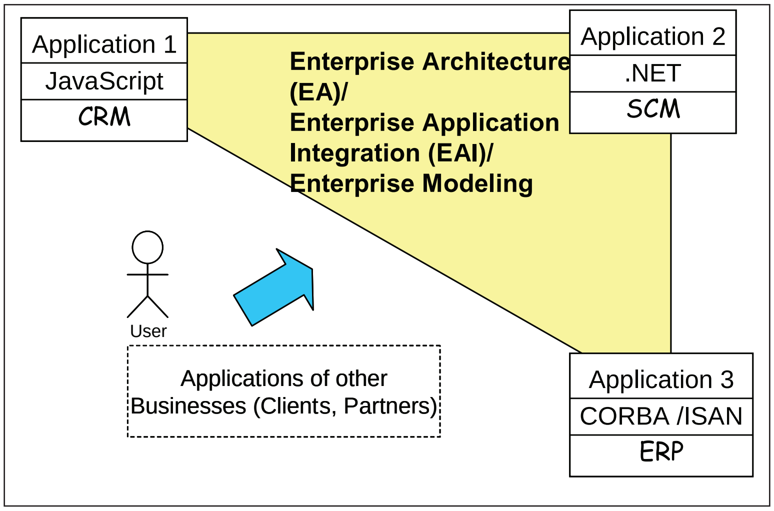
INTRODUCTION

A business enterprise uses a suite of different software applications to fulfill its various activities. These systems include supply chain management (SCM) systems, customer relationship management (CRM) systems, enterprise resource planning (ERP) systems, business intelligence (BI) systems, and other supporting financial and business systems. These enterprise systems do not operate in isolation. In fact, each of these systems depends on other systems, as well as large amounts of data in the background, to fulfill their own requirements. Specifically, supply chain management systems involve management of the flows of materials, information, and finance in a complex web of networks that include suppliers, manufacturers, distributors, retailers, and customers. The complexity of an SCM system requires it, as per Poirier (1999), to offer the right combination of data, products, and services to customers at the right time, right place, and right price. With rapidly increasing Internet access and business-to-business (B2B) connectivity, users of SCM are able to get their information needs easily—leading to what can be called electronic supply chain management (E-SCM) systems. E-SCM (Internet-based) systems are integrated together with all other enterprise applications, resulting in a comprehensive enterprise architecture (EA). Such an EA delivers the company a competitive advantage by opening up opportunities to streamline processes, reduce costs, increase customer satisfaction, and enable thorough strategic planning (Unhelkar & Lan, 2006). In today's modern business environment, it is important to further extend the advantages by incorporating wireless technologies and handheld devices in the organization's overall enterprise architecture. As Barnes (2002) mentions, the impact of wireless telecommunication on the Internet has taken a new turn. We use the mobile technology application for communications, working, banking, and shopping. The "time and location" independence provided by mobile technologies leads us into the era of mobile supply chain management (M-SCM) systems. It is important to understand these M-SCM systems within the context of the overall enterprise architecture. This chapter starts with a brief review of enterprise architecture and the issues related to enterprise application integration (EAI). This is followed by an understanding of the traditional SCM systems, together with the study of mobile technologies and applications. The chapter then describes the details of E-SCM and M-SCM. Finally, an outline of a model for integration of mobile technologies with SCM processes is then presented, together with its advantages and limitations.

ENTERPRISE ARCHITECTURE

An enterprise architecture represents the enterprise's key business, information, application, and technology strategies, and their impact on business functions and processes. EA consists of four key components: enterprise business architecture (EBA), enterprise information architecture (EIA), enterprise solution architecture (ESA), and enterprise technology architecture (ETA). The overall EA comprises software systems that may have been created using different programming languages and databases, and may be operating on different technology platforms. Figure 1 presents how EA is composed of different enterprise systems. However, Figure 1 also shows that users of the system want to see a unified view of the EA. This

Figure 1. Enterprise application integration composed of different enterprise systems



need for a unified view requires the enterprise to bring these various applications together, in an integrated fashion, resulting in enterprise application integration.

An enterprise business architecture that defines the enterprise business model and process cycles and timing also shows what functions should be integrated into the system. The enterprise information architecture focuses on which data and the corresponding data model should be integrated into the system. The enterprise solution architecture, also referred to as an application portfolio, is the collection of information systems supporting the EBA, which helps the user to easily understand and use the interface and components. Enterprise technology architecture is a consistent set of ICT standards which use infrastructures to support the EBA, EIA, and ESA. The infrastructures span across various different technical domain architectures, and include databases, applications, devices, middleware, networks, platforms, security, enterprise service buses, hosting, WLAN, LAN, Internet connection, operation system, servers, systems management, and so on (Pulkkinen, 2006).

Enterprise application integration maintains data integration and process integration across multiple systems, and provides real-time information access among systems. EAI not only links applications together, but also provides more effective and efficient business processes to the enterprise. There are numerous technologies that can be used for enterprise application integration, such as bus/hub, application connectivity, data format and transformation, integration modules, support for transactions, enterprise portal, Web service, and also service-oriented architecture (Finkelstein, 2006). Most importantly, however, the technologies of Web services build on extensible markup language (XML), Web services description language (WSDL), and universal description, discovery and integration (UDDI), which provide an excellent basis for integrating the applications of the enterprise—particularly when they are on separate platforms.

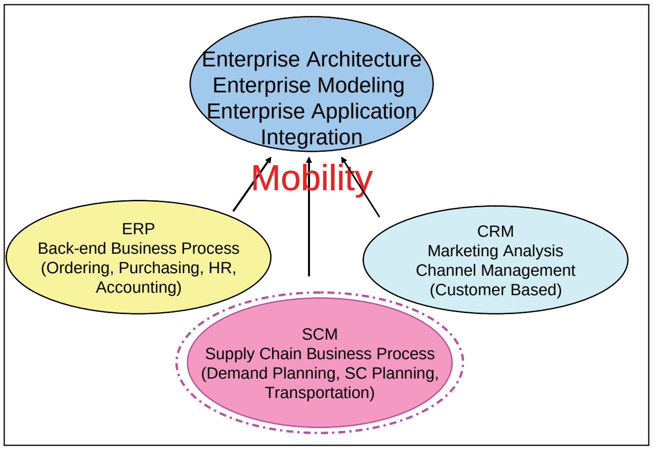
Linthicum (2000) declared that EAI enables the original chaotic enterprise processes to reach a semblance of order after the integration is achieved, resulting in increased efficiency on process flows, data integration, and data transportation. Furthermore, EAI also makes a more effective extension of enterprise processes. Irani, Themistocleous, and Love (2002) divided application integration into three categories: intra-organization, hybrid, and inter-organization. Intra-organizational application integrates packaged systems, custom applications, and EPR systems, and there are no transactions between external users or partners. Hybrid application integrates business-to–consumer (B2C) applications with IT infrastructure. Interorganizational application integrates all processes between extended enterprises, such as the supply chain, and also can be a transaction between virtual enterprises, for example, e-procurement.

Further to the above discussion, in order to bring about a successful EAI, it is also important to create a model of such integration—called an enterprise model (EM). An EM would describe the objectives pursued by an enterprise and, as per Brathaug and Evjen (1996), focus on four aspects: process, product, organization, and systems. Doumeingts, Ducq, and Kleinhans (2000) defined enterprise modeling as the representation of enterprise activities at a global and a detailed level, using functions and processes in understanding its running. A good EM would take into account not only the technical aspects but also business, social, and human aspects of the enterprise. Such a comprehensive EM will also make it easier for the incorporation of mobility.

Kamogawa and Okada (2004) pointed out that integration of enterprise systems focuses on integrating collaboration agreements, collaboration profiles, business scenario integration, business process integration, and messaging technology. The three major applications—CRM, SCM, and ERP—are all shown in Figure 2. Figure 2 also shows how these applications are integrated through the enterprise model. Our aim is to further apply mobility to the enterprise model. However, in this chapter the discussion on the application of mobility to EM will be restricted to its application to SCM systems.

EA/EM/EAI all integrate enterprise applications. Such integration cannot only enable the enterprise to present a unified view of the system to its suppliers and clients, but also reduces errors and improves quality by reducing or even eliminating duplication of data entry. Enterprise application integration brings about not only internal integration, but through extension also offers much more efficiency to its external suppliers, customers, and other trading partners over the Internet. Thus, providing mobility to EAI, and especially the SCM system, will connect existing and new systems to enable collaborative operation within the entire organization in real time—providing new and improved services without location and time limitations.

Figure 2. Enterprise model (based on Kamogawa & Okada, 2004)



EXISTING MODEL OF SUPPLY CHAIN MANAGEMENT

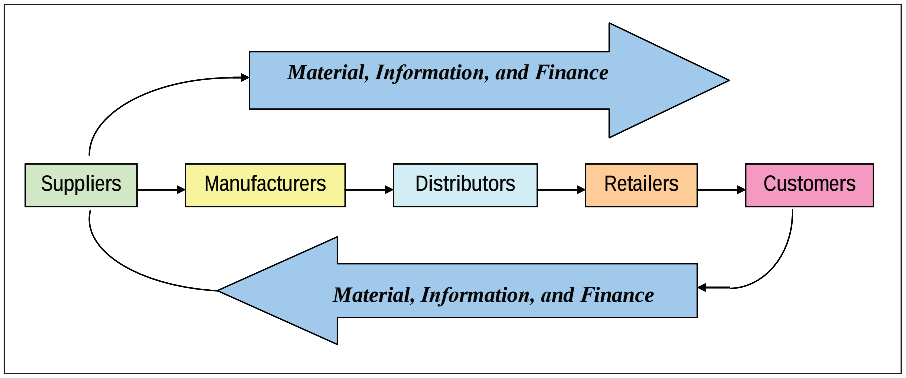
In order to successfully apply mobility to SCM, we consider SCM within the overall context of EM. Traditional supply chain management involves the flows of material, information, and finance in a network, including suppliers, manufacturers, distributors, retailers, and customers. This is shown in Figure 3, where the various parties are connected to each other through the ability to supply goods, provide information about the goods, and deal with the financial aspects of those supplies.

The traditional supply chain is a push model. As outlined by Lee (2000), material flow includes both physical products flowing from the suppliers to customers through the chain and reverse flows via product returns, servicing, recycling, and disposal. Information flows involve order transmission and delivery status. Financial flows include credit terms, payment schedules, consignment, and title ownership arrangements. These flows cut across multiple functions and areas within a company and across companies (and sometimes industries); this leads to big challenges in terms of both technologies and business. Organization and integration of these flows within and across companies are important for effective supply chain management.

Supply chains can exist in both manufacturing and service organizations. In manufacturing organizations, they are mostly concerned with the flow of products and information between supply chain member organizations—procurement of materials, transformation of materials into finished products, and distribution of those products to end customers. However, in service organizations, supply chains can focus on "values added" to the services being offered. Overall, the current information-driven, integrated supply chains enable organizations to reduce inventory and costs, to add product value, to extend resources, to increase speed time to market, and to retain customers (Burt, Dobler, & Starling, 2003).

There are complex relationships in supply chains, such as multiple suppliers serving multiple customers, or a supplier who may be a customer or even a competitor in different parts of the chain. This complexity is the reason why we refer to supply chains as "supply networks" or "supply webs." Because of the network complexity, correct quality and time transfer of information can be extremely difficult. In particular, the multiple layers in a supply chain have the potential to misrepresent order information. This misrepresentation can lead to numerous confusion and errors, such as excessive inventory, inactive capacity, high manufacturing and transportation costs, and increasingly dissatisfied customers. Achieving supply chain efficiency requires exact and timely information. And the longer and more complex the supply chain is, the greater the requirement is, according to Dong (2001), for the supply chain to have precision in

Figure 3. The supply chain flows (based on Lee, 2000)



terms of the quality and timing of information.

SCM systems primarily include the requirement for integration architecture; the varied objectives of all the participants in a supply chain; mutual collaborative functioning of interfacing systems; and the varied levels of functionalities required for customers, retailers, suppliers, and manufacturers. A comprehensive supply chain management system can be an integration of a customer relationship management system, supplier relationship management system, order/purchasing system, delivery products management (logistics management) system, as well as time management systems.

The goal of supply chain management is to reduce inventories by optimizing material and information flow without sacrificing service level. SCMs have a responsibility to maintain sufficient inventory levels to satisfy the demands. Furthermore, increasingly, industries with short inventory and product cycles, such as high-tech and customer electronics, are highly reliant on SCM to provide them with the ability to interact with their numerous suppliers and retailers. SCM also allows high-quality customer service by delivering the right products to the right place at the right time.

MOBILE (EMERGING) TECHNOLOGIES

Mobile technologies can be considered as one set of the significant emerging technologies (as per Unhelkar, 2005) that have the potential to influence supply chains. Wireless technologies encompass any aspect of communication that is achieved without land-based or wired mechanisms. Thus, mobility, in a strict sense, is a subset of wireless technologies. This is because there can be some wireless communications that need not be mobile (for example, transmissions from a wireless radio tower or between two stationary servers). We consider a range of wireless technologies in this section that are likely to influence the various business processes of an organization. Later, we will discuss the specific mobile technologies (such as RFID) from the point of view of their usage in M-SCM.

Wireless Technologies

Wireless technology refers to technology without wires and phone lines that uses a multiplicity of devices for communications (IBM, n.d.). The term "wireless technology" can also be used to describe modern wireless connections such as those in cellular networks and wireless broadband Internet. In modern usage, wireless is a method of communication that uses low-powered radio waves to transmit data between the mobile terminals (Elliott & Phillips, 2003). The terminals, such as mobile phones, iPods, personal digital assistants (PDAs), global positioning systems (GPSs), watches, email-only devices, handheld computers, and "wearable" technology, are carried by individuals and are far more "personal" than mere desktop PCs. The latest and important wireless technologies that require a brief discussion in this section are:

- "3G" mobile network
- Mobile satellite network
- Infrared
- Bluetooth
- Wireless
- Local area network
- WiMAX
- Radio frequency identification

Third-Generation Mobile Network

The development of 3G-related technologies has overcome the limitation of the previous generation of mobile technologies by allowing higher transmission rates and more complex e-commerce interactions (Barnes, 2002). Kuo and Yu (2005) and Huber (2002) list three 3G standards, including wideband code division multiple access (WCDMA), code division multiple access 2000 (CDMA2000), and time division–synchronized code division multiple access (TD-SCDMA), approved by the International Telecommunication Union (ITU).

W-CDMA is the most popular 3G mobile network which is capable of transferring multimedia between terminals; it is the technology behind the 3G universal mobile telecommunications system (UMTS) standard, combined with the 2G global system for mobile communications (GSM) standard, which is mainly dominated by European and Japanese firms.

Due to the promotion of the GSM organization and the 60% popularity usage of the 2G system in the global market, CDMA2000 gained the attention of many companies, especially U.S. and Korean firms that mainly support it. One of the advantages of the CDMA2000 system is the upgradeability of the narrowband CDMA system, so the user does not need to change his or her mobile device—just upgrade his or her user plan.

The TD-SCDMA includes three main key technologies: (1) TDMA/TDD principle, (2) smart transmitter and receiver, and (3) joint detection/terminal synchronization. It is mainly supported by China's Datang Telecom, which advocates its low-cost infrastructure.

Mobile Satellite Networks

Mobile satellite networks represent the convergence of the latest mobile technologies with space technologies. Satellites are operated at microwave radio frequencies in various bands, which are allocated by the ITU (2001). Olla (2005) declared that integrating space technology into mobile communications offers two main advantages. The first advantage is in providing access to voice and data service anywhere in the world—of which the current popular application is Internet phone (Voice over IP–VoIP). The second advantage is the exact positioning of useful location-sensitive information used for direction-finding-based and map-reading-based services, the current popular application of which is a car GPS. These applications are becoming commonplace, with Fitch (2004) pointing out that the technique for interfacing satellite links to global networks is well developed, including methods to overcome timing problems.

Infrared

Infrared (IR) technology provides directional electromagnetic radiation for "point-to-point" communication within short range. The radiation wavelength of IR communication is approximately between 750 nm and 1 millimeter. IR data transmission is a mobile application for short-range communication between a computer terminal and mobile device, such as a PDA or a mobile phone. Infrared communications are useful for indoor use in areas of high population density. IR does not transmit through physical barriers such as a wall, and so it does not interfere with other devices in the vicinity. Infrared transmission is, therefore, the most common way for remote controllers to control physical machines. Furthermore, infrared lasers are used to provide the light for optical fiber communications systems; they are the best choice for standard silica fibers, as using infrared lasers can be a cheaper way to install a communications link in an urban area (Okuhata, Uno, Kumatani, Shirakawa, & Chiba, 1997).

Bluetooth

Bluetooth is a short-range radio technology developed to connect devices without wires. It is an effective technology for a new generation of Internet-capable mobile terminals. It enables numerous innovative services and applications, which function regardless of the mobile operator. The most important solution enabled by Bluetooth technology is synchronization between a PC server and one or more other mobile terminals. Synchronization has been particularly successful in cooperative applications, providing access to SCM systems (Paavilainen, 2001). Buttery and Sago (2004) describe the Bluetooth application as being built into more and more mobile telephones, allowing some very interesting m-commerce opportunities to be created. As people currently carry mobile phones with Bluetooth technology, these technologies can be used for making payments and related service concepts through simple downloads on their mobile devices. Retailers might also be able to provide samples of products to download via a Bluetooth link located close to the actual item, potentially resulting in better customer service and an enriched shopping experience. Bluetooth can operate up to 10 meters (eventually up to 100 meters in future versions). Since Bluetooth technology is a radio transmission, it does not need line-of-sight with another Bluetooth-enabled device to communicate (Scheniderman, 2002). Once Bluetooth technology is in place, one can envisage consumers walking around and giving out messages wirelessly via Bluetooth in order to buy items from vending machines, or buying low-value tickets, or even making small-value "cashless" purchases, such as newspapers.

Wireless Local Area Network (WLAN)

WLAN technology is closer to the fundamental principle of the Internet, wherein anybody can establish an individual network as long as it follows the general intranet guidelines. The wireless links would provide a network connection to all users in the surrounding area, ranging from a single room to an entire campus. The backbone of such a WLAN network may still use cables, with one or more wireless access points connecting the wireless users to the wired network. Currently, laptop computers and some PDA devices can be attached to a WLAN network using a compact flash (CF) or a Personal Computer Memory Card International Association (PCMCIA) card. In the future, PDAs and mobile phones might support multiple network technologies. WLAN is expected to continue to be an important form of connection in many business areas. The market is expected to grow as the benefits of WLAN are recognized (Paavilainen, 2001; Burness, Higgins, Sago, & Thorpe, 2004).

WiMAX

WiMAX is defined as Worldwide Interoperability for Microwave Access by the WiMAX Forum. The forum describes WiMAX as "a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL." The forum also states that it "will be incorporated in notebook computers and PDAs by 2007, allowing for urban areas and cities to become 'metro zones' for portable outdoor broadband wireless access" (WiMAX Forum, 2006). WiMAX delivers 72 Mbps over 30 miles point-to-point and four miles non-line-of-sight (NLOS) (Ohrtman, 2005). Its purpose is to ensure that broadband wireless radios manufactured for customer use interoperate from retailer to retailer. The main advantages of the WiMAX standard are to enable the implementation of advanced radio features in a standardized approach, and provide people in a city with online access via their mobile devices.

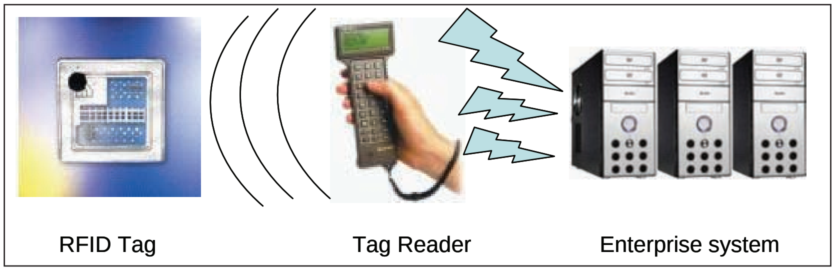
Radio Frequency Identification

RFID is an emerging technology that has been increasingly used in logistics and supply chain management in recent years. RFID technology can identify, sort, and control the product and information flow, all through a supply chain. Today, RFID is a standard technology that uses radio waves to automatically identify people or objects. There are several methods of identification, the most common of which use RFID tags and readers.

Ngai, Cheng, Au, and Lai (2005) proposed that RFID is made up of two components: the transponder, which is located on the object to be identified; and the reader, which, depending upon the design and the technology used, may be a read or write/read device.

Roberts (2006) states that an RFID system will typically comprise the following three components, as shown in Figure 4:

Figure 4. Important parts of an RFID system (based on Roberts, 2006)



- An RFID device (tag), which is a unique identifier for an object or person.
- A tag reader with an antenna and transceiver.
- A host system or connection to an enterprise system.

As Figure 4 shows, firstly we incorporate data inside an RFID tag. When the tag goes through a tag reader, the information inside the tag will automatically transfer to the host system. The host system is stored in a data center. After the data center analyzes and organizes the RFID tag information in the host system, specific useful tag information will be sent to a different enterprise SCM system.

Using an RFID system in the supply chain has been demonstrated by Asif and Mandviwalla (2005). Firstly, the SCM system constructs the item "where and when" during processing. When the items leave the manufactory and arrive at the place where they are to be read by the readers, the same information will be transferred directly to the distributor. The items are quickly sent to the correct trucks. As these items arrive at the retail outlet, they are read by the receiving RFID readers, and the retail outlet's inventories are updated automatically. Since the shelves at this outlet also have their own readers, they can directly increase replacement orders. However, using RFID technology in the SCM system, the items' quality can be automatically updated by the RFID reader sending into the SCM system. This provides highly location-based tracking, reduces the cost and human-error risks, and also improves the effectiveness and efficiency.

EPCglobal, a development of the earlier Auto-ID Center, is one of the two primary RFID standards

Table 1. Mobile technology application comparison table

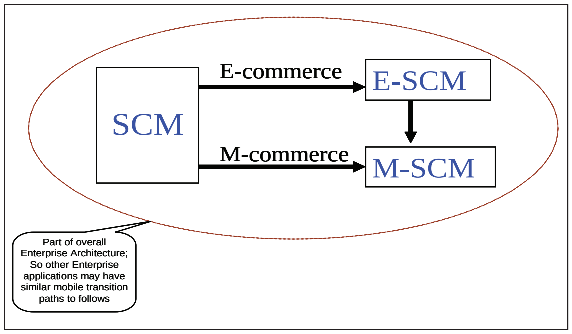
Mobile Technology	Functions and Applications
3G Mobile Network	• Application: mobile phone device • Higher transmission rate • Popular used and high marketing acceptance
Mobile Satellite	• Application: GPS device and Internet phone (Voice over IP–VoIP) • Space technology • Direction finding and map reading
Infrared	• Application: remote controller • Communication in short distance • Low cost
Bluetooth	• Application: Bluetooth device • Synchronization • Transfers data between a PC server and one or more other mobile device(s)
WiMAX	• Wireless online in urban areas by using mobile device or any computer
WLAN (Wireless Local Area Network)	• Wireless link PC or mobile device network connection in particular surrounding area
RFID (Radio Frequency Identification)	• Application: RFID tag and reader • Product tracking and controlling by automatically updating the RFID tag location through RFID reader

setting groups. It proposed an Internet-based supply chain model that is aimed at improving supply chain end-to-end efficiency. A key component of the EPCglobal model is the Electronic Product Code or EPC. The manufacturer adds an RFID tag to every item of its product line. Each tag contains a unique EPC, which is a 96-bit code that uniquely identifies objects (items, cases, pallets, locations) in the supply chain (EPCglobal, 2005).

APPLICATION OF MOBILE TECHNOLOGY IN SUPPLY CHAIN MANAGEMENT

Based on the literature surveyed so far, there appears to be a gap between what is considered traditional SCM, electronic SCM, and the potential offered by mobile SCM. The major gap in the current literature in the SCM domain appears to be a lack of discussion between the two types of commerce and, in particular, the value derived from the ability of mobility to provide time and location independence. As shown in Figure 5, SCM can be extended to the e-commerce environment and at the same time it can also be extended to M-SCM. However, there is also a potential, as again shown in Figure 5, for E-SCM to be extended to M-SCM. These are some of the important aspects of SCM systems studied in this chapter.

Figure 5. SCM to E-SCM and M-SCM



E-Supply Chain Management

E-commerce deals with a combination of hardware technologies, software applications, and changes to business processes and appropriate customer strategies. E-SCM can enable customers to use electronic connections to obtain the information and associated services from the organization's supply chain system. The objective of E-SCM is to understand customer demographics, purchasing patterns, inventories, orders, and order fulfillments, in order to enable customer satisfaction and creation of new business opportunities (Arunatileka & Unhelkar, 2003). E-commerce provides the basis for much more efficient supply chains that can benefit both customers and manufacturers. This is because e-commerce, through connectivity, brings together various parties involved in commercial transactions. In today's environment, customers are less forgiving of poor customer service and more demanding of customized products or services. As the competition continues to introduce new offerings modified to the special needs of different market sectors, companies have to respond by offering similar custom-made and highly personalized offerings. The ensuing production of various goods and services for multiple countries, customer sections, and distribution exits creates major challenges in forecast, inventory management, production planning, and after-sales service support. Internet-based E-SCM systems bring the companies a competitive advantage by opening up opportunities to streamline processes, reduce costs, increase customer satisfaction, and make possible thorough planning abilities (Unhelkar & Lan, 2006).

The supply-chain e-business model creates a virtual value chain, and information flows across the supply chain. All members of the supply chain have strong electronic systems, and the information sharing to the customer is very effective in the ordering process, product delivery, and other SCM issues (Arunatileka & Arunatileka, 2003).

The e-supply chain is a pull model; in a pull-based supply chain, production and distribution are demand driven so that they are coordinated with true customer demand rather than forecasted demand. This is enabled by fast information flow mechanisms to transfer customer demands to the various supply chain participants. This leads to a significant reduction in inventory costs and enhanced ability to control materials when comparing this to the equivalent push-based system (Levi, Kaminsky, & Levi, 2003).

M-Supply Chain Management

In the 21st century, we are in the era of wireless and handheld technologies, and the impact of the Internet and wireless telecommunication has taken a new turn (Barnes, 2002). Mobile technologies are at the core of the communication revolution. They have increased commercial efforts from the removal of physical connectivity for people, processes, and businesses, resulting in a significant impact on communication. Therefore, mobile devices can also be used to optimize the flow of information and materials. An increased number of mobile workers and time sensitivity drive companies towards advanced mobile solutions.

Paavilainen (2001) highlights that the solutions of supply chain management systems are highly time sensitive. The requirement of the time sensitiveness is that SCM systems must have the ability to transact products as close to real time as possible—opening up opportunities for the application of mobile technologies. By incorporating mobility in the SCM system processes, monitoring and receiving of immediate messages from the market can be improved. M-supply chain management focuses on the shortened cycle time from making an order to the fulfillment of that order—which, in most cases, would be delivery of the product to the customer. With mobility, response and confirmation time are much quicker than with the use of the standard Internet connections. Automatic data-reading and updating can be accessed from any mobile devices without the restriction of time and place. Traffic control systems (GPRSs) can be used to deliver products in the supply chain, and also automatically detect the products and report cars' and trucks' locations.

Eng (2005) declares that three main concerns of M-SCM are:

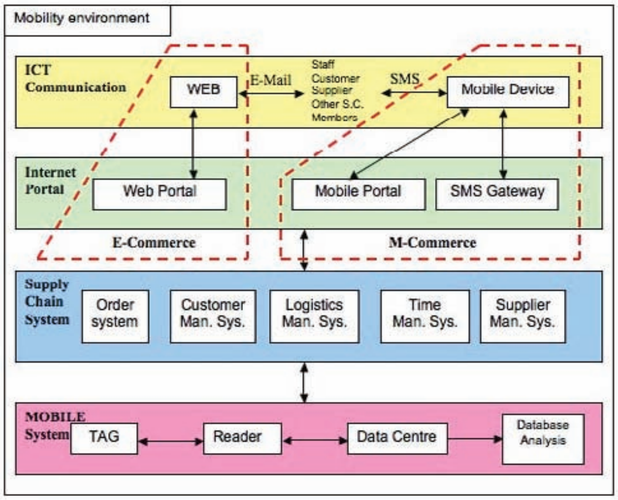
1. a place for efficient distribution of products and services,
2. timing for meeting customer demand and managing logistics, and
3. service quality for responsiveness and customer satisfaction.

In Figure 6, the M-SCM architecture is divided into four parts—the RFID system, SCM system, e-commerce, and m-commerce—and as proposed by us is an extension to the original ideas of Ngai et al. (2005). They state that RFID technology can be integrated with wireless networks to send information to a supply chain management system through a portal to staff, customers, and partners. We define that M-SCM refers to integrating the RFID system, e-commerce, and m-commerce through the Internet portal and ICT communication into a supply chain management system in a mobile environment. Moreover, we declare the RFID system's contents and supply chain management system's contents, and how e-commerce and m-commerce will integrate the SCM through the portal.

The RFID system typically integrates RFID tags, readers, and the host system that will store the received tag information in the data center. After the database analysis process inside the data center, information will be transferred from the RFID tag of each product to each company's enterprise SCM system.

The comprehensive supply chain management system can be an integration of a customer relationship management system, supplier relationship management system, order/purchasing (financial) system, delivery products (logistics) management system, and time management system.

Figure 6. Architecture of M-SCM systems (this model is proposed by these researchers as an extension to the original ideas of Ngai et al., 2005)



The e-commerce and m-commerce parts show how the communication can occur among customers, staff of enterprises, suppliers, and other supply chain management members to the SCM system. People can use e-mail via the Web to an Internet Web portal to access the SCM system to get information or conduct e-commerce. In addition, they also can use SMS via a mobile device to a mobile portal or SMS gateway to access the SCM system to get information or carry out m-commerce.

The aforementioned model can also be used to understand how existing supply chain processes transfer to incorporate mobility in them. These can be called "m-transformation of SCM" processes. When a company already has the supply chain management system in its enterprise architecture, we can help it add a mobile system and set up the Internet portal with ICT communication devices to upgrade the SCM to M-SCM. In M-SCM, the cooperation of real-time processes by using mobile technology applications provides a stable workflow of up-to-date information from both inside and outside the company. Mobile supply chain applications can also allow users to request information and conduct "ubiquity"—whatever they want, whenever they want it, wherever they want it, and how they want it.

INVESTIGATION INTO ADVANTAGE AND LIMITATION OF MOBILITY IN SCM

The traditional supply chain is a push model. However, the E-SCM and the M-SCM models that we are discussing in this chapter can be considered as pull models. Table 2 depicts the comparison of characteristics between the push and pull models of the supply chain, based on various factors.

From Table 2, Levi et al. (2003) are quite clear in stating that traditional SCM focuses on reducing the cost and recording the location of products into the system. The information flow is based on a push model. As such, the traditional SCM process undergoes a long cycle, and the process time cannot be easily estimated. E-SCM focuses on customer service, and the process is totally based on responding to customers' orders and requirements. Every member of the supply chain can access the information flow from the E-SCM system at any time if they want to track it. Thus, E-SCM can be said to follow the "pull model" of information; it shortens the product cycle and lowers complexity compared with the traditional SCM (push model). The M-SCM can also be said to follow the "pull

Table 2. Push and pull model of SCM (Levi et al., 2003, p. 127)

Portion	Push	Pull
Objective	Minimize cost	Maximize service level
Complexity	High	Low
Focus	Resource allocation	Responsiveness
Lead Time	Long	Short
Processes	Supply chain planning	Order fulfillment

model," wherein information is extracted from the system when desired by the user.

Both E-SCM and M-SCM provide 24-hour information access, accurate and fast billing, less paperwork/fewer duplicated processes, on-site technical support, and trouble-shooting databases. However, in E-SCM, the users of the supply chain can only access the information of SCM when they connect to the Internet. It is limited by the location, in that members still need to sit inside the office to plug in their computers. M-SCM members can access the system at any time and anywhere by using mobile tools with a satellite connection. This brings huge benefits to people with a more convenient and comfortable environment to increase efficiency in their part of the value chain.

Following, we would like to list the advantages and limitations of mobility in SCM.

Advantages

The M-SCM system provides real-time data that can be accessed after logging into the system (Eng, 2005). Batten and Savage (2006) highlight that M-SCM will eliminate considerable duplication of data entry through simplified automated order placement, order status inquiries, delivery shipment, and invoicing. Mobility goes through data entry when it is created to reduce paperwork, document tracking, and human error. It also brings security control. The M-SCM system shortens the organization planning and production cycles, establishes one central data repository for the entire organization, and facilitates enhanced communications through all supply chain members communicating with each other by mobility (Paavilainen, 2001). Moreover, the M-SCM allows all users to request information, place orders for whatever they want, whenever they want it, wherever they want it, and how they want it.

The investigation of mobile technology application into the supply chain systems will bring benefits to all members of the supply chain, which includes suppliers, manufacturers, distributors, retailers, and customers.

Suppliers: The M-SCM system reduces paperwork, the number of administrative employees, and inventory costs, so the company reduces the cost of the products and brings in more customers as well as retaining its present customers. It also brings increased financial incomes to the suppliers (Unhelkar & Lan, 2006).

The RFID system stores the product contents when these have been acquired. When the product is about to expire, all details are contained in each RFID tag for each item. This can help suppliers to quickly obtain the information they need, simply by scanning the RFID tag once only. Also, this can help the suppliers to forecast the schedule arrangements to process the materials and prevent materials from expiring.

Manufacturers: The M-SCM systems can provide the organization with shorter planning and production cycles, and establish one central data repository for the entire organization. Then manufacturers will know the amounts they need to produce, and save money on the products that nobody buys.

RFID has been used in manufacturing to identify items or groups of items, express production procedures, and ensure the correct product quality. It helps that the right materials arrive at the right place, and nothing will be lost (Duckworth, 2004).

Distributors: The M-SCM system ensures quicker time-to-market for the firm's products, provides the retailer with enough stock, and also reduces excessive stocks in the distribution center. A traffic control system can be used as a GPRS to deliver goods to customers/retailers, and also automatically detect control and report locations of cars and trucks.

RFID identifies the distributed items stored inside the containers or trucks, and helps the delivery process to be 100% correct to deliver the right items to the right place at the right time. It has been reported that the RFID program can estimate the need for physical cycle counting, saving companies hundreds of employee hours and days of down time (Mullen & Moore, 2006).

Retailers: No data need to be re-entered into the M-SCM system through the simplified automatic order placement, order status inquiries, delivery shipment, and invoicing. The RFID system processes automatic data-reading and reporting to the supply chain system of the products' location (Wyld, 2006).

The RFID system is also very useful in maintaining enough stock levels in retailers (Carayannis, 2004). It has the ability to automatically record sales, check inventories, and refill or order additional stock in order to reduce the amount of inventory. Some food or items with limited time span can be notified by the system to guarantee retailers having fresh products on the shelves all the time. In addition, it has been proven to reduce theft from the retailers' shelves during the product delivery process in the supply chain. Loss avoidance directly benefits the retailers by minimizing costs and improving selections (Mullen & Moore, 2006).

Customers: The M-SCM system improves customer service substantially by efficient distribution of products and service, timing for meeting customer demands and logistics managing, and service quality for responsiveness and customer satisfaction. It improves the firm's ability to attract new customers and also retain its original customers (Unhelkar & Lan, 2006).

Customers can access information about products via mobile gadgets, and also place/check their orders and pay their bills in the M-SCM system by mobility (Mei, 2004). The M-SCM also allows customers to enquire for information and purchase any products at any time, anywhere, by any method.

Limitations

Supply Chain Integration and strategic partnering: The limitation that has existed in traditional supply chain integration is "reliance and trust" among the partners (other supply chain members) in this mechanism. This is because when the supply chain system integrates all companies in the supply chain, the members need to consider how much information they should announce to other members. Moreover, the more information a company can share, the greater the efficiency and effectiveness of the system. Nevertheless, the company members of the supply chain depend on other members' reliance and trust to share the information. So, this is the critical limitation of the original supply chain integration.

Cost of M-SCM system and facilities implementation: When the companies in the supply chain want to install M-SCM systems in their companies, the cost of systems and facilities during the establishment period is an essential consideration. They need to prepare the project fee at the beginning, but this is not a small amount, and it is the reason why the companies in the supply chain always find it difficult to make decisions to implement the M-SCM system.

Different countries develop mobility at different levels—the Internet speed, WLAN population: As we mentioned earlier, the companies of a supply chain may not be only in one country. Different countries may develop mobile technology at different levels. Some countries are not able to provide wireless local area networks, and can only provide dial-up Internet speeds. In other words, there are many limitations for those companies that want to use the M-SCM systems in the whole supply chain.

Security and privacy issues: Sheng (2006) points out that the issue of security and privacy is indeed a great concern, especially when the members of a supply chain make payments by the m-payment system. The qualifications of any system to provide secure data transfer are regarded as an important standard for both existing and potential users of m-payment systems. The personal privacy of customer information is a major concern to the customer who is deciding whether to use the system or not.

Companies need to change their business process: When the members of a supply chain decide to install the M-SCM systems in their supply chain management system, the current business processes may not be available or suitable to use all the time. The system development team needs to go through the original business processes to modify the new business processes suitable for the M-SCM system users. Therefore, after the system implementation in the companies, the system team needs to prepare a training class for employees regarding the business processes change and the new system utilization in the future.

BENEFITS OF MOBILITY TO THE ENTERPRISE ARCHITECTURE

Enterprise architecture represents a technology-business philosophy that provides the basis for cooperation between various systems of the organization that could be inside or outside the organizational boundary. EA also facilitates the ability to share data and information with business partners by enabling their applications to "talk" with each other. Linthicum (2000) pointed out that many organizations would like to build their entire systems by using the emerging technologies of today, of which mobile technology is a crucial part. Using mobile devices in enterprise modeling can help real-time information access among systems, in production planning and control, inbound and outbound logistics, material flows, monitoring functions, and performance measurements (Rolstadas & Andersen, 2000).

According to Ghanbary (2006), by correct application of mobile technologies into the business processes, the business enterprises are likely to gain advantages such as increased profits, satisfied customers, and greater customer loyalty. These customer-related advantages will accrue only when the organization investigates its customer behavior in the context of the mobile environment.

It is very important to identify that not many organizations have existing mobile solutions. Umar (2005) states that next-generation enterprises (NGEs) rely on automation, mobility, real-time business activity monitoring, agility, and self-service over widely distributed operations to conduct business. Mobility is one of the most invigorating features, having an enormous impact on how communication is evolving into the future.

Enterprise application integration is a relevant approach to integrating core business processes and data processing in the organization. Lee, Siau, and Hong (2003) state that EAI automates the integration process with less effort. EAI is a business computing term for plans, methods, and tools aimed at modernizing, consolidating, and coordinating the overall computer functionality in an enterprise. With new achievements in information technologies, companies are vulnerable if they do not respond to technologies such as mobile technology in a fast and appropriate manner.

BENEFITS OF MOBILITY TO THE GLOBAL ENTERPRISE

In this globalization era, many enterprises in a supply chain are located in different countries. Enterprises in some countries can provide low labor costs, and some in different countries may have low material costs, or others in different countries may provide professional skills or ideas about product design. However, all enterprises want to sell their product globally. The resultant ability of businesses and customers to connect to each other ubiquitously—independent of time and location—is the core driver of this change (Unhelkar, 2005). It leads the supply chain management to global supply chain management. Mobile technologies are thus a key influence in any efforts towards the globalization of business (Unhelkar, 2004). The processes of such m-transformation can lead an existing business into the mobile business via the adoption of suitable processes and technologies that enable mobility and pervasiveness (Marmaridis & Unhelkar, 2005).

M-SCM can further enhance the global SCM by reducing timing and cost, increasing correct delivery and customer satisfaction, and allowing global enterprises to conduct their business at any time and anywhere. Long (2003) pointed out that international logistics management focuses on international ship delivery schedule management, time, place, and product quality management.

An M-SCM system covers from planning, purchase, and production, to delivery to the customer. Mobile technology raises global enterprises to a much higher level of efficiency and effectiveness. Global enterprises can conduct their business at any time and anywhere, and provide high-quality products at low cost, and also support customer service 24 hours a day, seven days a week, by using an M-SCM system.

COLLABORATIVE SUPPLY CHAIN MANAGEMENT IN AN ENTERPRISE ARCHITECTURE

Electronic collaboration has been studied and experimented on by many studies. In electronic collaboration, there has been ample focus on the effects of dynamic environment and the rapidly evolving technology on organizations. Undoubtedly, these changes cause organizations to restructure and introduce a new suite of business processes to enable them to collaborate with the business processes of other organizations.

There are some critical technological issues that could cause drawbacks in collaboration across multiple SCM organizations. These issues could be classified as collaborations between different platforms, managing technology and maintenance (hardware/software). Web services technology is the solution for the collaboration of applications on different platforms, also independent of their different environments.

The electronic collaboration of the business processes of different SCM organizations is causing many practical issues. These issues are as follows:

- The excess inventory and inefficiencies in the supply chain while different organizations are involved.
- Requesting information by understanding the specific organization's capability to handle the request.
- Collaboration can reduce waste in the supply chain, but can also increase market sensitivity and increase customer expectation.
- Customer satisfaction, which is directly related to the previous issue, as customers expect more.
- Competition among all members of the partnership.

As such, the SCM must also address the following problems:

- **Distribution network configuration:** Number and location of suppliers, production facilities, distribution centers, warehouses, and customers.
- **Distribution strategy:** Centralized vs. decentralized, direct shipment, cross-docking, pull or push strategies, third-party logistics.
- **Information:** Integrate systems and processes through the supply chain to share valuable information, including demand signals, forecasts, inventory, and transportation.
- **Inventory management:** Quantity and location of inventory including raw materials, work-in-process, and finished goods.

Collaboration should be taking place in order to make sure that all parties involved in the collaboration are satisfied. In the past, collaboration was inadequate, with retailers hesitant to share information with others; however, the technology is capable of providing more support for the collaboration. Based on Horvath (2001), collaboration requires individual participants to adopt simplified, standardized solutions based on common architectures and data models. The time to market is critical, and participants will have to forego the luxuries of customization and modification that characterized the proprietary infrastructures of the past.

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

The chapter has introduced enterprise application integration as a part of a comprehensive enterprise model, followed by a discussion of supply chain management systems in the context of the EM. The traditional supply chain management system and investigation of the opportunities to integrate specific mobile technologies (such as 3G mobile network, mobile satellite network, Infrared, Bluetooth, WiMAX, and WLAN) with supply chain management systems have also been discussed. This chapter has further considered the advantages and limitations of such integration. The discussions in this chapter are important for understanding how and where mobile technologies fit into the overall concept of the enterprise architecture. The discussion on the collaborative nature of Web services and the ability of supply chain systems to capitalize on the connectivity of Web services is also important for globalization and appears in the global supply chain management system.

The aim of this discussion is to provide a solid theoretical basis for future research direction by the authors in the area of mobility and its incorporation in an organization's systems and architecture. Therefore, this chapter is a door opening to further research in the areas of mobile technologies in "enterprise architecture" and "SCM systems." The authors have provided more details of mobility SCM systems—actually enterprise architecture based on contributing the integration of all the enterprise information systems. Our research is opening opportunities to future research in the area of investigating how mobile technologies influence integrating other systems of enterprise architecture such as enterprise resource planning, customer relationship management, customer order control and planning, material requirement planning, financial accounting, and so on. The team members of our group (MIRAG of AeIMS of UWS) are also investigating mobility influences on business process reengineering, Web services, and project planning. In addition, we still investigate our research into how and what should be included on contributing the comprehensive mobility enterprise architecture (M-EA) model.

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Chapter 3.13

Enabling the Glass Pipeline: The Infusion of Mobile Technology Applications in Supply Chain Management

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ABSTRACT

In recent years, the prospect of information exchange independent of time and place has been a compelling driver for organizations worldwide to adopt mobile technology applications in their various business practices. In particular, the application of mobile technology in Supply Chain Management has drawn widespread attention from researchers and practitioners who endorse adaptive and agile supply chain processes. This chapter discusses the applications of mobile technologies in various areas of supply chain management and the potential benefits of those technologies along the dimensions of reduced replenishment time and transactions and billing cycles. Among other discussions, the role of mobile procurement, inventory management, product identification, package tracking, sales force, and field service automation technologies is highlighted. To substantiate the basis for adopting mobile technologies for supply chain management, different market drivers for mobile applications are exemplified and applied to the three macro-level processes of supplier relationship management, internal supply chain management, and customer relationship management; a resulting typology of mobile supply chain management applications is presented.

INTRODUCTION

> *The nature of competition is shifting away from the classic struggle between companies. The new competition is supply chain vs. supply chain.* (Taylor, 2003, p. 3)

In recent years, we have seen various organizations from different industries focus their competitive strategies on improving their supply networks rather than concentrating on directly contending with specific companies. Companies such as Wal-Mart, Dell, and Proctor & Gamble not only have made significant headway in optimizing their own supply chains, they also essentially have redefined the way business is done in their particular industries. Their competitors have had to follow suit in order to maintain their own competitive position in the marketplace.

A major factor that has contributed to more efficient supply networks is the increasingly unhindered and efficient flow of information within and among supply chain partners. Several researchers and practitioners have commented on the importance of information flow in effective supply chains (Chopra & Meindl, 2003; Handfield & Nichols, 2002; Kalakota, Robinson & Gundepudi, 2003). Consequently, much has been said about the role of technology in enabling effective supply chains (Holten, Dreiling, Muehlen & Becker, 2002; Knolmayer, Mertens & Zeier, 2002; Poirier & Bauer, 2000).

Mobile technologies and applications offer an advanced level of efficient and effective communications among business partners in supply chains. These applications augment the static nature of their predecessor, e-commerce, phone, and fax-based technologies, by adding flexibility and spontaneity to extant business processes. Technologies in mobile procurement, inventory management, product identification, package tracking, sales force, and field service automation are expected to change the current landscape of Supply Chain Management (SCM). It is expected that mobile technologies will bridge the functionality gap in traditional Electronic Data Interchange (EDI), Enterprise Resource Planning (ERP) and Web-based SCM technologies by providing the end-to-end transparency that can help businesses perform better through improved supply chain planning and execution (Kalakota et al., 2003).

In this chapter, we provide a value proposition for mobile SCM technologies and applications. By highlighting the benefits of the latest mobile applications, this chapter aims to explicate the role of these technologies in transforming integrated and collaborative supply chains into adaptive supply networks. We start this discussion with our working definition of SCM, which will be the gate to our analysis of various technology applications. Following that, we discuss the current state of information technologies in SCM and subsequently rationalize the business drivers for implementing mobile SCM technologies. This is followed by an elaboration of a typology of mobile SCM technology applications. Our conclusion and ensuing inferences follow after a discussion on the future outlook for mobile SCM technologies vis-à-vis other SCM information systems.

SUPPLY CHAIN MANAGEMENT: A WORKING DEFINITION

There are as many definitions of SCM as there are publications, which is quite enormous within the supply management literature. Furthermore, the terminology used to describe the concept or idea behind SCM is interchangeably used in various contexts to refer to the same thing. For example, supply chains, supply networks, and supply webs often are used to describe the same idea—coordination and collaboration across business partners. Recently, however, there is an increasing tendency to use the terms *supply networks* and *supply webs* as opposed to the notion of *supply chains.* The advantage of using the former terms over the latter, is to emphasize that the links among business partners are not linear and sequential but are, instead, dynamic, interdependent, and flexible (Bovet & Martha, 2000; Murphy, 2000; Rayner, 2004).

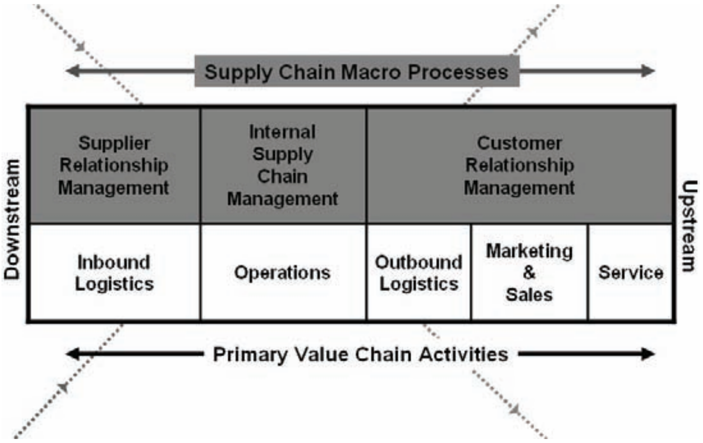
In this chapter, we use the terms *supply chains* and *supply networks* interchangeably, with the proviso that the nature of relationships among business partners is, indeed, more than just linear and sequential. As highlighted in the introduction and for the purpose of this discussion, we adopt a definition of SCM that incorporates the management of information flow as the primary functional component—material flow and financial flow both upstream and downstream the supply chain. For a descriptive and formal characterization, we adopt Handfield and Nichols' (2002) definition of SCM. The authors define SCM as:

> *The integration and management of supply chain organizations and activities through cooperative organizational relationships, effective business processes, and high levels of information sharing to create high-performing value systems that provide member organizations a sustainable competitive advantage.* (Handfield & Nichols, 2002, p. 8)

In addition to affirming the importance of high levels of information sharing, the definition prominently highlights the concept of a value system for sustainable competitive advantage.

The notion of a value system (also known as a value chain) is intertwined with that of a supply chain and needs some elaboration. Introduced by Michael Porter in his widely acclaimed book, *Competitive Advantage* (Porter, 1985), the idea of a value chain has been used to model a firm on the basis of its value-creating activities. The primary activities in the value chain include inbound logistics, operations, outbound logistics, marketing and sales, and service. Noticeably, it is several different business processes within the value-creating functions of a firm that constitute the various components in an organization's supply chain, as well. In fact, Chopra and Meindl (2003) classify all supply chain processes into three main macro processes; namely, Supplier relationship management (SRM), internal supply chain management (ISCM), and customer Relationship Management (CRM). Juxtaposing the value creating functions described by Porter (1985) with the three macro processes in a supply chain, it can be seen that inbound logistics and operations functions map diametrically to supplier relationship management and internal SCM, respectively, while the marketing, sales, and service functions map to the processes in customer relationship management. It is this inclusive framework of value-creating activities and supply chain macro processes that forms the basis of our discussion throughout the

Figure 1. Supply chain management functions and processes



rest of this chapter. Figure 1 summarizes these processes and functions in an inclusive conceptual model for SCM.

CURRENT STATE OF MOBILE SCM TECHNOLOGIES AND APPLICATIONS

As an affirmation of the prevalent adoption of wireless technologies, the Yankee Group predicts that close to 50% of large US enterprises will employ wide area wireless solutions, and that 3,000,000 mobile users will use these services (Yankee Group, 2004). In terms of technological maturity, third-generation (3G) technologies are emerging quickly, while more established technologies, such as Short Messaging Services (SMS) and the wireless Internet (e.g., Wireless Application Protocol [WAP]) are serving organizations to help fulfill their current business requirements. It is these existing and emerging technologies that act as the bearers of a large and ever increasing number of mobile SCM solutions. Furthermore, the diffusion of more advanced packet-switched data networks (e.g., GPRS, 1XRTT, etc.) is giving rise to innovative communication solutions. For example, Push-to-Talk services (P2T) that previously were available only to niche markets are now being deployed effortlessly over packet switched data networks and are being used to facilitate inexpensive interorganizational voice communications (Guy, 2003). At the same time, short-range wireless technologies, such as Radio Frequency Identification (RFID), Wireless Personal Networks (WPANs) such as Bluetooth, and Wireless Local Area Networks (WLANs) such as the 802.11, are becoming commonplace, forming the basis of wireless networking standards.

As anticipated, the previously mentioned technologies are finding their applications in various business processes in the organization’s SCM, as well. A case in point is the recent adoption of RFID solutions by Wal-Mart, exemplifying the wireless services market trends and opening doors for next-generation logistics management (Emily, 2004). Additionally, WLAN technologies already are being used widely in many industries, such as the energy sector (Yankee Group, 2001). Decreasing deployment costs as well as communication and network costs are being proclaimed as the primary drivers for the growth of this market (Rao & Parikh, 2003).

To capitalize upon the opportunities presented by mobile technologies, vendors of traditional SCM systems, such as SAP and Oracle, and new ones, such as HighJump and @Par, are vying for a piece of the pie. Most of the mobile SCM technology vendors currently offer their solutions in bundled packages as part of their m-business or m-commerce technology suites. Such an offering (under a broader umbrella of m-commerce) is in line with the treatise of mobile SCM solutions by researchers (Burchett, 2000; Cousins & Varshney, 2001). M-commerce can be succinctly defined as “a layer of applications atop the mobile Internet” (Rulke & Iyer, 2003) or explicitly as “an extension of e-commerce in a mobile environment” (Dholakia, 2002). Consequently, Mobile Supply Chain Management (MSCM) can be regarded as a specific branch of m-commerce, and it can be characterized as a layer of mobile applications that enhances existing supply chain mechanisms while enabling efficient business processes. Just like their e-commerce counterparts, the incumbent technologies in MSCM are being used increasingly to support an evolving complex transactions landscape. Researchers classify the types of transactions supported through mobile technologies under the business-to-consumer (B2C), business-to-business (B2B), employee-to-employee (E2E), business-to-employee (B2E), and machine-to-machine (M2M) domains (Alanen & Autio, 2003). With this transactions landscape in mind, let us now examine the driving factors behind the adoption of mobile technologies in SCM.

DRIVERS FOR MOBILE TECHNOLOGIES IN SUPPLY CHAIN MANAGEMENT

The use of information systems in any business context always has been driven on the basis of available technological capabilities as well as on managerial vision toward fulfilling certain business requirements via those technologies. This is why we see the proliferation of different types of information systems, depending on different eras in which they are adopted. For example, whereas data and transaction processing systems were the order of the day in the 1950s, decision support systems started emerging in the 1970s, followed by e-business systems in the 1990s. The current trend is on the collaborative aspect of information systems.

Within specific business contexts of the current era, SCM has attracted myriad information systems (e.g., Materials Requirements Planning [MRP I] systems, Manufacturing Resource Planning [MRP II] systems, Enterprise Resource Planning [ERP] systems and Advanced Planning and Scheduling [APS] systems), which all have seen their peaks during the evolution of SCM as a discipline. Whereas, these systems all have a distinct logistics-oriented flare to them, SCM also utilizes cross-functional information systems, such as decision support systems and customer relationship management systems in day-to-day activities.

There have been several drivers that have led to the adoption of different types of information systems in SCM. Perhaps the most significant driver in the adoption of such systems has been the realization of an increasing need to internally integrate within and among different business functions as well as to integrate externally with supply chain business partners (Holten et al., 2002; Poirier & Bauer, 2000). Handfield and Nichols (2002) highlight additional drivers that have led to the adoption of various types of information systems in SCM. These additional drivers include trends emerging from globalization, information management requirements, the need for new business processes, the desire to replace obsolete systems, and ensuring strategic cost management.

Table 1. Drivers for information systems in SCM

	Applications:				
Driver:	**Enterprise Resource Planning**	**Data Warehouses**	**Customer Relationship Management**	**Decision Support Systems**	**Mobile Technology Applications**
Internal Integration	•	•	•	•	•
External Integration			•	•	•
Globalization	•	•	•	•	•
Data Information Management		•	•		•
New Business Processes	•		•		•
Replace Obsolete Systems	•		•		•
Strategic Cost Management	•	•	•	•	•

(Adapted from Handfield & Nichols, 2002)

Table 1 summarizes a mapping of these drivers to different types of information systems in SCM and presents our extension of this framework to assimilate the drivers for mobile technologies. An elaboration of the specific drivers for mobile technologies follows.

Internal and External Integration (Toward Pervasive Computing)

As highlighted earlier in this chapter, internal and external integrations are extremely important drivers in the adoption of information systems in today's business environment. Whereas, systems such as MRP I and MRP II lacked the functionalities that allowed effective internal integration among various supply chain functions, external integration with supply chain partners is a challenging problem for even modern-day ERP systems. It was only with the advent of the Internet and the connectivity accorded by it that the newer Web-based applications, including the likes of CRM systems, were made possible; these applications enabled more cross functional operations inside the firm and outside, to a certain extent.

The adoption of mobile technologies in SCM promises to take the integration phenomenon to the next level (i.e., pervasiveness). Gupta and Moitra (2004) characterize pervasive computing as saturating an environment with computing and communication capability, yet having those devices integrated into the environment such that they disappear. The same authors also consider mobility and wireless connectivity as an essential component in pervasive computing. Accordingly, the adoption of mobile applications in supply chains is driven partially by their capabilities to enhance internal and external integration. Internal integration at the systems level is enhanced through seamless network connectivity between the front end and back end systems through wireless local and personal area networks (WLAN and WPAN). Basic voice communication capabilities, like cellular technologies and push-to-talk (P2T), further allow employees to connect effortlessly to one another. Moreover, remote data access by employees increases the internal integration by allowing internal users to access organizational data from anywhere at anytime. Similarly, external integration is enhanced, as mobile applications enable remote access to relevant information for customers, retailers, and distributors through wireless wide area networks. This is particularly important with the increasing trend in large-scale organizations to establish supplier parks in geographic vicinities around their main manufacturing and fabrication plants (Moline, 2002). Furthermore, mobile applications also enable the organization to access external mobile data resources. For example, using a global positioning system (GPS) and wireless data services, an organization can view the location and status of a shipment arriving from one of its upstream suppliers and prepare for it accordingly. Late delivery of shipment (as well as occasional early delivery) requires careful planning, especially in case of time-sensitive goods, and mobile technologies and applications provide hitherto unknown possibilities in improving the efficiency of managing this supply chain.

Globalization

Globalization is another factor that is driving the infusion of mobile technology applications in supply chains. In remote locations, specifically where fixed landlines and other forms of communications are not available, mobile communications can provide a valuable means for voice and data transmission. Many researchers and visionaries have suggested that a wireless infrastructure can reduce the great divide between the developed and the underdeveloped countries, and it has the potential to facilitate and promote business prosperity (Parker, 2000; Rice & Katz, 2003; Wareham, Levy & Shi, 2004). For example, the wireless infrastructure in China now has surpassed the fixed-line infrastructure in terms of penetration and coverage (GSM Association, 2004). This implies that businesses and people from other countries are more likely to engage in commercial transactions with firms located in China through mobile communication networks. The ascent of this mobile penetration, especially in developing countries, also can be attributed to the fact that once a mobile infrastructure (e.g., a mobile transmission tower) is set up, it does not require any additional work, such as installation and maintenance of landlines for communication. Furthermore, mobility is now regarded as a predominant characteristic of knowledge workers, and with the widespread availability and standardization of roaming capabilities, these knowledge workers are more likely to collaborate with other businesses through mobile technologies. Whereas, 15 years ago it was unthinkable to even call someone in a different part of the world, not to mention wireless connectivity with them while on the move, today, roaming agreements have made wireless connectivity around the globe a reality by connecting over 500 GSM/GPRS (Global System for Mobile/General Packet Radio Service) networks in almost 200 countries (GSM Association, 2004).

Also, with particular reference to SCM, there is an increasing tendency to outsource non-core functions to external service providers, such as third party logistics (3PL) companies. With contemporary provisions for boundary-less commercial exchanges under global economic forums, such as the North American Free Trade Agreement (NAFTA) and the European Union (EU), there is greater potential to offshore business functions to supply chain service providers in different countries. In fact, offshoring as a global phenomenon has been fueled by organizational attempts to gain competitive advantage through concentration on their core competencies while minimizing the costs of outsourcing at the same time (Bardhan & Kroll, 2003; Nair & Prasad, 2004).

Data Information Management

Mobile applications can improve the frequency and speed of communication (Gebauer, Shaw & Zhao, 2002). With data collection at the point of activity and the elimination of paper-based desktop-centric workflows, the velocity of transactions can be increased greatly. Proof of delivery and electronic signature capture technologies are being used in various businesses to enable more efficient and more streamlined information processes within the supply chain. Moreover, these processes, enabled through mobile technologies, allow real-time data access from the source, as opposed to batches of information being transmitted through various information systems at different times. Consequently, information synchronization errors that are attributed to batch processing can be reduced greatly.

While, on the one hand, real-time data transmission helps to increase the fulfillment velocity by making information instantaneously available throughout the supply chain, on the other hand, it facilitates enhanced visibility of supply chain processes by interacting directly with concerned parties through notification and alert mechanisms. The end result is reduced order-to-delivery time and more responsive service management.

New Business Processes

Mobile applications also are driven by the need to innovate operational business processes. Companies like Wal-Mart and McDonald's are well known for acquiring favorable market positions and competitive advantage through novel business processes. In fact, it has been conferred by many authors that it is the processes and not merely the underlying IT infrastructure that enables strategic advantage (Hurst, 2003). Hence, the need to gain and sustain competitive advantage can drive companies to innovate and re-engineer their business processes using new technologies (Barney, 1995; Porter, 1980).

The well-known market leaders in SCM are just beginning to avail the opportunities afforded by mobile technologies, as well. For example, Wal-Mart's adoption of Radio Frequency Identification (RFID) and subsequent coercion of its suppliers to do the same will be indubitably accompanied by the establishment of new business processes. The workflows associated with tracking pallets and items from receiving to sales and the management of inventory status all will be affected. Among other benefits, RFID technology is being touted as an enabler for improved inventory accuracy, reduced receiving costs, lower safety stock levels, and reduced cycle count efforts. With mandates from companies such as Wal-Mart, other businesses in various industries also will be driven to explore such technologies in order to revamp their own business processes.

Replace Obsolete Systems

The adoption of mobile technology applications also is being driven by the need to replace obsolete systems and associated business processes. For example, mobile telemetry services (i.e., the use of telecommunication devices to automatically record measurements from a distance) can replace manual on-site data entry and other forms of continuous monitoring (Salz, 2003). With the proliferation of cellular networks, it makes sense to monitor remote resources and assets using wireless technologies.

The previous example is not a completely new technology phenomenon. Often, information systems from one industry find their way into other industries with a certain level of customization. Telemetry solutions have prevailed in the agricultural and military sectors for years. Feeding livestock and examining contamination levels in water are among the applications that use telemetry in an agricultural context. Similarly, remote surveillance using airborne and satellite-based cameras is an example of a telemetry application used by the military (Forrester Research, 1998).

Changing business contexts necessitate newer technology infrastructures. As illustrated in the example, wireless services and applications have the potential to steer more versatility in today's supply chains by offering features and functionalities that may have been tested in other business functions or in totally different industries. It is only a matter of time before more mobile technology applications emerge and change the current supply chain landscape.

Strategic Cost Management

As elaborated throughout this chapter, cost reduction is a major driver in adopting any new technology in SCM. Under compelling demands from various stakeholders, supply chain managers constantly are looking for ways to optimize operations with the objective of reducing operating costs. A feature that makes mobile technologies a viable contender for the supply chain applications market is their ability to account for financial information in real time. Technologies such as GPS (Global Positioning Systems), telemetry, and RFID can feed real-time data to static tethered information systems. Furthermore, by streamlining the order-to-cash process, mobile technologies can reduce the complexity in the overall supply chain execution (Kalakota et al., 2003).

Overall, it can be said that mobile technology applications are driven by a multitude of market forces, and the adoption of such applications is likely to have an impact on business functions across different industries. Mobile SCM technologies can provide processing efficiency in the form of time, cost, and quality of operations. Based on these various benefits that can be availed through the adoption of mobile SCM technology applications, organizations need a road map to implement these technologies in their various business functions and subsequently integrate these into a seamless mobile infrastructure. The next section provides a typology of mobile SCM technology applications that can facilitate an organization's efforts in this area.

A TYPOLOGY OF MOBILE TECHNOLOGY APPLICATIONS IN SUPPLY CHAIN MANAGEMENT

In presenting our system of classification for mobile technology applications in SCM, we will discuss various mobile applications vis-à-vis their associated bearer technologies. Furthermore, to help us with our analysis, we will utilize the functions and processes from the inclusive SCM framework elaborated earlier in this chapter (see Figure 1). Table 2 at the end of this section illustrates the dimensions of our typology and the incumbent technology applications that are described herein.

Mobile Technology Applications in Supplier Relationship Management (Upstream Processes)

Three things in the life of a supply chain planner are for certain: death, taxes and reconciliation. (Hammer, 1997, p. 18)

This statement by Michael Hammer (1997) epitomizes a classic problem in SCM. Traditional information systems fall short in their functionality in order to reconcile cash and inventory at various points in the supply chain. It is not surprising, then, that manifest reconciliation emerges as the most popular application in mobile SCM (see Table 2). An example in upstream supply chain processes is the enduring difficulty in reconciling purchase orders to truck manifests at check-in times and freight pickups. The solution to such problems lies in the integrated use of bearer technologies, such as RFIDs, WWANs, and WLANs. Using emerging technologies in smart bar coding, the receiver can seamlessly scan incoming shipments, note discrepancies between purchase orders and truck manifests, make relevant changes to purchase orders, and update back-office systems as well as supplier databases at the same time. Furthermore, the ability for the driver to connect instantaneously with the materials planner for the upstream supplier helps to resolve exceptions and system errors at the point of delivery. Together, these technologies allow increased transaction velocity in the supply chain and higher levels of supplier coordination versatility (Kalakota et al., 2003).

Also, mobile technologies based on GPS allow for greater inventory visibility throughout the supply chain. By pinpointing the location of delivery trucks and the status of delivery packages, upstream suppliers can coordinate shipment schedules with downstream customers, who, in turn, can communicate expectations to their own downstream business partners. Telematics, which is defined as the integration of wireless communications, vehicle monitoring systems, and location devices (GSM Association, 2004), is one such suite of applications that is known to enhance confidence in business functions, including SCM, through facilitating greater visibility and enabling greater control in the supply chain (Hanebeck & Tracey, 2003).

Mobile Technology Applications in Internal Supply Chain Management (Internal Processes)

Mobile technologies also offer significant advantages to internal business operations by facilitating express and streamlined workflows. Among others, workflow applications in business operations include document approval, expense reporting, payment, and purchase orders (Kalakota et al., 2003). According to a recent pilot study by Gebauer, Shaw, and Zhao (2002), the most significant benefits in wireless procurement services result from speeding the overall processing time of an approval request. It is estimated that close to half of the processing time of a purchasing request is due to managers being out of the office, and, from their study, the researchers conclude that wireless technologies can appreciably help manager approvers as well as finance and accounting

Table 2. A typology of mobile technology applications for SCM

Supply Chain Macro Processes & Value Chain Activities

Bearer Technologies

	Supplier Relationship Management	Internal Supply Chain Management	Customer Relationship Management		
	Inbound Logistics	Operations	Outbound Logistics	Marketing & Sales	Service
GPS	☐ Load Verification ☐ Vehicle Dispatching ☐ Package Tracking ☐ Asset Tracking ☐ Telematics		☐ Route Management ☐ Vehicle Dispatching ☐ Package Tracking ☐ Asset Tracking ☐ Telematics	☐ Location-based Information Access	☐ Telemetry
WWAN	☐ Advance Shipping Notifications ☐ Manifest Reconciliation		☐ Advance Shipping Notifications ☐ Manifest Reconciliation		
Cellular	☐ Delivery Confirmation ☐ Manifest Reconciliation ☐ Electronic Signature Capture ☐ Exception Notification ☐ Driver Contact	☐ Approval Workflows ☐ Managerial Contact ☐ Employee Contact	☐ Delivery Confirmation ☐ Manifest Reconciliation ☐ Electronic Signature Capture ☐ Exception Notification ☐ Driver Contact	☐ Sales Promotion ☐ ATP/CTP Channel ☐ Reverse Logistics ☐ Location-based Push Services ☐ Sales Contact	☐ Service Contact ☐ Telemetry
P2T	☐ Delivery Confirmation ☐ Exception Notification	☐ Employee Contact	☐ Delivery Confirmation ☐ Exception Notification		☐ Employee Contact
RFID	☐ Asset Tracking ☐ Barcode Scanning	☐ Barcode Scanning ☐ Telemetry	☐ Asset Tracking ☐ Barcode Scanning		
WLAN (Wi-Fi / Bluetooth)	☐ Back-office Updates	☐ Telemetry ☐ Manifest Reconciliation ☐ Receiving & Payment Workflows	☐ Back-office Updates		

Mobile SCM Applications

Acronyms Glossary: ATP/CTP—Available-to-Promise/Capable-to-Promise; GPS—Global Positioning System; P2T—Push-to-Talk; RFID—Radio Frequency Identification; WLAN—Wireless Local Area Network; WWAN—Wireless Wide Area Network approvers by providing support for delegation, communication, notification, and information access (Gebauer et al., 2002).

Another major category of mobile technologies that is redefining internal supply chain processes is wireless product identification. This suite of technologies is regarded as an enabler for handling efficiency, customisation, and information sharing (Karkkainen & Holmstrom, 2002). An example of wireless product identification technology is an RFID system that comprises electronic product codes stored on RFID tags. These tags can be read seamlessly through tactically placed RFID scanners, which, in turn, transmit inventory information to back-office systems through specific middleware. The advantage of such systems is that they can be used without requiring line of sight. The tag readers, hence, can be attached to forklifts, mounted in freight and shipment pathways, or built into stacking shelves. The idea in using such a technology is to eliminate the extra step in scanning pallets or items and to automate the process.

Other internal mobile applications that drive process efficiencies include direct machine-to-machine data exchanges through telemetry. As defined in the previous section, telemetry is the use of telecommunication devices (including wireless) to automatically record measurements from a distance. The automatic notification of inventory management system by an RFID reader when inventory gets depleted below a certain level would be an example of a telemetric application. Again, this type of application can facilitate efficient and streamlined process flows in warehouse and inventory management systems.

Finally, as mentioned earlier, wireless technologies usually are always strongly integrated with other SCM enterprise systems. Back-office updates resulting from real-time data capture at the source are almost never stored or used independently of these systems. The medium of transmission for updates between wireless devices and enterprise systems can be in the form of a WLAN, based on short-range Wi-Fi technology or the proximity-based Bluetooth technology.

Mobile Technology Applications in Customer Relationship Management (Downstream Processes)

Many technology applications in the outbound logistics function coincide with those in the inbound logistics function. This is because of the sophisticated omni-directional nature of supply networks of today, where the position of an organization might be that of an upstream supplier as well as a downstream customer at the same. Similar technologies can be utilized in both cases, albeit in different business contexts. For example, in the instance of delivering a package to a customer, the manifest reconciliation is still a useful application, except this time, the customer invoice will be reconciled with the bill of loading. Similarly, GPS bearer technologies can be used in conjunction with transportation management systems to determine dispatching routes and daily delivery schedules for outbound freight drivers and delivery personnel.

The marketing and sales function in customer relationship management can benefit greatly from information access provided through wireless handheld and pocket-pc-type devices. Using their handhelds, field sales employees can connect directly to back-office inventory management systems or enterprise resource planning systems in order to perform available-to-promise (ATP) checks or capable-to-promise (CTP) checks, respectively (May, 2001). They then can provide up-to-the-minute information to their customers. Not only do these types of applications result in lower costs, due to increased employee productivity and more streamlined workflows and faster decision-making, they also result in higher levels of customer satisfaction. Returns processing and reverse logistics presents yet another area where mobile technologies can help alleviate business pain spots. By allowing drivers and field service representatives to accept returns (due to product defects or a change of mind from the customer) and with the ability to dispatch pickup trucks in near vicinity, if need be, businesses can drastically increase customer satisfaction levels and operational productivity.

Lastly, with respect to mobile technology applications in the service function, telemetry applications have the potential to provide yet again an effective means of monitoring and controlling remote resources. Service levels can be monitored, and personnel can be assigned, based on the type of problem incurred. These applications can help to reduce employee time and costs associated with routine administration of assets in remote locations.

From the discussion in this section, it should be evident that the mobile supply chain applications described herein, along with their respective bearer technologies are indeed in harmony with the various drivers for mobile technologies described earlier. Table 2 presents our typology of mobile technology applications as a juxtaposition of bearer technologies and their functional scope in different supply chain activities. In the next sections, we discuss our future outlook for these mobile technology applications followed by our conclusions.

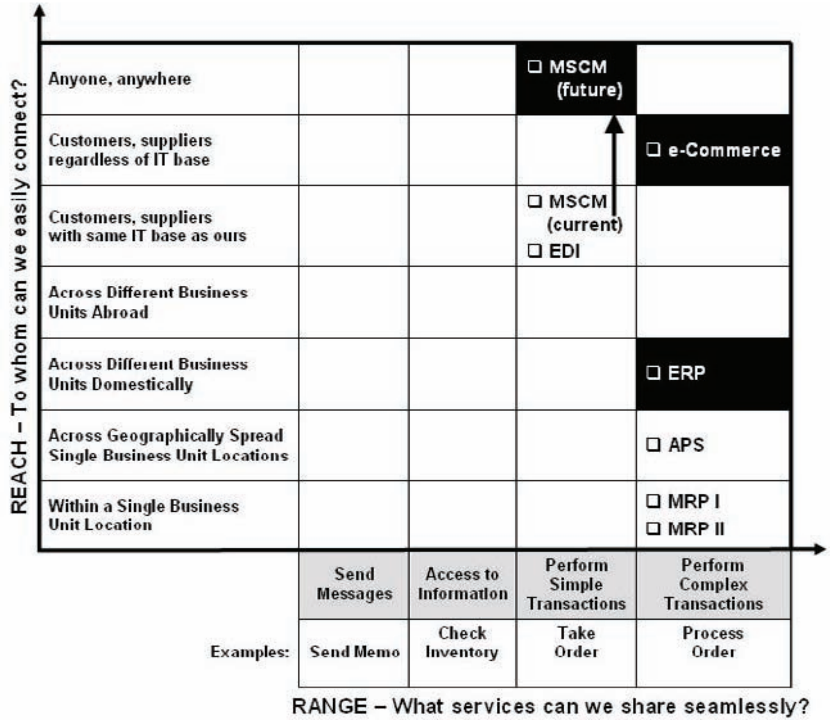
FUTURE OUTLOOK

Recent developments in new wireless technologies, more sophisticated end-user devices, and improved network coverage all have resulted in greater adoption rates for mobile applications (Alanen & Autio, 2003). However, in order to predict the future pathway of different types of mobile technology applications described in this chapter, we need to consider them vis-à-vis other technologies that have been used in SCM for some time, such as MRP I, MRP II, APS, ERP, EDI, and e-commerce systems. It is the combination of these functional and enabling technologies that constitutes the essential technology base for different supply chain environments. As elaborated throughout this chapter, mobile technology applications have the potential to assimilate in this current portfolio of technologies by improving process efficiencies and allowing streamlined access to these traditional back-end systems.

First, let us consider the technical interaction between current systems and how mobile technology applications are changing the current landscape. To reiterate our point from the previous section, mobile technologies currently are being used in conjunction with other systems, such as enterprise resource planning (ERP) systems, and it is our belief that this joint utilization will prevail at least in the short-term future. In order to explicate our position further and discuss our viewpoint for the future of mobile SCM technologies, we utilize the range/reach framework developed by Broadbent, Weill, and Clair (1999). The framework was used originally to explain the findings of an academic study that explored the functionalities of different types of information systems, and it lends well to our discussion of SCM systems. Figure 2 depicts our conceptual positioning of various SCM systems along the two dimensions.

As depicted in Figure 2, it can be seen that the current positioning of MSCM applications is such that these applications are bound to augment the reach and range of other enterprise systems (including ERP, MRP, and APS systems) that support various supply chain processes. The two types of technologies are complementary, in that although contemporary enterprise systems such as ERP are capable of performing complex transactions, they are limited to operations cross-functionally across the same organization. Wireless applications can help overcome these spatial boundaries in order to allow communication, collaboration, and coordination across different businesses. Furthermore, with the ongoing standardization of communication protocols, the introduction of new transmission mechanisms (e.g., GSM/GPRS), and

Figure 2. Positioning of various SCM systems in the range/reach framework (adapted from Broadbent et al., 1999)



improved network coverage worldwide, wireless connectivity very soon can enable the anytime/anywhere business paradigm across global supply chain partners. Figure 2 illustrates the direction of this shift upwards from the current position of MSCM applications along the dimensions of range. However, it should be noted that, although this advancement in mobile technologies may enable more complex transactions to be executed than is possible today, the level of complexity cannot catch up to that of e-commerce and ERP systems. This is because of the nature of computing resource requirements for these complex systems. Hence, in the near to medium future, mobile technology applications in SCM will complement other more complex technologies, such as ERP systems and e-commerce systems. The shaded cells in Figure 2 illustrate this unison among the three systems.

Lastly, theorists and practitioners also envisage that mobile technologies will find their way into horizontal, function-specific services, only after they have been tried and tested in vertical, industry-specific applications (Alanen & Autio, 2003; Forrester Research, 2001).

CONCLUSION

The adoption of mobile technology applications for SCM is being driven by various business and technical factors. At the end of the day, managers at the helm of decision making are interested in increasing productivity by reducing process costs and time, increasing process responsiveness, and improving product and service delivery quality. Researchers and futurists contend that MSCM technology applications can turn that vision mentioned previously into a reality by enabling new processes in order to seamlessly connect into existing supply chain planning and execution systems. Through omni-directional, real-time transmission of information, instantaneous reconciliations, and elimination of non-value-added activities from the supply chain, these new mobile applications are enabling increased fulfillment velocity, improved inventory visibility, and higher levels of supplier coordination versatility in the supply network.

In this chapter, we have discussed various categories of mobile technology applications for SCM. A typology based on these applications and associated bearer technologies was presented to highlight various applications within the three supply chain macro processes of supplier relationship management, internal SCM, and customer relationship management. The current and predicted positioning of these technologies in the near to medium time frame shows that the business process changes that will be instigated by the introduction of mobile technologies will lead to gradual, albeit fundamental, transformations in the organization's operations.

It is hoped that the discussion of technology drivers and the typology of mobile applications will prove to be a useful conceptual vehicle for understanding mobile SCM technologies and aid practitioners in making a business case for adopting these technologies. Finally, organizations that recently have undertaken MSCM initiatives can provide useful test beds for the validation of these conceptual models. Case studies investigating the undertakings of these organizations and their experiences with different technologies can provide valuable insights for revising and improving the ideas presented in this chapter.

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Chapter 3.14

Bridging the Gap:

Connecting Internet-Based Spatial Decision Support Systems to the Field-Based Personnel with Real Time Wireless Mobile GIS Applications

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ABSTRACT

Internet GIS provides a collaborative communication environment for sharing data, information, and knowledge. Mobile GIS can add both geospatial information and global positional systems (GPS) coordinates from remotely located field-based personnel to spatial decision support systems (SDSS). By adopting broadband wireless telecommunication technology for connecting Internet GIS and mobile GIS devices, decision makers can gather near real-time information from field personnel and, equally quickly, distribute updated information back to the field. This chapter introduces a collaborative GIS prototype that demonstrates an interoperable framework for combining Web-based GIS technologies and wireless mobile GIS applications. The integrated framework provides real-time or near real-time GIS data update functions (such as adding new spatially located map features or GPS tracking locations) between mobile GIS devices and Internet GIS servers. Although these real-time GIS functions can be very important during time-urgent emergencies, they can be equally beneficial and highly cost effective during routine field activities.

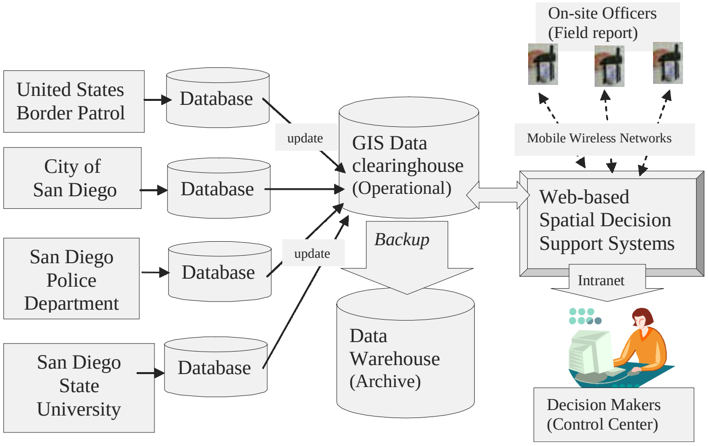
INTRODUCTION

Internet GIS (Peng & Tsou, 2003) can facilitate the implementation of collaborative GIS in the form of a Web-based spatial decision support system (SDSS) having remote communication channels. Currently, the greatest challenge for Web-based spatial decision support systems is the creation of a real-time or near real-time GIS-based communication channels between senior decision makers and multiple in-field personnel (such as first-responders). The objective of this book chapter is to introduce an integrated collaborative GIS architecture that combines Web-based GIS and wireless mobile GIS with a spatial decision support system. By adopting wireless telecommunication technology and advanced Internet GIS tools, decision makers can benefit from real-time information obtained from in-field personnel. In turn, in-field personnel benefit from more timely updated information from decision makers. The two-way communication mechanism between in-field personnel (*in situ* agents) and decision makers can facilitate a better and timelier decision-making process. Such an integrated framework combined with a client-side wireless mobile GIS application and a server-side Web-based decision support system will help optimize field-based management tasks, whether they are time urgent such as emergency dispatch, or a more mundane utility service call.

Both mobile GIS and Internet GIS technologies have been available for almost 10 years. However, very few collaborative GIS projects or spatial decision support systems have adopted both technologies for collaborative work. A principle problem has been the lack of comprehensive communication framework to combine Internet GIS and mobile GIS. Recent dramatic progress in broadband wireless technology has opened a new direction for connecting Internet GIS and mobile GIS with collaborative GIS architectures. Moreover, the GIS community is working on the establishment of interoperability standards, network-based GIS communication protocols, and XML-based geospatial data structure. These efforts from the GIS and telecommunication communities are beginning to facilitate the seamless integration of mobile GIS and Internet GIS.

Figure 1 displays an integrated spatial decision support system prototype that demonstrates an interoperable framework for combining Web-based GIS technologies and wireless mobile GIS applications. The major consideration of this prototype framework is to facilitate the interoperability between heterogeneous systems and platforms. To enhance interoperability, the integrated SDSS utilized a standardized Web-mapping interface, along with OGC Web Map Service (WMS) interfaces (provided by ESRI's ArcIMS OGC WMS connector) to provide online mapping functions and the display of remotely sensed data. By adopting XML-based metadata frameworks (ISO 19115 standard, 2003), multiple network-based geospatial information servers

Figure 1. Interoperable framework for Internet-based spatial decision support systems and wireless mobile GIS applications



work together via a centralized GIS data portal (data clearinghouse) with a duplicated backup data warehouse server. Each individual participating agency (such as police departments, university GIS centers, border patrol sectors, fire departments, etc.) can implement and update their own data systems and services while maintaining an aggregated system-wide interoperability through multiple data warehouses and Web-based decision support systems. The Web-based SDSS will be used by decision makers and spatial analysts in a control center to collect and process information via a secure intranet or encrypted mobile wireless networks in order to make better and more timely decisions, and to initiate improved responses to on-site personnel.

One unique design strategy of this Web-based spatial decision support system (Figure 1) is to combine distributed database connectivity and a centralized data archive system. The GIS data clearinghouse will automatically fetch the newest updated data from remote data servers (located in US Border Patrol, San Diego Police Department, and City of San Diego). Then the clearinghouse will maintain an archived, centralized database inside the system. The Web-based SDSS interface will only create a single database connection channel to access the operational GIS data clearinghouse, rather than establishing multiple database connections from various data resources at the same time. If any distributed data nodes (servers) are not available (due to system shutdown or networking problems) during an operational runtime, the GIS data clearinghouse will retrieve archived datasets from the backup data warehouse automatically. This unique design will improve the efficiency of database connection, and provide a more reliable Web-based SDSS framework.

This chapter also provides an overview of current Internet GIS and mobile GIS technology, and discusses implementation issues and experiences in creating this SDSS prototype. This Web-based prototype (http://geoinfo.sdsu.edu/reason) was funded by a NASA research program, REASoN (Research, Education and Applications Solution Network). The project goal is to assist in the development of a border spatial decision support system (BSDSS) for allocating and deploying resources to secure U.S. borders. A team of security agents with the U.S. Border Patrol, law enforcement, state and local resource protection agencies, researchers from San Diego State University (SDSU), and remote sensing technology companies is collaborating on this project. Case-study experiences, data security and classification, encryption for wireless communication, and two-way communication techniques are highlighted in this chapter.

ADVANCED GEOSPATIAL TECHNOLOGIES FOR COLLABORATIVE WORKS

Collaborative GIS is an integrated GIS framework that can facilitate its participants to work on geospatial related tasks with a shared understanding of geospatial information. The development of collaborative GIS is related to collaborative spatial decision making (CSDM) (Jankowski & Nyerges, 2001), computer-supported cooperative work (CSCW) (Li & Coleman, 2002), and group decision support systems (GDSS). According to Jankowski and Nyerges (2001), the term “collaborative” indicates a higher level of operation agreement among the participants comparing to other terms such as “communication,” “cooperation,” and “coordination.” Collaborative GIS, or spatial understanding (and decision) support systems can be used to “facilitate geographical problem understanding and decision making for groups, including groups embroiled in locational conflict” (Jankowski & Nyerges, 2001, p. 50).

One major research gap in collaborative GIS is the connection between system design and actual GIS applications and usage (Jankowski & Nyerges, 2001). Most collaborative GIS projects emphasize the location/relocation problem tasks, rather than the spatial dispatch coordination or emergency response plan. With the availability of the Internet, many collaborative GIS started to adopt the Web-based environment for their development frameworks (Churcher & Churcher, 1999; Dragicevic & Balram, 2004; MacEachren & Brewer, 2004). However, very few collaborative GIS extend the system framework from Web-based GIS to wireless GPS-enabled devices. This chapter will try to fulfill these gaps to combine both the application-oriented system design strategy and the integration of Web-based GIS and wireless mobile GIS devices. The following sections highlight recent developments in Internet GIS, mobile GIS, and wireless networks used to establish collaborative GIS architectures.

Internet GIS for Collaborative Works

Internet GIS is a collection of network-based geographic information services that utilize both wired and wireless Internet functionality to access geographic information, spatial analytical tools, and GIS Web services. The major goal of an Internet GIS is to develop a high-level GIS federation, that is, to be fully interoperable, where users can transparently access remote services and yet still maintain their autonomy (Bishr Yaser, 1996). The GIS community started to research online distributed GIS in the mid-1990s (Gardels, 1996; Peng & Tsou, 2003; Plewe, 1997; Tang, 1997). The development of Internet GIS was motivated by the adoption of an open and distributed architecture and the redesign of GIS metadata and distributed component frameworks. The contents of Internet GIS include not only displaying Web-based maps or sharing online geospatial information, but also providing advanced GIS analysis functions and new information services. Internet GIS are built upon a distributed computing framework, which is an example of the revolution of information systems from traditional architecturally closed and centralized information systems to more open and distributed information service architectures (Tsou & Buttenfield, 2002).

The driving force behind this GIS architecture transformation is the availability of new technology in network communications and programming. New languages such as Java, Python, and C# (C-sharp) support platform-independent applications across the Internet. Advanced network technologies such as Microsoft .NET framework, J2EE platform, and Common Object Request Broker Architecture (CORBA) provide a comprehensive scheme for distributed component technology essential to the development of Internet GIS. Distributed component technology allows clients to access heterogeneous servers dynamically, which is an essential feature of distributed geographic information services (GIServices). In the future, traditional geographic information systems (GISystems) designed as isolated islands, will become increasingly less attractive, possibly disappearing altogether. The cost efficiencies and flexibility of reusable and interoperable open and distributed-services interfaces provide much greater economies. GIServices focus on open, distributed, task-centered services that broaden geographic information uses into an increasingly wider range of online geospatial applications These include digital libraries, digital governments, online mapping, data clearinghouses, real-time spatial decision support tools, distance learning modules, and so on.

In general, Internet GIS can provide a collaborative communication environment for sharing data, information, and knowledge. The easy and ubiquitous access of Web-based interfaces can help various GIS users (decision makers, remotely located field agents, and the general public) to gain access to essential geospatial information for their individual needs. Online geospatial analytical functions can be combined and integrated to develop collaborative GIS architectures with other external systems and platforms (such as mobile GIS, hotel reservation systems, or financial management systems). The following section describes a mobile GIS, which is another important component of collaborative GIS architectures.

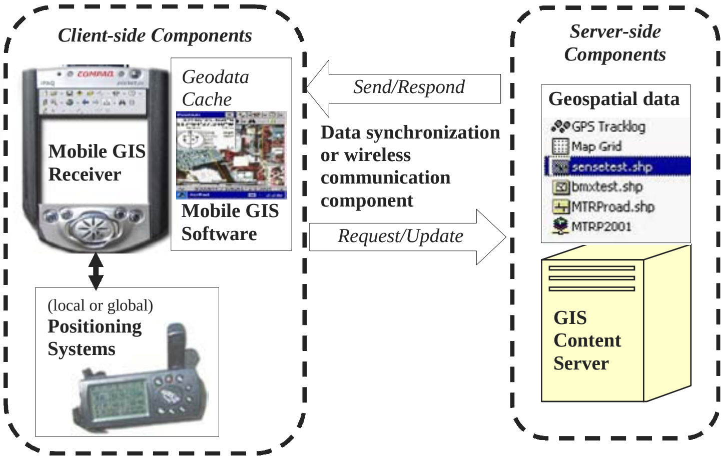
Mobile GIS for Collaborative Architectures

Mobile GIS is an integrated software/hardware framework for the access of geospatial data and services through mobile devices via wireline or wireless networks (Tsou, 2004). There are two major application areas of mobile GIS: *field-based GIS* and *location-based services (LBS).* Field-based GIS focus on the GIS data collection, validation, and update in the field, such as adding or editing map features or changing the attribute tables on an existing GIS dataset. Location-based services focus on business-oriented location management functions such as navigation, street routing, finding a specific location, tracking a vehicle, and so forth (Jagoe, 2002; OGC, 2003). The major differences between the field-based GIS and LBS are the data-editing capabilities. Most field-based GIS applications need to edit or change the original GIS data, or modify feature attributes. LBS rarely change original GIS datasets, but rather use them as background or reference maps for navigation or tracking purposes.

Most field-based GIS software packages are cross-platform and independent of hardware devices. On the other hand, LBS technologies focus on creating commercial value from locational information. Each mobile phone system has its own proprietary operating systems that are very difficult to customize. The architecture of mobile GIS is very similar to the Internet GIS. It follows the concepts of client/server architecture as in traditional Internet GIS applications. Client-side mobile GIS components are the end-user hardware devices that display maps or provide analytical results of GIS operations. Server-side components provide comprehensive geospatial data and perform GIS operations based on a request from the client-side components. Between the client and server, there are various types of communication networks (such as hard-wired cable connections or wireless communications) to facilitate the exchanges of geodata and services. Figure 2 illustrates the six basic components of mobile GIS: 1) positioning systems, 2) mobile GIS receivers, 3) mobile GIS software, 4) data synchronization and wireless communication component, 5) geospatial data, and 6) GIS content servers (Tsou, 2004).

Mobile GIS can provide geospatial information and GPS coordinates for field-based personnel conducting remote field *(in situ)* GIS tasks. For example, landscape architects may use mobile GIS to display a remotely sensed image as a background in a remote field location, and then

Figure 2. Architecture of mobile GIS (Tsou, 2004)



draw a preliminary design for a tree line based on GPS locations. Facility management workers can download a newly updated power-line map to identify the connections required at a specific power pole. To enable comprehensive mobile GIS, wireless communication is essential for connecting mobile GIS devices and GIS content servers. The next section introduces recent progress in broadband wireless technology that can bridge the gap between mobile GIS and Internet GIS.

Recent Progress in Broadband Wireless Technology

Recent progress of broadband wireless technology is the major momentum for the integration of mobile GIS and Internet GIS. The wireless service coverage and the bandwidth (speed) are the two key issues for wireless communication. There are many different wireless technologies, ranging from a walky-talky to high-speed WiMAX, to satellite phone systems. Based on the speed of data transfer, current wireless technologies can be categorized into two groups: narrowband wireless systems and broadband wireless systems. To communicate between mobile GIS and Internet GIS, broadband wireless technology is a better choice because most geospatial information and remote-sensing data are very large and complicated, which requires broadband wireless communication. Currently, there are no clear definitions about the distinction between narrowband and broadband in the telecommunication industry. This paper will define broadband communication as a communication speed (both input and output speed) greater than 1Mbps, such as Wi-Fi or EV-DO. Narrowband wireless systems have data transfer rates that are less than 1Mbps such as current GPRS and CDMA technology.

Generally, there are three different types of wireless communication systems: ad-hoc systems, cellular phone systems, and Wi-Fi/WiMAX data network systems. The ad-hoc wireless systems are custom designed for specific applications such as direct satellite phone systems, General Mobile Radio Service (GMRS) for walky-talky devices, or ham radio communication. Usually, these systems are narrowband and localized for a small group of special users, and require specialized user licenses.

Cellular phone systems are the most popular wireless systems, and are supported by several distinct telecommunication infrastructures to provide comprehensive service coverage. Originally, the focus of cellular phone systems was to provide voice communication rather than digital data transfer. The evolution of cellular phones started from the first generation (1G: analog signal mobile communication), to 2G (digital signal communication, speed range from 9.6Kbps to 14.4Kbps), to 2.5G (larger data speeds from 20 to 100Kbps), to 3G (third generation: near broadband speed ranging from 144Kbps to 2Mbps) (Janowski, 2005). Some researchers indicate the future development of 4G (fourth generation) cellular phone systems can provide ultrabroadband speed from 2Mbps to 10Mbps. 3G and 4G mobile cellular phone communication systems can provide high-speed communication and allow other wireless devices, such as PDA and Pocket PC, to receive multimedia services (such as streaming audio and video on the devices).

Wi-Fi/WiMAX data network systems are another promising category for broadband wireless mobile GIS communication. Both Wi-Fi and Wi-Max are the wireless network standards defined by the IEEE 802 LAN/MAN Standards Committee (http://grouper.ieee.org/groups/802/). The IEEE 802 committee forms multiple working groups in developing local area network (LAN) standards and metropolitan area network (MAN) standards such as 802.3 (Ethernet), 802.11 (wireless LAN), 802.15 (wireless personal area network - WPAN), and 802.16 (broadband wireless access – WiMAX). Currently, the most common wireless LAN infrastructures are the IEEE 802.11 (or Wi-Fi) technology. IEEE 802.11 specifies the physical and media access control (MAC) layers for operation of wireless local area networks (WLAN). The 802.11 standard provides for data rates from 11Mb/s to 54Mb/s (Pandya, 2000). The term Wi-Fi (wireless fidelity) is the global brand name across all markets for any 802.11-based wireless LAN product. Many computers, PDAs, printers, and so forth, have begun to adopt Wi-Fi, or IEEE 802.11, as their major communication channels. There are four extensions in the 802.11 group technology (a, b, g, and n).

WiMAX is an emerging IEEE 802.16 standard for broadband wireless wide-area network (WWAN) or metropolitan area network (MAN) applications. WiMAX can provide a larger coverage of service area than Wi-Fi. Its communication signals can cover a 4-6 miles range (up to 20 miles for the long distance setting). WiMAX can provide broadband to areas that do not have cable or DSL services. Presently, WiMAX includes two steps of the IEEE 802.16 technology. The IEEE 802.16**d** is the first step, which will be used to specify large area wireless communication via outdoor antennas in a fixed location. A fixed WiMAX service can provide up to 75 Mbps speed with Sub 11Ghz radio frequency. The IEEE 802.16**e** will be the next step (under development), used to specify portable wireless hardware for mobile WiMAX services. The new mobile WiMAX can provide roaming capability and enable more persistent connectivity within a service area (Intel, 2004a).

Table 1 illustrates the major wireless standards that are suitable for mobile GIS with collaborative GIS architectures. Note that the two major wireless systems (cellular networks and IEEE 802 groups) both focus on the development of next-generation broadband wireless communication coverage. However, the two systems are not currently compatible with each other due to the different radio frequency. From a GIS user's perspective, it is very difficult to switch seamlessly between Wi-Fi and EVDO wireless network while working in the field or traveling. Actually, the two systems may have to compete with each other in the future, because the new voice-IP technology will enable Wi-Fi or WiMAX to provide wireless phone services over a large area.

Table 1. Suitable broadband wireless standards for mobile GIS communication (table modified from Intel, 2004b, http://www.intel.com/netcomms/bbw/, and Janowski, 2005, p. 100)

	IEEE 802 Standard Groups						**Cellular Phone Network**		
	Wi-Fi	**Wi-Fi**	**Wi-Fi**	**Wi-Fi**	**WiMAX**	**Portable WiMAX**	**Edge**	**EV-DO**	**UMTS**
Standard Group	802.11a	802.11b	802.11g	802.11n	802.16d	802.16e	2.5G	3G	3G
Network Type	WLAN	WLAN	WLAN	WLAN	WWAN Fixed	WWAN Portable	WWAN	WWAN	WWAN
Speed	Up to 54 Mbps	Up to 11 Mbps	Up to 54 Mbps	Up to 200 Mbps	Up to 75 Mbps	Up to 30 Mbps	Up to 384 Kbps	Up to 2.4 Mbps	Up to 10 Mbps with HSDPA technology)
Range	Up to 300 feet (150 feet radius)	Up to 300 feet	Up to 300 feet	Up to 300 feet	Typical 4-6 miles (up to 20 miles for long distance setting	Typical 1-3 miles	Typical 1-5 miles	Typical 1-5 miles	Typical 1-5 miles
Radio Frequency	5GHz	2.4GHz	2.4GHz	2.4 or 5GHz	Sub 11GHz	2-6GHz	1900 MHz	400, 800, 900, 1700, 1800, 1900, 2100MHz	1800, 1900, 2100MHz

INTEGRATION OF INTERNET GIS AND WIRELESS MOBILE GIS

Collaborative GIS are required to support interactive spatial query and visualization of geospatial problems from its participants. By combining Internet GIS and wireless mobile GIS, the new framework of collaborative GIS can provide more interactive GIS functions and real-time data update from distributed participants and decision makers. However, we need to establish a seamless and robust linkage between Internet GIS and mobile GIS in order to provide such high-level services. An integrated spatial decision support system will rely on three major components: Internet GIS, mobile GIS, and broadband wireless communication networks. Each component will need to be customized in order to provide real-time or near real-time GIS functions. Interoperability and upgradeability are two key issues for successful system integration and long-term operation because these GIS technologies change rapidly. The following sections will discuss the major issue in establishing the robust linkage between Internet GIS and wireless mobile GIS, and their major challenges.

The Linkage between Internet GIS and Wireless Mobile GIS

The first issue of the linkage between Internet GIS and mobile GIS is the communication type. There are two types of communication: real-time synchronized communication (via Wi-Fi or cellular phone signals) and cable-based asynchronous communication (via USB or serial ports). Both mechanisms can provide two-way communication between Internet GIS and mobile GIS. For cable-based connections, the Internet GIS servers can send geodata to the mobile GIS receivers whenever the connection is available. Then the mobile GIS receiver can upload geodata or new information back to the Internet GIS server later on. For real-time wireless communication, the mobile GIS receivers can create a continuous link to the Internet GIS server, and the server *responds* to the request in real time by sending the new map to the receiver. To facilitate two-way communications, several middleware or data synchronization software packages (such as Microsoft ActiveSync or Web Services) are required for bridging the mobile GIS applications and Internet GIS. For collaborative GIS, Internet-based protocols, such as TCP/IP and HTTP, can provide an open and standardized communication channels for the linkage between Internet GIS and mobile GIS applications.

The second issue of the linkage is the data exchange methods between Internet GIS and mobile GIS. There are two major methods: data transmission and database connection. The first method, data transmission, is to utilize network data transfer tools like FTP or HTTP to upload or download the whole data items. The second method is to create a database connection between the Internet GIS and mobile GIS that can provide more advanced database query and search functions. Most collaborative GIS will prefer the second method because the first method (data transmission) requires a higher network bandwidth when the size of GIS data becomes large. The format of data/databases is another consideration for data exchange methods. For example, mobile GIS units can send text-based GPS signals to the Internet GIS via a database connection. An alternative method is that a segment of GPS signals can be converted into a compressed binary file, then use FTP to send the file back to the Internet GIS server. Both approaches can fulfill the need of data exchanges between Internet GIS and mobile GIS.

The Challenges for the Integrated Spatial Decision Support Systems

There are several challenges in creating an interoperable SDSS framework. The first challenge is to ensure interoperability across the mobile

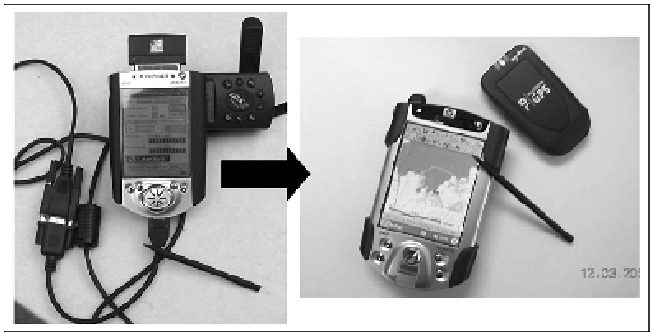
GIS and Internet GIS interface. Most mobile GIS software and devices are vendor-based and use proprietary data formats and specialized communication protocols. Proprietary data formats and protocols will create difficulty during the customization of mobile GIS software when fitting various field-based GIS tasks. Some mobile GIS platforms required a specialized combination of hardware devices, which cannot be substituted or replaced by other systems. Therefore, the ideal mobile GIS software should utilize standard data formats and protocols and be independent of hardware devices, allowing later upgrade or substitution. The same criteria should be applied to the choice of Internet GIS server and its software packages. For the development of collaborative GIS, the software and data format independence is also very important because the participants of collaborative GIS might come from different agencies that have different computing resources and hardware equipments.

Figure 3 illustrates an example of an independent hardware device upgrade used to replace a proprietary cable-based GPS. The cable-based GPS device is replaced with a wireless blue tooth GPS within the same mobile GIS unit.

The second challenge in creating an interoperable SDSS framework is the search and indexing functions for geospatial information on the Internet. Most GIS users have problems in finding online data effectively because they lack a comprehensive data search and indexing mechanism for geospatial data sets. One possible solution is to create detailed metadata information archived in an easily accessible mode, such as a GIS Web portal. The user-friendly GIS Web portal should have a powerful search engine to connect hundreds of data clearinghouses at the same time. Some researchers suggest that what is needed is a Google-like geodata search service that can rank the importance of geospatial data by their popularity and linkage numbers. For collaborative GIS, the metadata search engine will help different participants to gather the information they need effectively, and provide a better understanding of geospatial problems.

The third challenge in creating an interoperable SDSS framework is to the ability to merge the services of online data download and interactive Web-based mapping tools together. Both types of Internet GIServices are needed for creating a collaborative GIS environment. However, most current Internet GIS applications separate the functions of data downloads and Web mapping as two separate and distinct functions. From a GIS end-user perspective (or a decision maker's perspective), both raw data and online maps can fulfill the same GIS need during the decision-making process. For example, a city mayor may want to find out the location of major hotels in downtown areas. He or she can either view the locations from a Web-based map viewer, or download a

Figure 3. Independent mobile GIS hardware upgrade (from a cable-based GPS to a blue tooth GPS)



GIS hotel map into his/her GIS software package to view it off-line. Both approaches can provide the mayor with the same geospatial information he/she needs. Therefore, a comprehensive GIS Web portal should index both raw GIS data and Web-based mapping services together.

The fourth challenge is to enable real or near real-time data updates and two-way communications between clients (field agents) and their server (control and command centers) via broadband wireless networks. The availability of wireless networks will be the major technical challenge in setting up real-time mobile GIS applications. Many locations, such as national parks, or rural areas, lack wireless network coverage, making it difficult to implement broadband wireless devices or stations. Data security in wireless communications has also become another technical challenge. Currently, it remains very difficulty to create a fully automated mechanism on the server side to receive updates from remotely located field agents. Most current Web-based mapping servers still require manual conversions to update geodata received from field agents. Without automated data conversion and update mechanisms on the server-side, each Internet map server will require a full-time analyst operating the map server for real-time or near real-time data updates.

The following section introduces a success development of an integrated spatial decision support system that addresses some of the problems mentioned above while providing real-time or near real-time GIS data update and GPS tracking functionality.

The Establishment of a Real-Time Spatial Decision Support System

Based on the previous considerations, the research team developed an integrated, real-time SDSS framework that utilized state-of-the-art mobile GIS application software (ArcPad and ArcPad application builder), global positional systems (GPS), and wireless networking technologies (IEEE 802.11b, Wi-Fi standard). This SDSS architecture provides a scalable client/server wireless framework to access large volumes of geospatial information and remotely sensed data. The two-level real-time SDSS allows in-field agents access to multiple Internet map servers via their mobile devices, and the ability to submit updated field reports or messages back to a control and command center.

Figure 4 and Figure 5 illustrate the two scales of wireless architecture for real-time spatial decision support systems. The first level (level-1) is an independent, localized mobile wireless framework (Figure 4). The second level (level 2) is a wide-area, control-center-based wireless systems that directly connects decision makers to in-field

Figure 4. Level-1: Independent, mobilized wireless mobile GIS infrastructure

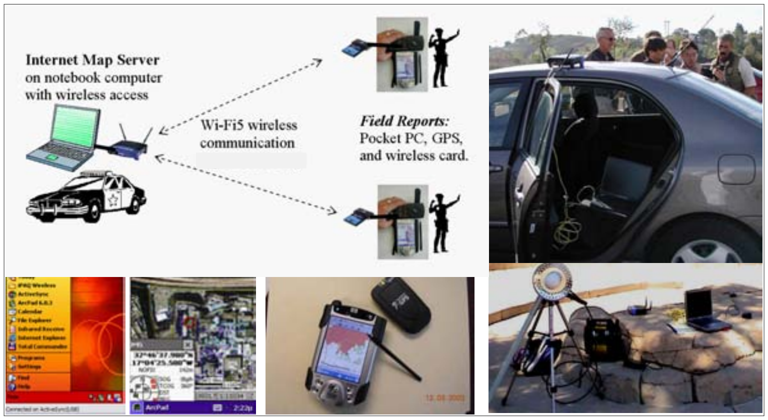
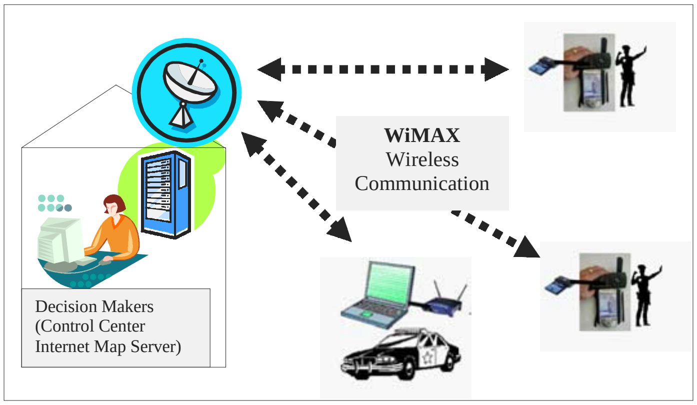


Figure 5. Level-2: Control-center-based wireless mobile GIS infrastructure (under development)



agents and to the first level mobile systems (when the vehicle drives back to the WiMAX cover areas) (Figure 5). Currently, our research team has completed the first level framework testing and implementation, and is planning to implement the second level framework once the WiMAX network is available.

The level-1 real-time SDSS framework utilizes a wireless local area network for the communications between mobile GIS receivers and portable Internet map servers. In the prototype, an Internet map server (ESRI ArcIMS) was installed on a notebook computer equipped with a wireless access port (Linksys Wireless Access Point Router). The notebook and wireless access port were placed inside a vehicle, and used the vehicle's electrical system, via the cigarette lighter socket, to power the wireless communications components. Field staff then used Pocket PC's equipped with Bluetooth GPS and Wi-Fi cards to access remotely sensed imagery and GIS data layers from a large capacity database residing on the notebook Web server via wireless communication channels (Wi-Fi) (Figure 4).

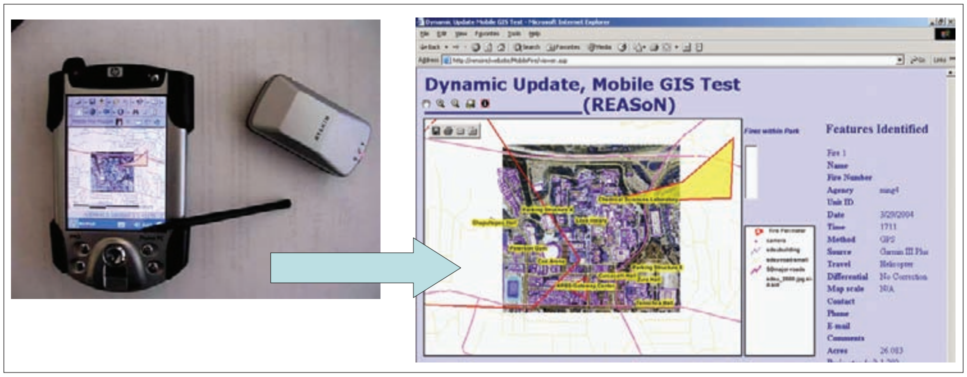
The level-2 framework will utilize WiMAX broadband wireless networks. Both in-field agents and level-1 mobile SDSS will be able to communicate to the control and command center and decision makers. Since WiMAX coverage may not reach into rural areas, updated information from level-1 systems can be uploaded to the control center map server when the mobile systems enter WiMAX coverage areas. Utilization of two levels of scalable wireless framework for real-time and near real-time SDSS will provide a more cost-effective information update and sharing mechanism between centralized decision makers and remotely located field agents.

Using the two-level wireless SDSS framework, Wi-Fi and WiMAX can provide two-way communication channels between Internet map servers and mobile GIS devices, such as Pocket PC and notebook computers. The Internet GIS software and mobile GIS packages will be customized to provide real-time display on the Web-based map viewer.

The following paragraphs and figures (from Figure 6 to Figure 9) will introduce some key examples in our prototype development for a real-time SDSS. These examples demonstrate the efforts to create an open, Internet-based communication channels between Internet GIS and mobile GIS, and the Web GIS data portal for collaborative GIS participants.

Figure 6 illustrates a prototype testing of real-time GIS data updates functionality from a mobile GIS device (left) to an Internet Map Server (right). The system was created by using ESRI's ArcPAD, MS Access databases, and ESRI ArcIMS. The figure shows that a triangle polygon, digitized on

Figure 6. Real-time wireless GIS data update (adding new polygon) via an open Internet-based communication protocol between mobile GIS and internet GIS (Web map services)



Fire 1
Name
Fire Number
Agency mng4
Unit ID
Date 3/29/2004
Time 1711
Method GPS
Source Garmin III Plus
Travel Helicopter
Differential No Correction
Map scale N/A
Contact
Phone
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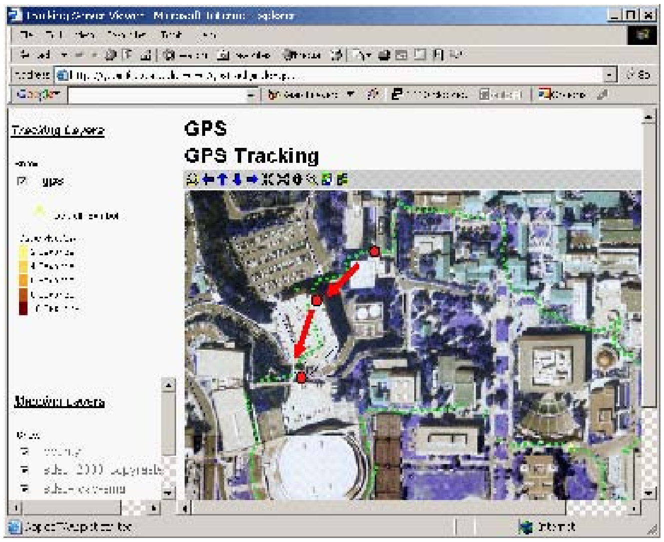
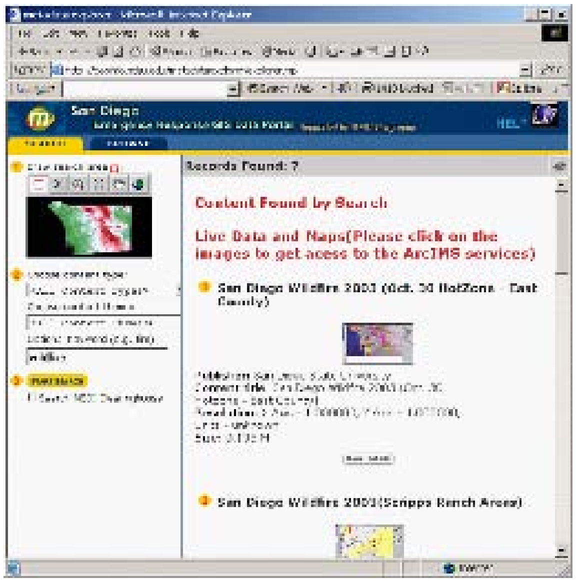
Figure 7. Web-based real-time GPS tracking services via an open Internet-based communication channel (sending mobile GIS device signals back to an Internet map server)



the Pocket PC by remotely located field agents, was successfully submitted and updated at the centralized Internet map server via Wi-Fi channels with TCP/IP. One unique feature is that the system utilizes an open Internet-based protocol (TCP/IP) that can be easily applied in a different network environment. Most traditional GPS tracking devices only utilized proprietary protocol that cannot be shared or applied by other applications or different networks. This type of functionality will be very useful during emergency response or security management incidents, such as drawing a safety buffer-zone area around an accident. The original real-time update function was develop by an ESRI technical group, and then customized by our REASoN project team.

In addition to real-time GIS updates or data submissions, another important real-time SDSS function is GPS tracking of all in-field agents. Figure 7 shows a Web-based GPS-tracking map browser that illustrates a simulated security officer carrying a Pocket-PC with GPS functionality

Figure 8. Web interface for the San Diego Emergency Response GIS data portal (http://geoinfo.sdsu.edu/metadataexplorer)



Records Found: 7

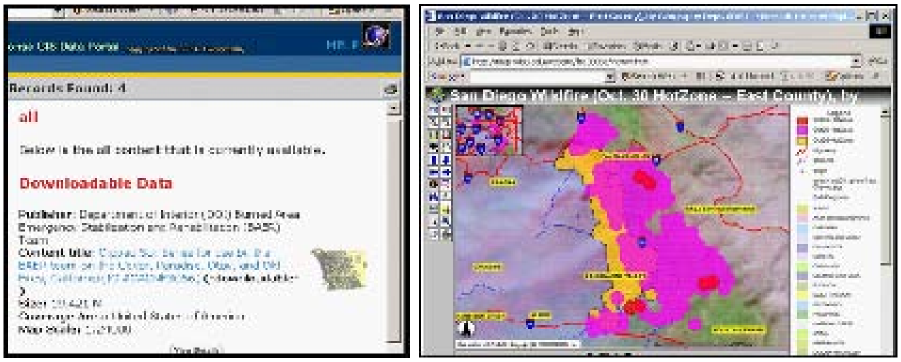
Content Found by Search

Live Data and Maps(Please click on the images to get acess to the ArcIMS services)

San Diego Wildfire 2003 (Oct. 30 HotZone - East County)

San Diego Wildfire 2003(Scripps Ranch Areas)

Figure 9. Data download and online mapping functions in a Web portal


Records Found: 4

all

Below is the all content that is currently available.

Downloadable Data

across the campus of San Diego State University. In the Web browser, the red dot can dynamically move according to the GPS signals received from the security officer's Pocket PC. This testing was created by using ESRI's Tracking Server (beta-version) with customized ArcPAD GPS functions. Due to the lack of WiMAX wireless channels on the campus, the system relied on a GPS simulator to create the real-time GPS signals feeding to the Internet map server via TCP/IP.

The development of a GIS Web portal is another important component for spatial decision support systems. A comprehensive GIS Web portal should include download services for both raw GIS data and Web-based mapping services. Figure 8 illustrates a GIS Web portal, developed for our project, called San Diego Emergency Response GIS Data Portal. This Web portal was created by using ESRI ArcIMS Metadata Server Extension with ArcSDE and MS SQL server. Users can type keywords or select themes to query the metadata of geospatial information stored in the Web portal. The Web portal includes both downloadable data and online mapping services (Figure 9).

To summarize, this section introduced the development of a real-time or near real-time spatial decision support system prototype. By combining real-time GPS tracking, GIS Web portals, online mapping services, and real-time in-field agent data updates, it is possible to create a Web-based decision support system designed to help optimize field-based management tasks, such as emergency dispatch or utility service calls. The two-level Wi-Fi and WiMAX wireless networks can be used to create an effective collaborative GIS framework that provides the two-way communication channels for the Web-based decision support system.

There are some limitations in our prototype design. First of all, the security of wireless communication and mobile GIS devices is a major concern of the U.S. Border Patrol. Mobile GIS devices are very likely to be stolen because the device size is so small. Some critical information and criminal apprehension data are very sensitive and need to be protected within the system framework. However, the current technologies in wireless communication and mobile devices can only provide very limited protection mechanisms. The second limitation of our system is the balance between open-source packages and vendor-based GIS software. Most of our prototype system adopted vendor-based GIS software packages because the vendor-based GIS packages already have many needed GIS functions available, and can significantly save our system development time. However, vendor-based Internet GIS and mobile GIS packages might become difficult to customize or develop new GIS functions, compared to the open-source packages. In the long run, vendor-based GIS packages might need more effort to create additional new GIS functions for the future prototype development.

FUTURE TRENDS

In the future development of collaborative GIS frameworks or Web-based decision support systems, many innovative Web technologies, such as Grid computing and Semantic Web, can be adopted. These Web technologies, from a technical perspective, will enable more efficient and intelligent data search mechanisms and online mapping services.

Ideally, multiple geodata and GIS functions from heterogeneous servers or platforms should be connected and integrated dynamically to conduct a specific geospatial analysis tasks. To dynamically construct distributed GIServices, tremendous amounts of geospatial data and computational results would be requested and transferred across the network. Therefore, the GIS community needs to establish a comprehensive GIService framework in order to keep all available heterogeneous GIService components synchronized in terms of data flow and operation procedures. Such a framework needs to become dynamically adjustable in order to accommodate complicated network environments (dial-up modem, cable modem service, ISDN, T1/T3, wireless channels, etc.). The recent development of Grid technology provides a possible framework for the deployment of Internet GIService with its powerful computational and resource management capabilities. In the computer science community, the focus of Grid technology is to resolve low-level Grid computing technology issues (e.g., communication, protocols, and resource management) and to build a collaborative network architecture for Grid (e.g., Globus Toolkit). However, the deployment of collaborative GIS needs a high-level application framework rather than low-level Grid computing architecture. Grid technologies have been rapidly evolving since the mid-1990s. There are two types of Grid technologies, "data Grid" and "computational Grid." Data Grid (Chervenak, Foster, Kesselman, Salisbury, & Tuecke, 2001) can offer a basic architecture for geospatial data management with coordinated data storage, data access, metadata, and security services. Data Grids can provide various downloadable GIS data and online mapping services via the grid's metadata search engine. Computational Grid (Foster & Kesselman, 1999) will primarily be concerned with issues related to building the infrastructure to meet the requirements for high-performance computational needs. Both data Grid and computational Grid are emerging to provide effective computing resources for sharing and integration.

Semantic Web is another future trend for collaborative GIS. Semantic Web can facilitate the Web-based data sharing within a global network system. This technology can provide better definition of Web data and services, allowing large-scale data sharing and reuse (Berners-Lee, hendler, & Lassila, 2001). A working group in W3C (World Wide Web consortium) has defined related standards and languages for the applications of semantic Web technologies (http://www.w3.org). RDF (resource description framework) was designed to organize Web information into triple terms for easier data retrieval (http://www.w3.org/RDF/). To better handle terms and relations in semantic Web, Web Ontology Language (OWL) was also proposed to define terminology used for specific contexts and properties in terms of classes and relations (http://www.w3.org/TR/owl-guide/). Besides the reorganization of online content, recent breakthroughs have been made in defining Web services using mark-up language. OWL-S is a specification designed to help Web services discover and use the mark-up language. (http://www.w3.org/Submission/2004/SUBM-OWL-S-20041122/). In addition to all of the standards set by W3C and other organizations, semantic Web tools have been developed for data parsing, metadata processing, ontology management, and RDF/OWL formatting. To facilitate the integration of heterogeneous collaborative GIS frameworks, we might need to create a geospatial semantic Web that requires developing a geographic Web ontology language (G-OWL) to facilitate the geospatial data sharing and service integration.

CONCLUSION

On December 26, 2004, people from around the world began to realize the power of nature, and that natural disasters are a daily risk we must address. Following a massive 9.0 earthquake in the Indian Ocean, a horrifying tsunami destroyed the coastline areas of 11 countries, and caused a massive number of deaths (over 150,000). Many geographers and GIS professionals asked themselves a fundamental question: "Why did such a tragedy happen in these areas and could we have responded better?" What if these areas have an advanced collaborative, Web-based emergency response system?

A Web-based spatial decision support system could assist the local governments and emergency response teams in identifying potential threat areas so critical "hot zones" could be quickly and accurately identified. A Web-based GIS data portal could be used to rapidly generate the most effective evacuation routes and emergency plans during natural hazard events including wildfires, flooding, and tsunami. Real-time or near real-time GIS could also assist public policy officials, firefighters, and other first responders with identifying areas where their forces and resources are most needed. Many people agree that an integrated and comprehensive geographic information system (GIS) is an essential component for successful disaster prevention and mitigation. Clearly, collaborative GIS could become a vital technology to save lives and assist in recovery.

This paper gives a brief introduction about the capability of collaborative GIS. It is important to educate people and organizations on the utility of collaborative GIS technology, and why it is to their benefit to adopt the technology in their daily lives. As always, the cost of disaster recovery and mitigation is much more expensive than the cost of early prevention using systems such as a Web-based SDSS.

In order for collaborative GIS to be most effective for natural hazard prevention and response purposes, the system should be incorporated into the regular planning activities; training; and exercises conducted by local, regional, and federal government officials and agencies. An example of the routine use of an SDSS in improving emergency response would be the application of real-time SDSS by local governments to monitor the roadway traffic, air quality, and E-911 responses. Monitoring daily roadway traffic can quickly be transformed into monitoring evacuation routes or routing emergency relief aid. Without training, familiarity, and exercises, any emergency response tool, including a real-time SDSS, may not be effective to an official, organization, or government when an actual hazard situation occurs.

This chapter introduced a real-time Web-based spatial decision support system for use by decision makers and *in situ* agents to collect and process information via a secure intranet or encrypted mobile wireless networks to make better and timelier decisions. The goal of an integrated SDSS is to bridge the gap between traditional control-center-based spatial decision support systems and field agents through the use of real-time wireless mobile GIS applications and their benefits to decision making.

The unbelievable tragedy in December 26, 2004 taught us many valuable lessons. We should use collaborative GIS as a tool to understand and respect the power of Nature. When viewing online maps, satellite images, categorizing land-use data, or conducting spatial analysis, we are actually communicating with Nature, and trying to understand her behaviors at that moment. Therefore, the Web-based SDSS introduced in this chapter is not a tool to be used to conquer Nature or to fight back Nature, but a tool to learn the knowledge of Nature, and to collaborate with her.

ACKNOWLEDGEMENT

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Chapter 3.15

Choosing Technologies for Handheld and Ubiquitous Decision Support

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ABSTRACT

Wireless, handheld devices are becoming increasingly popular in health care settings, but the full potential of their role in patient-specific decision support remains to be achieved. This article presents a multicriteria framework for choosing technologies apropos to handheld and ubiquitous decision support architecture. This framework is illustrated through architectural middleware choices made in the context of a podiatry and diabetes care network. Performance issues are found to be very important in the handheld space, and minor aspects of connectivity and other constraints drive significant changes in choices of architectural approach. The resulting architecture employs layers, including serialized objects, XML payloads, event notification, Web services, and dynamic class loading, with the mix varying among the system interfaces. The overall recommendation is that organizations wishing to fully exploit mobile technology must use a flexible policy and pursue a process of technology choice that is scenario-based and iterative to take into account discoveries from prototyping and field-test experience.

INTRODUCTION

Handheld computers acting as personal digital assistants (PDAs) are growing in popularity in health care. They are increasingly trusted (particularly as sources for reference material), used, and considered to be efficient (Cimino & Bakken, 2005). A mid 2004 survey (Grasso, Yen, & Mintz, 2005) found 52% of medical students reporting handheld computer use, with drug reference and clinical calculators the major clinical applications of the technology. Characterizing the use and capability of PDAs is an exercise in measuring the position of a moving target, but the dominant trend sees students as a key user group and reference for education as a key application area. PalmCIS (Chen, Mendonca, McKnight, Stetson, Le, & Cimino, 2004) illustrates the less common use of mobile technology as a terminal for viewing patient data. In a nursing context, Chang, Lutes, Braswell, and Nielsen (2006) found that mobile technology integrated with a hospital's mainframe system improves the communications between shifts. Lu, Xiao, Sears, and Jacko (2005) and Fischer, Stewart, Mchta, Wax, and Lapinsky (2003) also have reviewed handheld applications in health care, and Wu and Straus (2006) and Lane, Heddle, Arnold, and Walker (2006) have conducted systematic reviews. Wu and Strauss found limited, but supportive, evidence that handhelds improved documentation taken by physicians. The more functionally ambitious handheld solutions in health care are generally "home-grown" (i.e., purpose-built for a specific application context).

Handheld computing and mobile communications move us closer to a ubiquitous computing environment, where the notions of "a computer" or "the information system" become less central to the attention of the end user and where many often loosely coupled subsystems collaborate to achieve an overall goal. At the University of South Australia (UniSA), we have been following a vision of ubiquitous decision support for chronic disease management with an emphasis on diabetes and foot care that integrates the roles of clinical decision support, provider education, and patient education (Warren, Lundstrom, Osborne, Kempster, Jones, Ma, & Jasiunas, 2004). Two key elements of this vision have been a handheld data collection and decision support application for students at the UniSA Podiatry Clinic (Lundström, Warren, Jones, Chung, & Jasiunas, 2003); and an individualized Web-based consumer diabetes information service (Ma, Warren, Phillips, & Stanck, 2005).

In the context of ongoing iterative development of handheld and ubiquitous decision support, one is faced with a diversity of architectural options in an environment of rapidly changing technology. The remainder of this paper presents a framework for consideration of relevant technology choices, with particular focus on middleware architecture, which is illustrated in terms of a cycle of development in the UniSA podiatry/diabetes management environment. The outcomes highlight the sensitivity of technology appropriateness to existing constraints and the ongoing relevance of performance.

METHODS

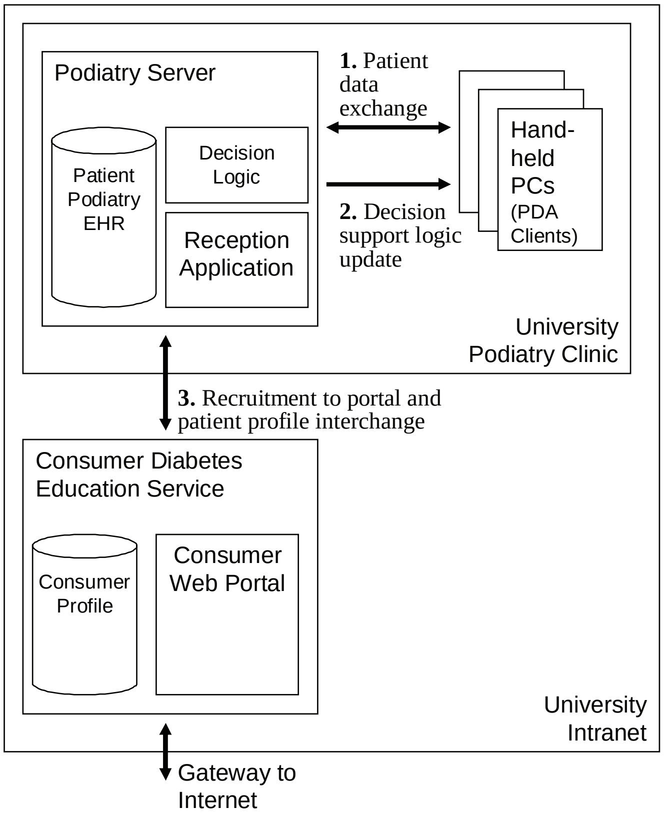
Setting

A spiral development lifecycle has been pursued with the UniSA Podiatry Clinic from mid 2002. The objectives of a cycle for calendar year 2005 entailed: (a) achieving a production client-server system in the podiatry clinic, allowing students to undertake podiatry assessments using handheld computers with results logged to a central database; (b) active decision support for the podiatry students on the handheld terminal to critique assessment and plan in terms of recorded observations; and (c) interfacing of the podiatry clinic to a diabetes consumer education service such that the clinic acts as a recruitment point for the education service, and podiatry observations lead to tailoring of educational priorities. The environment, with the major communication scenarios addressed in the 2005 cycle, is illustrated in Figure 1.

Aspects of the design were fixed at the commencement of the 2005 cycle, constituting developments, investments, and decisions that were undesirable or infeasible to back away from. These fixed aspects of the design include: (a) use of Hewlett-Packard iPAQ pocket PCs with Microsoft Windows operating system as the podiatry clinic terminals; (b) the elements recorded in the podiatry review, user interface design for data capture, and podiatry clinic server database design (encompassing some 200 specific observations, including some free-hand sketches); (c) the use of Bluetooth for communication within the podiatry clinic (due in part to administrative "turf" problems entangling development on 802.11 standards); and (d) the implementation of the Web portal for the consumer diabetes education service to be impacted minimally.

Outside of these fixed constraints, the outstanding architectural decisions concerned the approach to data interchange at the application level among the major system components, including interchange of decision support logic, a realm that can be termed "middleware architecture." All of these communication interfaces were required to support modification of content in the future, but the decision support content was seen as the most volatile, with plans for active iterative refinement of the logic in a future cycle. Experience with an earlier cycle prototype indicated that the data transmission speed performance of the podiatry server to handheld data exchange link was problematic, although a naïve analysis of Bluetooth bandwidth left the source of the problem unclear.

Figure 1. Podiatry/diabetes care network setting (technology choice scenarios numbered)



Procedure

Our procedure was informed by Serain's (2002) "criteria based table model" (p. 211) and the practice of defining scenarios that are to occur within the architecture, as demonstrated by Goedicke and Zdun (2002) and Dobrica and Niemelä (2002).

Major architectural options were identified and each assessed in terms of a number of criteria. It should be noted that the architectural options are not, in general, mutually exclusive, and assessment on criteria is qualitative. The purpose of the resulting option-×-criteria grid is to inform the synthesis of candidate designs, not to support a mechanistic choice of a single option. Each cell of the grid should be populated with an explanation of the qualitative judgement and possibly include a number of unresolved issues. This procedure is iterative. Review of the option-×-criteria grid can result in options being dismissed, merged, or split.

Criteria

The decision criteria group was separated into what classically is called "functional" and "'non-functional" requirements, although we prefer to designate the criteria groups as *case-specific* and *generic*. One case-specific criterion is identified for each major system interfacing scenario. In the current setting, these scenarios are:

1. distributing and synchronizing patient data (around the podiatry clinic);
2. ability to transfer decision support logic (from the podiatry server to handheld PCs); and
3. ability to transfer profiling information (to focus consumer diabetes education, moving data between the podiatry clinic and Web-based consumer education setting).

The generic criteria are fairly standard aspects of systems integrity, but many take on a degree of specific meaning in the health computing context:

- Security—acceptable handling of patient data (notably HIPAA compliance in the United States, although not in demonstration context);
- Performance—chiefly latency, and also reliability;
- Maintainability—outlook for the long-term feasibility of the solution in terms of a continuing user community and availability of technical staff for maintenance;
- Maturity/vailability—presence of standards (de facto or otherwise) to provide stability and practicality of acquisition;
- Flexibility—supporting explicitly expected changes and reasonable estimation of long-term change (A special bonus is if one technology is flexible enough to encompass multiple requirements of the system, making the system simpler overall.); and
- Feasibility—to further diffuse "tick-box" thinking, a summative assessment that the technology is actually practical and can fulfil the requirements in question.

RESULTS

Technology Assessment Decisions

Initial brainstorming in the development team (authors Darren Woollatt, Jim Warren, and Paul Koop) revealed seven options for further exploration from among a diverse range of health-specific initiatives, relatively modern generic solutions, and solutions of historical interest for comparison. Probably the least generally well-known option under consideration was iROS (Open Source Technology Group, 2006), which had a track record of use for enabling "interactive rooms" through a messaging service and was familiar to the authors. An abbreviated first-cut option-×-criteria grid is shown in Figure 2. The full grid, as used by the development team, occupies a color A3 sheet in 10-point type with 40 footnotes on ancillary pages.

With respect to the first scenario, remote method invocation (RMI) and iROS emerged as strong options based on transfer of serialized objects. Simple object access protocol (SOAP) (W3C, 2004) also had promise. It also had an edge in extensibility, if serialized objects were not used, but required use of XML, which seemed like it might be a performance issue, especially on the client (handheld) side, where computing power for parsing a large XML payload is quite limited. All three options are capable of having XML components to the message, which could then support Health Level Seven (HL7)(2006) or OpenEHR (n.d.) as a further layer.

Performance analysis revealed that a "typical" patient review as a serialized object was 564kB in size and required about 14 seconds to transfer over our BlueTooth connection from the client to server using iROS. However, application of a compression routine from the Sun Microsystems Java Development Kit JDK reduced this to 14.5kB and brought the transfer time (with the negligible compression time included) down to an acceptable 0.85 seconds. iROS was compared to SOAP and found to be about 2.5 times faster for the same test object. Encryption of several sensitive fields (again using a JDK routine) also was included with no observable performance impact, yielding an overall acceptable solution to scenario 1.

Figure 2. Abbreviated option—criteria grid for middleware architecture technology choices

Criterion	HL7	openEHR	iROS	SOAP	CORBA	DCOM	RMI
Scenario 1	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Scenario 2	Yes, Arden	N/A	1, 2	1, 2	1	1	1
Scenario 3	Yes	Yes	Yes	Yes	Yes	3	Yes
Security	Add on	Add on	Add on	Add on	Built in	Built in	Built in
Performance	4	4	4	4	4, well-studied	4, well-studied	4
Maintainability	5	5	OK	Good	OK	3	Good, part of JDK
Maturity/ availability	5, 6	5, 6	6	6	6	3	6
Flexibility	Suits purpose	Suitable for scenario 1 and 3	Very flexible	General	General	General	General
Feasibility	7	7	Good	Good	8	3	Good

[1] *Can transfer guideline representation for interpretation on client*
[2] *Can serialize object with decision logic for execution on client*
[3] *Operating system and language limitations of DCOM (or .NET) are a concern; current Diabetes Consumer Education Service is on Linux*
[4] *A concern for Scenario 1—must be measured in context*
[5] *Steep learning curve and technology is rapidly changing, although adherence to a standard is a plus.*
[6] *Open with freely available implementations and user communities; somewhat more restricted to members for HL7. iROS community rather small but deemed adequate*
[7] *HL7 v3 requires process using RIM to create new messages for our highly specialized application; somewhat better supported and more approachable process using openEHR archetypes*
[8] *Possible, but over-spec to needs in absence of multilanguage and legacy system integration motivators of CORBA*

Layering of HL7 or openEHR was not pursued in this scenario, due to performance concerns, availability issues that parallel scenario 2 and 3 as discussed below, and minimal perceived relevance for a system as tightly coupled as the podiatry server and handheld client. The iROS solution was chosen over an RMI solution largely due to developer familiarity.

With respect to scenario 2, SOAP emerges as particularly promising for invocation of decision support methods on the server from the handheld devices. However, a significant constraint in this scenario is that the users may wander outside of BlueTooth range at the time when decision support alert logic must be checked. (This is done interactively in the consulting rooms, whereas scenario 1— completion of the previous patient and start of the next—is done in close physical proximity to Clinic reception desk and the server.) As such, we are restricted to methods that actually transfer the decision support *logic* to the client at some time between user login and start of processing on the first patient of the user session.

One promising option for transfer of decision support logic was to use a representation scheme, such as the Arden syntax (Jenders, 2006) of HL7. However, this requires the client to interpret logic statements in a high-level specification language, raising issues around performance, as well as the question of availability of such an interpreter to run on a handheld PC. Given the difficulties of an interpreted logic solution, the technology choice taken was to write the decision logic in Java such that all decision alerts shared a common Java interface. Central update of decision logic is achieved by redirecting the handheld client's class loader to the server (see Figure 4), exploiting the compactness of a Java archive (JAR) file to move the logic as Java byte code.

In scenario 3, SOAP wins out. While the podiatry server and Diabetes Consumer Education Service currently reside on a common university intranet, the probability of the clinic and Web-education services becoming more widely distributed is high, and hence the ability of the SOAP protocol to cross organizational firewalls provides maximum maintainability of the solution.

The case is strong for layering either HL7 or openEHR onto the SOAP message that transfers the patient profile (observations collected in the podiatry clinic of relevance to diabetes education; some 40 data items in the current data sets). The application fits well with the model of either an HL7 message or an openEHR EHR extract. At the time of implementation, however, neither HL7 v3 nor openEHR were offering a convenient Java toolkit; this situation is changing rapidly (see the Future Research section). The medium-term solution implemented was to provide the profile as an XML payload, but to leave the reconciliation of that payload to the HL7 RIM or an openEHR archetype for future extension of the system. W3C standards of XML signatures (Eastlake & Reagle, 2006) and XML encryption (Reagle, 2006) are applied to meet the security requirements of scenario 3.

Resulting System

With the technology assessment decisions taken as per above, the result is a close coupling of the podiatry server to the PDA clients (handheld PCs) and a looser coupling of the podiatry clinic (through the podiatry server) to the Diabetes Consumer Education Service. The PDA clients communicate to the server over BlueTooth. A sequence of iROS messages, as illustrated in Figure 3, keeps the client up-to-date with the available patients in the waiting room (tracked via a Microsoft .NET application local to the podiatry server) and transfers patient data prereview and postreview. The PDA client implements a common user interface for decision support alerts, the decision logic, which is loaded from the podiatry server when a user logs onto the podiatry application on the PDA (as per Figure 4).

At the end of the podiatry review for patients with diabetes, the PDA client prompts the user to

Figure 3. Sequence diagram for podiatry application client/server interaction

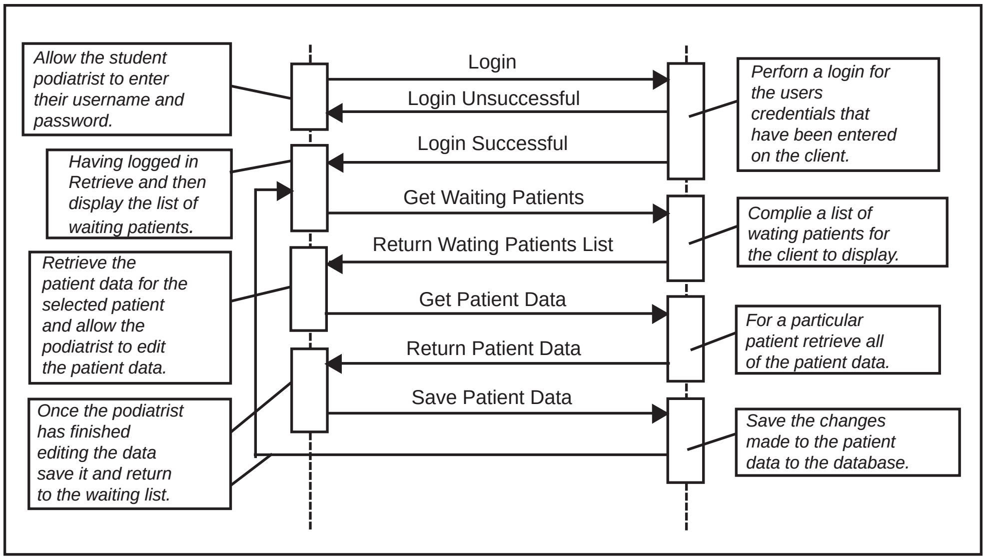
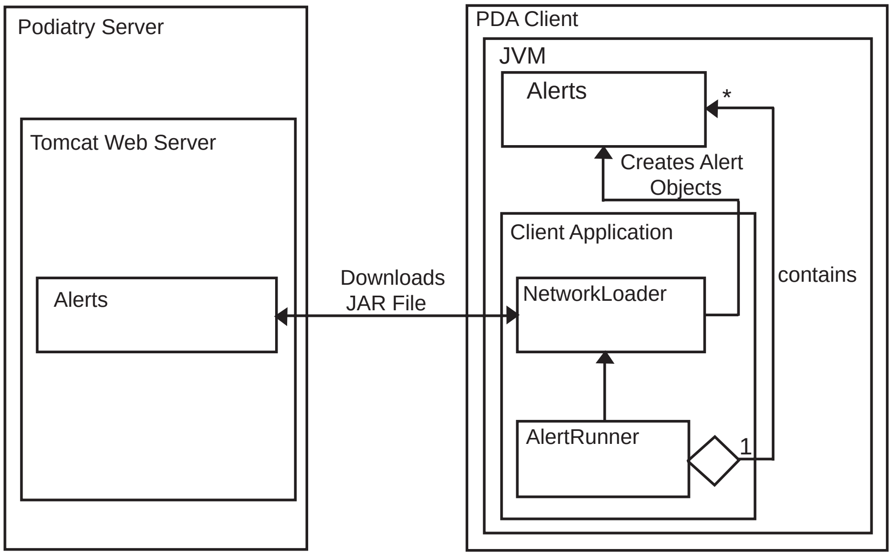


Figure 4. Architecture for updating client decision support logic



ask whether the patient would like access to the Consumer Diabetes Education Service. When the podiatry server receives the message to update the patient database and sees the request for an education service account, a SOAP request is issued for an account to be created on the consumer portal. Upon receiving the SOAP result, the server prints a hardcopy invitation letter for the patient with login information, including their specific username and password as provided by the Consumer Diabetes Education Service. Upon login to the portal, the consumer is prompted for consent for the transfer of information from the podiatry clinic, at which time a getProfile method is invoked from the education service to the podiatry server, causing clinical data to be extracted from the patient's podiatry reviews. This data is composed into an XML snippet by the podiatry server and returned to the education service for parsing into its own consumer/patient profile database.

DISCUSSION

We have reached an age that is ripe for innovation in handheld and ubiquitous information technology. It has never been easier to integrate applications across a range of platforms to achieve decentralized behavioral changes, such as improved chronic disease management. Specifically, growing acceptance of handheld computing in the health workplace, ubiquity of short-range radio communications, and the advent of Web services standards are making it feasible and inexpensive to field health data collection and decision support tools. Moreover, it is increasingly easy to "tack on" new avenues for the exploitation of existing functionality (taking an existing application and putting it on the Web, adding a mobile portal, mounting it as a Web Service for other applications, etc.). And many of these integration solutions are well packaged for programmers using common development environments, such as JDK and Microsoft .NET.

The range of available technology choices presents in itself a challenge. An open-minded, explicit and semistructured (but not overstructured) process of technology evaluation is warranted. Mandating a technology choice will cull potential opportunities by making them infeasible for the present, where a more flexible policy could allow them. The process of technology choice must be iterative to take into account discoveries from prototyping and field test experience, even if these emerge uncomfortably late in the project schedule (better late, or even cancelled, than an on-time, on-budget failure). Choices must be scenario based, not just generic criteria based, as subtly different constraints can make major differences in the feasibility or acceptability or particular technology choices.

Performance is a particularly sensitive issue in that technologies can yield surprisingly high latencies and surprising variances in performance among technologies and their implementations, latencies that can render a solution unusable under field conditions. This problem is acute with low-powered mobile devices, especially when using advanced solutions recently ported from mainstream computer systems. While performance of mobile devices will continue to improve, one can expect it to continue to lag the performance of nonmobile counterparts.

The issues of choice are well illustrated in our experiences with middleware architecture. A show stopper emerged on the issue of disconnected operation (for access to decision support alert methods), removing all choices based on remote method invocation from one of our scenarios. Latency was a strong issue in another scenario, driving a technology choice (and also requiring a well positioned use of compression). In addition, we placed a high value on programmer experience and toolkit availability to go ahead with what was known and involved a short learning curve. We found that very different middleware architecture technology choices came through as appropriate for each of our three major system interfacing scenarios.

Many (if not most) experienced developers will disagree with our specific choices. We fully admit to our own biases, idiosyncratic experience levels, and valuation of the features and limitations of certain options. The important message is not in our choices, but the process of choice and acknowledgment of the diversity of outcomes, even within the same development group, in differing scenarios with differing constraints.

An interesting feature of our solutions for the reported development cycle is that we did not use some of the obvious health-specific technology standards. However, we left room for their adoption in the near future.

FUTURE DIRECTIONS

We may be poised for a time where the easy uptake of health informatics standards begins to parallel their mainstream counterparts, such as SOAP and other XML-based methods. The HL7 Java SIG API (Hendler & Schadow, n.d.) indicates the emergence of appropriately usable mechanisms to integrate HL7 with ubiquitous computing applications, such as the one described in this article. In a case, such as integrating the podiatry clinic with a Consumer Diabetes Education Service, this API should prove an excellent fit. Similarly, recent release of the openEHR specification project release 1.0 (OpenEHR, n.d.) should promote further development of Java APIs on this paradigm. Proposal for a Java Compiler for GELLO,an object-oriented query expression language,(Index of /hl7/arden/2005-05-AMS, n.d.) is also timely. As per our decision support scenario, allowing use of the ubiquitous JVM as the decision support interpreter, rather than needing to port (and get adequate performance from) a high-level guideline expression interpreter, is an excellent solution where system capacity and performance are issues.

A question remains as to whether performance of new health informatics packages will be acceptable for use on small devices, including PDAs. We can expect that these devices will remain dependent on application-specific coupling to servers for many scenarios, where more than a few fields of patient data must be exchanged or where the devices must sometimes operate in disconnected mode.

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Chapter 3.16

Mobile Technologies in the New Zealand Real-Estate Industry

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ABSTRACT

The Real Estate industry can be viewed as a prime candidate for using mobile data solutions since it possesses a dispersed workforce as well as intensive and complex information requirements. This paper investigates the perceived value of mobile technologies in the New Zealand Real-Estate industry. It was found that mobile technologies are perceived as a strategic element in the Real-Estate industry. However, the use of data services still is bounded by industry practices and voice remains the most used application among agents. [Article copies are available for purchase from InfoSci-on-Demand.com]

INTRODUCTION

Mobile Business-to-Employee (B2E) applications have the potential to improve business processes and transform entire industries (Scornavacca et al., 2006b, Basole, 2005, Barnes et al., 2006, Wigand et al., 2001, Scornavacca et al., 2006a). A particular industry that is well suited to gain from the potential benefits of mobile technologies is the Real-Estate industry – since it possesses intensive information requirements as well as a distributed workforce (Basole, 2005, Wigand et al., 2001, Crowston et al., 2001, Sun et al., 2006). It is important to understand and to identify the strategic role that mobile technologies can actually play in this industry (Scornavacca et al., 2006a).

The aim of this paper is to investigate the perceived strategic value of mobile technologies in the New Zealand Real-Estate industry. Through multiple qualitative case study method, six participants from distinct organizations participated in this research - four of them representing Real-Estate agencies, one representing the industry association, and one representing a telecommunication provider. New Zealand offers an excellent opportunity for study as it has a booming house market and enjoys almost total cellular coverage from two different network providers (Barnes et al., 2006, Scornavacca and McKenzie, 2007, Scornavacca et al., 2006b). In addition, the country has a very high mobile phone penetration – with a population of 4 million people, there are over 3.8 million active mobile phones in the country (Geekzone, 2007).

The remainder of the paper is structured as follows. The following section will present a brief review of relevant literature. This will be followed by an explanation of the research methodology applied—multiple case study. The results of the research are then provided, along with an analysis. The paper concludes with a discussion of the key research findings, limitations, and suggestions for further research and practice.

M-BUSINESS AND THE NZ REAL-ESTATE INDUSTRY

M-business can be understood as the use of mobile information technologies enabling organizational communication, coordination and management of the firm (Walker et al., 2006, Barnes, 2002). Analysing the value chain, Barnes (2002) identified that connectivity, interactivity, flexibility, location and ubiquity are key characteristics of m–business that define its uniqueness and potential. Furthermore, Folinas et al. (2002) as well as Siau and Shen (2003) identified some additional characteristics of m-business such as personalisation, time sensitivity and reachability.

The current literature is concerned with mobile interactions that are dominantly embedded within the Business-to-Consumer (B2C) relationships (Scornavacca et al., 2006a, Varshney and Vetter, 2000, Siau and Shen, 2003). However, there has been an increasing shift of focus onto the importance and potential of B2E applications (Basole, 2005, Berger et al., 2002, Leem et al., 2004, Oliva, 2002, Scornavacca et al., 2006a, Folinas et al., 2002).

Mobile B2E applications have the greatest value to employees that are constantly working remotely from their base of operations and need the support of information and communications technologies (ICT) in order to accomplish their specific business tasks in real-time. Employees must be able to update and retrieve information seamlessly (Basole, 2005, Barnes et al., 2006, Oliva, 2002, Walker et al., 2006).

Mobile B2E is known to provide a number of benefits to organizations (Scornavacca et al., 2006b, Basole, 2005, Barnes et al., 2006, Walker et al., 2006). Previous studies examining the impact of mobile B2E applications in New Zealand observed an overall improvement on individual and organizational performance generated by the enhancement of information accuracy and flow (Barnes et al., 2006, Walker et al., 2006). However, these authors also found that the development of mobile solutions has been limited to the improvement of existing processes, and is quite dependent on the performance of mobile networks and bandwidth availability.

The Real-Estate industry plays a significant role in a country's economy (Seiler et al., 2001). Traditionally, the industry has made its contributions through the ability of handling and transferring Estate specific knowledge and information (Crowston et al., 2001). This traditional model is being challenged by the threat of disintermediation, brought on by the emergence of new technologies, like the Internet. As a result, the focus has shifted from sole information handling to providing value adding services in coordination with information transfers (Muhanna and Wolf, 2002).

METHODOLOGY

The purpose of this study is to gain insight into the strategic value of emerging mobile technologies in the New Zealand Real-Estate industry. The study follows multiple qualitative case study method (Benbasat et al., 1987, Creswell, 2003). The selection of case research as the research method is appropriate since this study investigates an area where theories are at formative stages and little research has been completed up to date. In addition, case study is particularly useful in this instance since practice-based problems and emerging technologies are the focus of the investigation (Benbasat et al., 1987, Orlikowski and Baroudi, 1991, Yin, 1994).

Participants were selected through a convenience sampling strategy (Paré, 2004). In order to capture different perspectives within the Real-Estate industry, a total of six participants from distinct organizations were selected for this study: four of them representing Real-Estate agents and agencies, one representing the industry association, and one representing a telecommunication provider.

Participant 1 is a resource manager of the Real-Estate Institute of New Zealand. Some of her responsibilities include promoting the industry, providing expert advice and support to institute members. Due to her role at the Institute she is able to provide a valuable and broad view of industry in regards to the elements investigated in this research.

Participant 2 is a mobile solutions specialist at a leading New Zealand telecommunications provider. While representing one of the technology providers, she is also able to relate to specific issues of the Real-Este industry - she is responsible for the nationwide corporate account a major Real-Estate company in New Zealand.

Participants 3, 4, 5 and 6 split their time as Real-Estate agents and branch managers of four Real-Estate agencies located in three major NZ cities. They provide valuable insights from the front-line since they still work as agents while being responsible for running the local branch as well as managing the sales people.

A interview protocol was developed and validated (Benbasat et al., 1987, Creswell, 2003). The final protocol contained twenty-five open ended questions which aimed to:

- Gain an understanding of the background of the interviewee
- Gain an understanding of the organization that she/he represents
- Identify mobile applications currently in use in the organization and industry
- Identify key benefits and inhibitors for mobile applications at an individual and organizational levels
- Explore the perceived impact of mobile technologies in the Real-Estate industry
- Identify suitability of advanced mobile applications
- Explore the perception of the future of mobile application in the Real-Estate industry

The data collection was carried out primarily through semi-structured interviews. Each interview lasted between 40 minutes and 50 minutes. The interviews were recorded on audiotape and supplementary field notes were made during the interviews. Some supplementary data was collected through supporting documents volunteered by the interview participants. The content of the interviews were transcribed and the data analysis was carried out using a matrix (Creswell, 2003, Miles and Huberman, 1994).

RESULTS

In this section, the results are presented. Initially, the perceptions regarding the business benefits and challenges at the organizational/industry level are explored. This is followed by an analysis of the current and potential benefits of mobile technologies at the individual level (agent). Finally, the Mobile Enterprise Model (Barnes, 2003) is used in order to examine the strategic value of mobile technology in the Real-Estate industry.

Business Benefits and Challenges

The results indicate that the device of choice in the NZ Real-Estate industry is the standard mobile phone, which is mostly used for voice communications and occasionally to send and receive short-messages (SMS). The use of smart phones and internet enabled PDAs still is moderate despite its potential usefulness for a number of routine tasks accomplished the agents (e.g. scheduling and accessing information).

Despite the low use of data applications, the interviewees indicated that mobile technologies are allowing agents to better meet information requirements in the selling process as well as information demands of clients.

The core perceived business benefits generated by mobile applications that emerged in the interviews are illustrated in Table 1. Each perceived business benefit is further classified accordingly to its predominant effect at the strategic or operational level.

Overall, the main benefit being provided by the use of mobile technologies refers to the enhancement of the information flow in the organization which is a critical success factor in this type of business.

Taken as a whole, industry representatives and branch managers' perceptions are mostly similar in regards to the use of mobile applications – focusing on the ability to connect stakeholders. However, participants 1 and 2 had more positive views regarding the strategic value of mobile technologies. They (1 and 2) highlighted strategic benefits such as allowing organisations to nurture their market share and enabling new services in order to gain a competitive edge.

Table 1. Key business benefits

Benefits	Strategic/ Operational	
Expanding market share	X	
Improved customer service		X
Information flow	X	X
Streamlining business processes	X	
Efficiency		X

All participants shared similar views regarding the main challenges holding the full deployment of mobile applications within the industry. The following issues were identified:

- **Development of Value Adding Mobile Applications and Partnerships –** There is a clear need for applications that are easy to use and closely tied to business processes as well as focused on core business functions. Identifying suitable hardware, software and application areas that suit industry specific needs are currently some of the major challenges for the full deployment of mobile technologies in the Real-Estate industry. Although having a strong understanding of the capabilities of their own products and services, software developers as well as telecommunications providers seem to have a limited knowledge of the Real-Estate industry and how to leverage their offerings to that industry. Perhaps partnerships among key-players at the industry level could enable specific applications to be developed and supported throughout the value-chain. Such initiative could perhaps change the current perception of one of the branch managers interviewed:

> *Technology can prove as a great source of procrastination, it actually distracts salespeople from what they should do. You sit around playing with gadgets that don't particularly streamline your business.*

- **Costs:** The costs associated with utilising mobile technologies have high implications at the organisational level. One of the branch managers said:

Calls are huge cost to us, our telecommunications bill is huge, and you could say it's a cost of business, but unfortunately at the moment, it is a big cost to our business.

It was noticed that perceptions regarding the cost of mobile technologies can certainly hinder an organisation's desire to explore further solutions in this arena. In addition, investments in technology were commonly seen as a risk.

- **Network Connectivity:** The majority of participants interviewed expressed some concerns regarding network connectivity. One of the branch managers pointed out:

We've got a person in the office who was on the "X" network. She lives in a suburb with poor coverage from "X". As result she's just flicked to the competitors' network…". Participant 2 reinforced this notion by saying: "People seem to want coverage in every single lift there is, and wherever their car happens to be….

Individual Benefits and Challenges

Results have shown that mobile applications are adding value to the day-to-day business of agents. Improving communication, information access as well as enabling them to address time sensitive issues. Overall, the use of mobile technologies is perceived as a factor to increase individuals' productivity.

The perceived key benefits of mobile technologies to agents are listed in Table 2. It was also identified which benefits are perceived as already in place and which of them are mostly seen as "potential benefits".

The mobile nature of Real-Estate agents means that a large proportion of their time is spent away from the office. Agents can easily lose touch with the occurrences at the office, leading to a lag of communicating critical information. One of the managers highlighted:

Table 2. Key individual benefits

Benefits	Current	Potential
Reachablility	X	
Data access		X
Image	X	
Information accuracy		X
Improved communications	X	
Improved customer service	X	
Increased productivity	X	
Personalisation of services		X
Improving business processes	X	

in this game you need to be ready to run, a phone call could be worth $10000 to you.

Undoubtedly, the interviewees noted that the advent of mobile technologies has meant that agents are able to leave the office, while retaining a level of contact with the organization as well as key stakeholders (buyer and vendors). Even though the use of mobile technologies is perceived as currently enabling core benefits to the agents, it is still mostly seem as an area "full of potential" for further developments.

The participants have identified the following challenges to be overcome in order to have a wider adoption of mobile data services by individuals operating in the Real-Estate industry.

- **Perceived Cost/benefit:** For an agent, the costs are mostly associated with the purchase of hardware and network connection. The participants shared the opinion that mobile technologies are simply seen as a part of business expenses instead of a strategic factor of competitiveness. The opinions regarding costs are commonly associated to frustration and decisions to adopt a certain technology are usually made on the basis of the lowest cost instead of best cost/benefit ratio.

- **Training**: it was identified that the majority of sales consultants have not come from a technical background and many of them may require one-on-one assistance in overcoming the learning curve for utilizing the new technologies. A manager indicated:

We've got a reasonably aging population in sales consultants, so technology is something that they're trying to embrace and it's not something that is obviously natural to them.

If appropriate training was not undertaken by the agents, mobile applications were deemed to be underutilized – or not used at all.

- **Usability:** Display size and input methods were the main challenge identified by the interviewees in regarding the usability of mobile technologies.
- **Traditions of the Real-Estate industry:** There is a strong focus in the industry to foster relationships and development of social networks, and closing sales face-to-face. A participant pointed out "

real-Estate doesn't happen on the computer or on the phone. You have to get in people's faces.

Another manager said:

I've sold real Estate for a number of years and I don't sell anymore now than I did 15, 16 years ago and I didn't have all the bells and whistles then.

Although there was an agreement that mobile technologies can enhance business processes, there was still a strong belief that the 'qualities of a salesperson' cannot be changed or assisted effectively through the utilisation of mobile technologies.

The potential widespread adoption of mobile technologies in the Real-Estate industry relies mostly in the hands of the agents - as a branch manager commented:

We (agency) don't typically impose anything on our staff when it comes to technology, they'd either see that it is meaningful and useful, or they won't use it. If you impose it on them, and they don't see any value in it - they won't use it anyway.

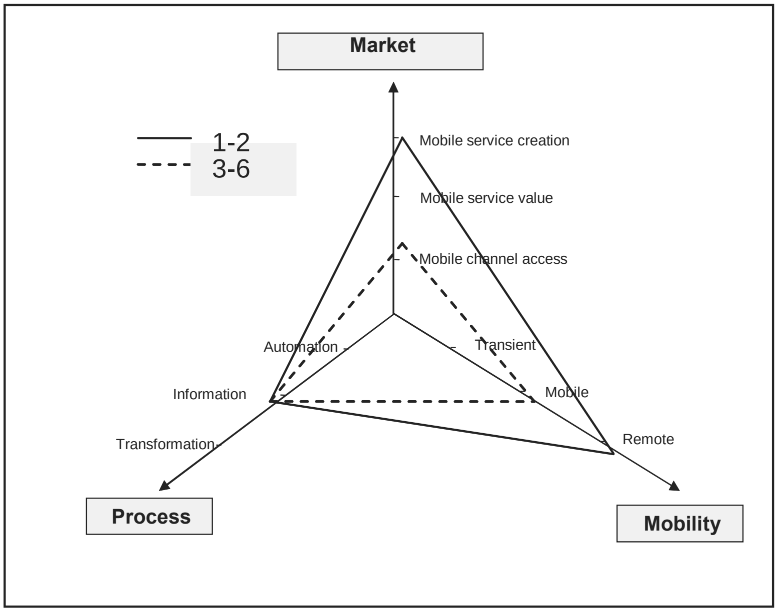
Enterprise Mobility

Based on the previous analysis of business benefits and challenges the mobile enterprise model (MEM) (Barnes, 2003) can be used to identify the strategic value of mobile applications. The MEM achieves this by mapping businesses against three axes: mobility, process, and market (Figure 1).

Mobility measures the location dependence of workers, including transient (tied to specified locations), mobile (increased independence with periodic location specific needs), and remote (almost completely independent from a specified location). From the perspectives of Participant 1 and 2, the level of geographic dependence for the agents are extremely low and salespeople have the ability to be almost completely removed and independent from the office. Mobile technologies can provide agents with remote linkages into corporate information systems allowing higher degrees of freedom from the office. From the branch manager perspective, mobile technologies are allowing salespeople to have geographic independence for prolonged periods of time - however there is still a need of "a base of operations" for a number of business processes.

Process maps the business transformation as a result of the introduction of mobile technologies. It can be classified in three levels: automation, information and transformation. The NZ Real-Estate industry appears to have barely reached the "information level". Developments such as the use of mapping systems to enable remote

Figure 1. Mobile enterprise model



agents to access and display properties images as location could certainly support the existing processes and improve service delivery.

Market maps the value propositions, starting with mobile channel access (use as a channel for information access), mobile service value (adding value to market offerings) and finishing with mobile service creation (use of entirely new offerings). Participants 1 and 2 see the potential for m-applications to allow for mobile service creation, using mobile applications to create entirely new services. However, participant 1 felt that such development may be not valued by agents. The branch managers focused on mobile channel access. However, they expressed some indication of the value that new mobile services may have to their business and to gains of competitiveness. The differences in perspectives of enterprise mobility are illustrated above in Figure 1. Participants 1 and 2 are represented by the solid line while participants 3-6 are indicated by the dashed line. It is clear from the illustrations that participants 1 and 2 have a more positive perception of the strategic value of mobile technologies.

CONCLUSION

The distributed nature of the work of Real-Estate agents as well as the intensive use of time sensitive information makes this industry a primary candidate for the deployment of mobile technologies. This study aimed to investigate the perceptions of key-industry players towards the strategic value of mobile technologies in the Real-Estate industry in New Zealand.

The participation of six organizations representing Real-Estate agencies as well as the industry association and one of the main telecommunications providers allowed us to capture different views and realities regarding the applications of mobile technologies in this industry.

This study was able to identify current and potential benefits that mobile technologies may provide to this industry. In addition it was also able to identify the current challenges that inhibit a wider uptake of these technologies.

It was found that despite the wide availability in NZ of advanced mobile technologies such as laptops with wireless capabilities, PDAs' and smart-phones, most agents are only using standard mobile phones for voice communications.

The prevailing perceived business benefits derived almost exclusively from the ability to access the mobile channel, aiming for efficiency gains and improving customer service. However, there were challenges such as cost, network coverage, the identification and development of industry specific mobile application as well as nurturing partnerships across the industry value chain.

At the individual level, perceived benefits surrounded the ability to be constantly able to reach and to be reached by other parties involved in the sales process. Cost, training and tradition of business practices appeared as barriers for the adoption of mobile data services.

The perceptions captured in this research indicate that there was a consensus among participants that mobile technologies play a vital role in the Real-Estate industry. However participants' opinions were quite divergent regarding to what extent there is room for further development.

Although there was agreement that mobile technologies can enhance business processes there was still a strong perception that the 'qualities of a salesperson' cannot be changed or assisted effectively through the utilisation of mobile technologies. Some perceptions indicate that many agents believed that relying too much on technology could be risky. In addition, there was a clear belief that the salesperson's role is about building networks and relationships with clients and associates. Therefore the perceived strategic value and enthusiasm for adopting mobile technologies could be diminished by long standing traditions and business practices of the Real-Estate industry.

Most of the technology adopted by the branches (and agents) was not guided by a strategic planning. As a manager commented they are adopted on a *"need to survive basis"*. This makes it evident that 'catching up' with technology is a common practice instead of outlining a strategy towards the adoption of new technology. Even for the more pro-active adopters there was a feeling of risk of being overwhelmed by technology.

Above all, this study provides an interesting initial point of discussion for the current literature in mobile business. Previous studies (Varshney et al., 2004, Beulen and Streng, 2002, Muhanna and Wolf, 2002, Yuan and Zhang, 2003, Barnes, 2002, Barnes, 2004, Kadyte, 2004, Tollefsen et al., 2004, Basole, 2005) suggest that an industry that has qualities such as intensive information requirements, distributed workforce as well as time sensitive processes would be a primary candidate for a successful deployment of mobile technologies. However, contrary to some of the literature, this study found that despite the fact that the New Zealand Real-Estate industry possesses the qualities abovementioned, a full deployment of mobile technologies is still bounded by its tradition of business practices.

The findings described in this research, while generalizable to its peculiar context, must be closely scrutinized in their application to other contexts. The research was conducted at a singular point in time and consisted of only one round of data collection with six participants. The results were drawn solely from the interviewees' perspectives and thoughts.

Future research should aim to widen the current scope of this research focusing on the individual level. A longitudinal study is also suggested in order to understand the sustainability of benefits and how they change over time. Research efforts could also explore the effect of mobile technologies on individuals' performance.

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Chapter 3.17

Group Support Systems as Tools for HR Decision Making

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INTRODUCTION

In the late 1960s, a new type of information system came about: model-oriented DSS or management decision systems. By the late 1970s, a number of researchers and companies had developed interactive information systems that used data and models to help managers analyze semistructured problems. These diverse systems were all called *decision support systems* (DSS). From those early days, it was recognized that DSS could be designed to support decision-makers at any level in an organization. DSS could support operations, financial management, and strategic decision making.

Group decision support systems (GDSS) which aim at increasing some of the benefits of collaboration and reducing the inherent losses are interactive information technology-based environments that support concerted and coordinated group efforts toward completion of joint tasks (Dennis, George, Jessup, Nunamaker, & Vogel, 1998). The term *group support systems* (GSS) was coined at the start of the 1990s to replace the term GDSS. The reason for this is that the role of collaborative computing was expanded to more than just supporting decision making (Patrick & Garrick, 2006). For the avoidance of any ambiguities, the latter term shall be used in the discussion throughout this article.

Human resources (HR) are rarely expected like other business functional areas to use synthesized data because HR groups have been primarily connected with transactional processing of getting data into the system and on record for reporting and historical purposes (Dudley, 2007). For them soft data do not win at the table; hard data do. Recently, many quantitative or qualitative techniques have been developed to support human resource management (HRM) activities, classified as management sciences/operations research, multiattribute utility theory, multicriteria decision making, ad hoc approaches, and human resource information systems (HRIS) (Byun, 2003). More importantly, HRIS can include the three systems of expert systems (ES), decision support systems (DSS), and executive information systems (EIS) in addition to transaction processing systems (TPS) and management information systems (MIS) which are conventionally accepted as an HRIS. As decision support systems, GSS are able to facilitate HR groups to gauge users' opinions, readiness, satisfaction, and so forth, increase their HRM activity quality, and generate better group collaborations and decision makings with current or planned HRIS services. Consequently, GSS can help HR professionals exploit and make intelligent use of soft data and act tough in their decision-making process.

BACKGROUND

In the early 1980s, academic researchers developed a new category of software to support group decision making. Execucom Systems developed Mindsight, the University of Arizona developed GroupSystems, and researchers at the University of Minnesota developed the SAMM system (Power, 2003). These are all examples of early group support systems. "A Group Support System could be any combination of hardware and software that enhances group work. GSS is a generic term that includes all forms of collaborative computing" (Turban, Aronson, & Liang, 2005, p. 374). The increased need for GSS arises from the fact that decision making is often a group phenomenon, and therefore computer support for communication and the integration of multiple inputs in decision support systems is required. The desire to use GSS therefore comes from the need of technological support for groups.

GSS are designed to remedy the dysfunctional properties of decision-making groups, such as groupthink, lack of coordination, information overload, concentration block, and so forth. These systems are becoming popular in aiding decision making in many organizational settings by combining the computer, communication, and decision technologies to improve the decision-making process. These systems use a key tool to improve the quality of decisions made by a group. This key tool is the anonymity of members of a decision-making group. The purpose of GSS is to maximize the benefits of group work while minimizing the dysfunctions of group work. This maximization and minimization can be made possible by GSS mainly by two factors: anonymity and parallelism.

MAIN FOCUS

Strengths and Weaknesses of GSS

GSS provide support for communication, deliberation, and information flow especially for group activities that may be distributed geographically and temporarily. Group work has numerous benefits and advantages. First, groups are better at understanding problems and catching errors than individuals (Korpela, Sierila, & Tuorninen, 2001; Kwok & Khalifa, 1998). Second, a group has more information than any one member which when combined can create new knowledge. Third, working in a group stimulates creativity and synergy. Finally, groups balance out the risk-tolerant and risk-averse. GSS offer many benefits. First, GSS support parallel information processing, parallel computer discussion, and generation of ideas. Second, they promote anonymity, which allows shy people to contribute and helps prevent aggressive individuals from driving the meeting. Finally, these systems help keep the group on track and show the big picture. The two keywords here are parallelism and anonymity (Turban et al., 2005).

Some of the potential dysfunctions of group work are not automatically eliminated by GSS: first, groupthink, as suggested above, where people begin to think alike and not tolerate new ideas; second, lack of coordination, excess time consumption, poor quality solutions, and non-productive time; third, duplication of efforts and high cost of meetings, including travel; and finally, information overload, concentration blocking (disturbance from inappropriate influences, free-riding discussions), and group misrepresentation (improper or badly chosen groups) can be added as the potential dysfunctions of group work. Process dysfunctions are caused by structural characteristics of the group setting that could hinder a group from reaching its full potential. Process dysfunctions hinder productivity because of unequal participation or unequal air time. This happens in a setting where only one person can take control of the floor. This sort of dysfunction can be countered by the use of computerized exchanges because people may enter their comments and thoughts simultaneously. Power (2003) utters that simultaneous expression of ideas may be beneficial to the quantity of ideas generated. This is because computers have the capacity for concurrency. Finally, process dysfunctions are usually caused by limitations in the structure and forms of meetings.

Social dysfunctions, as Power (2003) describes, can hinder group productivity through undesirable social processes that occur in the group. Social processes refer to those activities, actions, and operations that involve the interaction between people (De Millo, Lipton, & Perlis, 1979; NASA, 1996). For example, a group may limit the quality and quantity of input from any of its members by social processes such as evaluation apprehension, conformity pressures, free riding, social loafing, cognitive inertia, socializing, and domination due to status imbalance, groupthink, and incomplete analysis. These problems arise from processes present in all groups and are rooted in the ways in which group members change their behavior to adapt to the group. Finally, the prevalent analysis of group decision making is that social influences within the group lead the rational individual astray.

The view of GSS portrayed by Power (2003) is that they are text-based tools made with the purpose of remedying some problems of decision making in copresent groups. These systems claim to remove the social obstacles that prevent individuals from attaining their full potential in the group. Anonymity is central to achieving this full potential of individuals in a group. Shy people tend not to speak in a group discussion face-to-face. This hinders them from contributing to the group. GSS solve this problem by allowing these individuals to evade their shyness in the public and input their contributions through individual human computer interaction devices, thus achieving the goal of removing this social obstacle from these individuals and facilitating them to reach their full potential in the group. Meanwhile, the systems help prevent aggressive individuals in the group from driving the meeting, which is typically a potentially intimidating source to the shy people in a group.

Recent GSS Research Findings

Decision making in an organization today has become more the work of some form of group. Whether this group is a board, team, or a unit, important issues can be at stake. It is fair to ask, given the possible problems that occur in a group setting: Would the group setting have a negative effect on the quality of decisions that have to be made by the group? Current research in this area suggests that GSS, if implemented and used correctly, can improve the quality of group decision making significantly by minimizing the negative effects of group decision making and by maximizing the benefits of group collaboration and decision making. GSS have come a long way since their inception. Current and previous research efforts have made significant findings on the effects of the numerous criteria that affect the decision-making process in a group setting while using GSS. The results show that while the Internet has made it easier and less costly to use GSS than ever before, the social effects of group decision making can have a significant effect on the quality of decisions made in a group setting using GSS. By manipulating things such as visual cues, group vs. individual-based incentives, anonymity, group size, feedback, leadership role, communication mode, type of tool used, social presence (degree of personal connection in communication settings) (IJsselsteijn, 2003; Markopoulos et al., 2003; Nowak, 2001), face-to-face vs. distant, shift work or nonshift work, the fit between facilitation style and agenda structure, and finally, a relationship vs. a task focus, it is possible to significantly impact the quality of decisions made by a group using GSS.

According to Barkhi, Jacob, and Pirkul (2004), GSS are divided into two groups: distributed GDSS (DGDSS) and face-to-face GDSS (FGDSS). DGDSS groups consist of members who use GSS at the same time but at different places. On the other hand, FGDSS groups consist of members who use GSS at the same time and same place. The authors studied and compared the decision process and outcomes of groups that use FGDSS to those that use DGDSS. The results indicate communication mode and incentive structure can influence the effects of each other. Therefore, the appropriate design of incentive structures may be important to the success of virtual organizations.

The Web-based multicriteria group support system (MCGSS), according to Lu, Zhang, and Wu (2005) and Zahir and Dobing (2002), is designed so that users can enter their preferences in an easily understood and user-friendly interface through a Web browser. They state that easy-to-learn and user-friendly interfaces are essential if GSS are to become more commonly used in organizational decision-making and that MCGSS uses a new visual mode of preference entry. The relative importance of any two objects is expressed through a pair of side-by-side bars drawn in a graphical window. The ratio of the heights of two bars represents the user's relative preference for the two objects. Bar heights can be adjusted dynamically by dragging the mouse or utilizing some other device. Their article presents the design of a Web-based MCGSS that can be used by a group of geographically dispersed decision makers. This system takes advantage of Internet technology and enables a novel procedure to aggregate intensities of preferences.

In line with Kim (2006), the role of leadership facilitates group processes by adding structure to group interaction. The effects of leadership on group performance in GSS settings still remains one of the least studied areas of GSS research. An analysis of comments by group leaders show that they are more efficient when making comments on group objectives and interaction structure, but this is only true in the early stages of group interaction. In the later stages, it is of increasing importance that group leaders make comments that encourage interaction and maintain cohesion between members of the group. Dennis and Wixom (2001/2002) present a meta-analysis investigating five moderators. These moderators are as follows: tool, the type of group, task, the size of the group, and facilitation. The authors studied their effects on GSS. Results of the study draw multiple conclusions. First, process satisfaction is less for decision-making tasks than it is for the idea-generation tasks. Second, the GSS tool itself influences decision quality. Finally, the authors conclude that group size is an important moderator when it comes to measuring satisfaction with the process and decision time.

Rutkowski, Fairchild, and Rijsman (2004) demonstrate experimentally that in the context of dyadic conflict, patterns of interpersonal communication, supported by a particular group support system technology, affect the quality of decision making. The authors found that GSS are efficient tools that support intergroup communication and relations. The authors also delved further into this topic and discussed the implications of their research on the study of intercultural negotiation and conflict resolution. They observed that groups are becoming increasingly important in organizations and that intercultural negotiation and conflict resolution use electronic groupware to facilitate communication and workflow. Barkhi (2005) compared the performance and information exchange truthfulness of groups under these various experimental conditions. The author utilizes a game theory perspective to study the behavior of members in these groups. The results indicate that communication channel and incentive structure mitigate strategies that lead to decision choices and information exchange truthfulness among members in a group.

GSS can improve communication and learning as demonstrated by Bandy and Young (2002). Their study examined the impact of two collaborative technologies and a priming agent upon communication complexity and learning style in a group decision-making context. Their findings revealed that communication complexity was significantly greater in groups using GSS compared to groups using simple chat systems, suggesting that characteristics of the GSS served to structure discourse among group members. Burke (2001) examined how GSS learning environments (face-to-face vs. distant) and task difficulty level (simple vs. difficult) influenced participation levels and social presence among accounting students working collaboratively on an accounting task.

Hostager, Lester, Ready, and Bergmann (2003) examined the effects of agenda structure and facilitator style on participant satisfaction and output quality in meetings employing GSS. This study indicates that GSS facilitators should try to find a fit between their facilitation style and the agenda structure, while not forgetting to adopt either a relationship or a task focus and ensuring that they are consistent with their choice. GSS are designed as an analysis tool to support the decision processes of a group. Inherent in the design is the developer's desire to make the basic meeting process better either by increasing process gains or reducing process losses. Further, it is suggested by Martz and Sheperd (2003) that one way that GSS attack these losses is by providing immediate feedback.

GSS IN THE REAL WORLD

There are three options for setting up GSS technologies. One of them is in a special-purpose decision room, another is at a multiple-use facility, and the third is a Web-based groupware with clients running wherever the group members are.

Facilitating Meetings

One example of the use of GSS is the system developed by a group of researchers at the University of Arizona to facilitate the organization of meetings. A typical meeting room consisted of a microcomputer for each participant, as well as a large projector for the display of either individuals' work or the combined results of the group efforts. A typical meeting is composed of a three-tier process consisting of electronic brainstorming, idea generation, as well as voting. Under the electronic brainstorming phase, all group members typed at separate terminals using electronic brainstorming software, and recorded their ideas regarding questions posed for the day. Even though these sessions were anonymous, everyone could see the abundance of ideas. Additionally, an issue analyzer assisted the group in identifying and consolidating key ideas generated from the idea generation. Lastly, a voting tool provided various methods for prioritizing key terms. Here, even though voting is anonymous, the results are readily displayed for all to view. This group support system by Nunamaker, Briggs, Mittleman, Vogel, and Balthazard (1996/1997) was used at an IBM site. It was found that process structure helps focus the group on key issues and discourages irrelevant digressions and unproductive behaviors.

Web-Based GSS

A Web-based decision support system (DSS) is a DSS built with Web technologies so that the DSS users access with Web browsers through an Internet connection. In addition, Web-based DSS applications that are developed by companies may be deployed on company intranets to support internal business processes or can be integrated into public corporate Web sites to enhance services to trading partners (Power & Kaparti, 2002).

Most Web-based DSS are currently individual DSS systems (Bharati & Chaudhury, 2004). On the contrary, Web-based GSS provide a broader approach to solving complex problems that are less structured. As noted earlier, there are a few Web-based GSS and one of them, GroupSystems, is a local area network-based client-server that exists for online collaboration. Several commercially available Web-based GSS products also contain decision-making tools. These products provide support to the group decision-making process with tools that facilitate brainstorming, idea generation, organization, prioritization, and consensus development (Facilitate.com, 2006).

Distance Learning

Several courseware packages that have GSS functions facilitate distance learning. They range from such tools like Blackboard, through Microsoft NetMeeting, to PlaceWare Virtual Classroom. Distance learning, as a tool, can be an effective part of GSS. Many corporations have taken advantage of it mostly through Web-based streaming and other private company intranets. Distance learning, therefore, can act as a strong collaborative and knowledge management tool in GSS, with a distinctive feature, namely, being accessible every hour of the day.

GSS for Political Events

The multifaceted use of GSS is reflected in the dynamism inherent in organizational structures. For instance, political risk associated with corporations' decisions to expand internationally could be alleviated using GSS. This is because the key to analyzing political events is obtaining good information about these events. GSS thus provide higher reliability in accessing this needed information, through anonymity, simultaneity (may apply only to certain types of GSS), and documentation, features that are lacking in face-face interactions. Among other advantages, anonymity offers participants a greater degree of freedom in expressing their thoughts, and presents them with a greater sense of confidence to be more critical. Blanning and Reining (2005) suggest a two-characteristic framework depending on whether analysis of the event under consideration is static or dynamic, as well as whether the analysis is one-dimensional or multidimensional.

FUTURE TRENDS

GDSS is transforming into GSS and the same ideology used for enhancing group meetings is being used in other areas as well. The idea is not just to increase the effectiveness of decision making, but to incorporate the current improvements in communication technology to redefine collaboration. Anonymity is also becoming more and more widespread in this new Internet culture; its effects on collaboration are very interesting as discussed (e.g., allowing shy people to contribute and helping prevent aggressive individuals from driving the meeting). The findings presented in this article uncover the social effects that might affect group work. These findings can also be applied to other fields in which collaboration is experiencing growth as in education and social networking. By combing the Internet, emerging technologies, and the findings in social behavior as they relate to group work, with the exploding growth currently being experienced in communication, the results and the rate of introduction of new ways of collaborating will be absolutely amazing.

CONCLUSION

GSS, if implemented and used correctly, can improve the quality of group decision making significantly by minimizing the negative effects of group decision making and by maximizing the benefits of group collaboration and decision making. GSS have come a long way since their inception. Current and previous research efforts have made significant findings on the effects of the numerous criteria that affect the decision-making process in a group setting while using GSS. The results show that while the Internet has made it easier and less costly to use GSS than ever before, the social effects of group decision making can have a significant effect on the quality of decisions made in a group setting using GSS. By manipulating things such as visual cues, group vs. individual-based incentives, anonymity, group size, feedback, leadership role, communication mode, type of tools used, social presence, face-to-face vs. distant, shift work or nonshift work, the fit between facilitation style and agenda structure, and finally, a relationship vs. a task focus, it is possible to significantly improve the quality of decisions made by a HR group using GSS.

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KEY TERMS

Distributed Group Decision Support Systems (DGDSS): Groups consisting of members who use a GDSS at the same time but at different places.

Face-to-Face Group Decision Support Systems (FGDSS): Groups consisting of members who use a GDSS at the same time and same place.

Group Polarization: The tendency of people to become more alike or extreme in their thinking following group discussion. It is also the phenomenon that is generally considered decision bias.

Group Support Systems (GSS): Can also be referred to as group decision support systems (GDSS). GSS is any combination of hardware and software that enhances group work. GSS is a generic term that includes all forms of collaborative computing.

Multicriteria Group Support Systems (MCGSS): GSS designed so that users can enter their preferences in an easily understood and user-friendly interface through a Web browser. Multicriteria is a linguistic term oriented fuzzy group decision making method which allows the group members to express their power, favor, and judgment in linguistic terms. See Lu et al. (2005) for reference of the model.

Social Presence: The degree to which people establish warm and personal connection with each other in a communication setting. Changes in the level of social presence can affect group communication.

Time/Place Framework: A framework for classifying IT communication support technologies. The matrix consists of four possibilities: same time/same place systems, same time/different place systems, different time/different place systems, and different time/same place systems.

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Chapter 3.18

A Knowledge Integration Approach for Organizational Decision Support

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ABSTRACT

This study proposes a new methodology that facilitates organizational decision support through knowledge integration across organizational units. For this purpose, this study develops a decision support loop and explains how to organize individual knowledge related to a specific business problem and formulate and test the organized knowledge using cognitive modeling techniques for decision support. This study discusses the proposed approach in the context of an application case involving a beverage company. The application case shows the validity and usefulness of the proposed approach.

INTRODUCTION

Knowledge management (KM) can be defined as the uncovering and managing of various levels of knowledge within individuals and teams and within an organization. The aim of KM is to improve organizational performance. One of the prerequisites for successful KM is an appreciation of what Nonaka (1994) described as “tacit” knowledge. Effective KM requires such “tacit” knowledge to be transformed into “explicit” knowledge and then organized accordingly (Brown & Dugid, 1998). Integrating individual knowledge from diverse areas into organizational knowledge leads not only to new knowledge but also to new understanding (Cai, 2006; Huber, 1991; Siau 2000). This in turn helps decision makers choose the appropriate action to achieve organizational goals (Brown & Dugid, 1998; King, 2006; Stein, 1995).

However, competitive advantage results from applying knowledge, rather than knowledge itself (Alavi & Leidner, 2001). However, most KM research (Davenport, De Long, & Beers, 1998; Grover & Davenport, 2001; Kankanhalli, Tan, & Wei, 2005; Lee & Kim, 2001; Sambamurthy & Subramanu, 2005; Xu, Tan, & Yang, 2006) has focused on identifying, storing and sharing knowledge for efficient and effective transaction processing. There has been little research into the application of organizational knowledge or KM in the core business management tasks of decision making and strategy development. Yet the scope of knowledge application in these top-level tasks is organization wide. Knowledge application at this level, therefore, would influence organizational performance even more than knowledge management in transactions processing, where the scope is more localized. The research gap shows the need to shift the focus away from obtaining and storing knowledge to using it appropriately for business decision making.

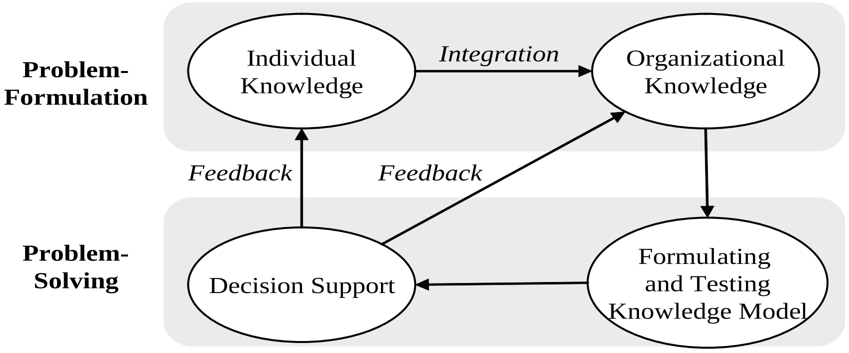
Based on the research needs outlined above, this study aims to propose a new methodology for organizational decision support through knowledge integration across organizational units. Bridging the gap between having knowledge and using it is a very valuable endeavour, both for theorists from the descriptive perspective and for practitioners from the normative perspective. For this purpose, this study develops a decision support loop. The developed decision support loop explains (1) how to organize individual knowledge related to a specific business problem using cognitive modeling, and (2) formulate and test the problem reflected in the organized knowledge using cognitive matrix and causal path identification for decision support. We apply the proposed approach to a decision support case of a beverage company. The application case shows the validity and usefulness of the proposed approach.

This paper is organized as follows. First, we propose a decision support loop formed by integrating individual knowledge as it resides in mental models into an organizational model. Next, we compare the approach of this study with other approaches. We then discuss the proposed model based on its application to a real-world managerial problem.

DECISION SUPPORT THROUGH KNOWLEDGE INTEGRATION

This study proposes a decision support loop through knowledge integration across multiple knowledge sources, as illustrated in Figure 1. Based on an identified managerial problem, individual knowledge is gathered and then integrated into organizational knowledge, which captures

Figure 1. Decision support loop



and defines the problem. This constitutes the problem formulation phase. Managerial problems commonly entail two stages in their resolution: problem formulation and problem solving (Smith, 1989). To provide a linkage between knowledge integration and decision support, the organizational knowledge model is formulated and tested, and then decision guidelines are generated based on the knowledge model. This constitutes the problem-solving phase.

To facilitate this decision support loop, we propose a cognitive modeling methodology. Table 1 illustrates an overview of the proposed methodology. We will discuss the goal, tasks, and details of each step in the following sections.

Individual Knowledge

Knowledge is useful only when it is related to a target task or problem. If the knowledge is not helpful in a given situation, it can be deemed not knowledge at all in that situation, even though it might be in another situation. Individual knowledge means individual and partial mental model knowledge related to the target problem. As a way for capturing knowledge, cognitive modeling has been used to represent relationships that are perceived to exist among the attributes and/or concepts of a given environment or problem (Eden, 1988; Fiol & Huff, 1992). The cognitive modeling method thus can be applied to capture individual (departmental) or partial knowledge (Lenz & Engledow, 1986).

As one of the tools for cognitive modeling, the cognitive map has been widely used in previous research (e.g., Axelrod, 1976; Siau & Tan, 2005, 2006; Zhang, Wang, & King, 1994). Cognitive mapping techniques are known as effective tools to elicit and represent human cognition (Siau & Tan, 2005). In this study, the cognitive map is represented in matrix as well as diagram forms. Diagram representation is used for capturing cause-effect relationships in an organization because it is relatively easy to see how each of the causal factors relates to each other. Matrix representation is used for identifying the most

Table 1. An overview of a cognitive modeling methodology for the decision support loop

Step	Objective	Task	Details
Individual knowledge	Lower-level cognitive model generation	Specify goals Identify causal factors Identify causal connections	Use brainstorming, interview, document analysis, and survey
Organizational knowledge	Higher-level cognitive model generation	Integrate lower-level cognitive models	Link maps based on common causal factors Resolve discrepancies through meetings
		Assign causal values	Use an eigenvector assignment algorithm
Formulating/testing knowledge model	Identification of significant causal paths	Identify causal impact paths and compute the causal values	Use a causal path computation algorithm
Decision support	Identification of core factors	Identify the most positive/negative impact factor for the organizational goal	Compute the most positive/negative impact value for the goal factor
	Identification of core business activities	Identify the path that makes the most positive impact factor stronger	Compute the largest path value for the most positive impact factor
		Identify the path that makes the most negative impact factor weaker	Compute the smallest path value for the most negative impact factor

effective causal path because it is convenient to apply a mathematical algorithm.

A prior cognitive model or belief structure shapes each department's interpretation of information, and affects its decision making or task processing (Huber, 1991). These cognitive models vary across organizational units, depending on their different responsibilities and viewpoints. For example, the marketing team might have knowledge regarding the way in which delays in delivery affect sales volume, but not know how such a delivery delay could be minimized. In contrast, the delivery team might know little about increasing sales but a lot about minimizing delivery delay. In this way, each team has a partial mental model or individual team knowledge about the target issue.

In this study, the cognitive model is generated through three tasks. The first task, specifying the goal, facilitates the generation of a robust cognitive map from the rest of the tasks because goals serve as guides to action (Simon, 1964). Clarifying the goal of each functional unit, therefore, helps to capture the cause-effect relationships among cognitive elements. A number of techniques can be used to generate and validate the cognitive maps of the organization: brainstorming, interview, document analysis, and survey.

Organizational Knowledge

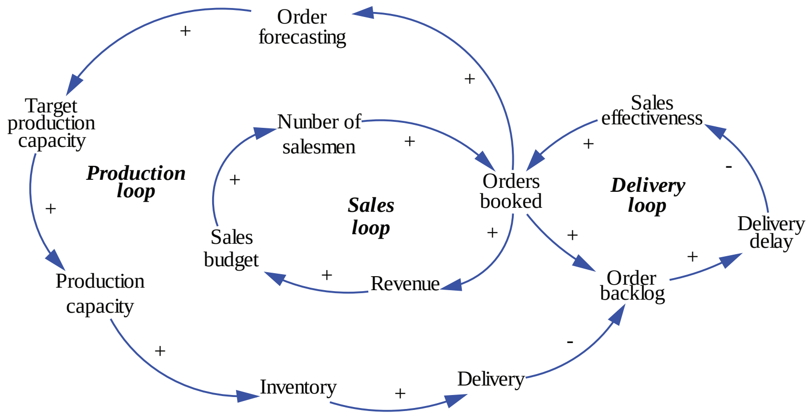
In real-world situations, not only human employees but also each functional department tends towards a silo viewpoint and understanding. Before knowledge is integrated across functional areas, each department may diagnose a business problem from its own viewpoint. Thus, each department may identify a core issue and suggest a solution without first adopting a cross-functional viewpoint. For this reason, cross-domain knowledge integration and sharing have been suggested as an important issue for KM (e.g., Hanse, 2002; Nadkarni & Nah, 2003; Nilakanta, Miller, & Zhu, 2006) and for enhancing organizational performance (e.g., Cai, 2006; Nambisan & Wilemon, 2000).

For organizational knowledge modeling, we generate an integrated global (higher-level) cognitive model by combining local (lower-level) cognitive models, which leads to a combined view for the problems. The integrated cognitive model represents the cognitive model of the group, which consists of individual departments. Local reasoning is done at each functional (operating or product) unit to form its own local cognitive model. However, global reasoning is necessary to combine local cognitive models into an integrated cognitive model. Because cognitive maps tend to impose structure on a vague situation, group members can gain a clearer understanding of problems and opportunities (Weick & Bougon, 1986).

In order to combine the local cognitive maps, we first identify the common causal factors between any two local cognitive maps, and link the maps based on these factors. Each common causal factor plays the role of a coupling device. In turn, the next local cognitive map is joined with the previous result. In this way, the combination process continues until all local cognitive maps are exhausted. While the local cognitive maps are being combined into a global cognitive map, various discrepancies between the maps might arise. In that case, these discrepancies should be detected and resolved through the meeting in which the related functional units participate in order to create a complete global cognitive map.

Integrating the different bodies of individual knowledge constitutes organizational knowledge in that a network of knowledge is produced across different areas in the organization. Organizational knowledge is a specific knowledge model related to a target concern or problem. It can also be modeled on a cognitive model. For example, for the purpose of revenue enhancement, individual knowledge from the sales, production, and delivery teams can be integrated as in Figure 2. This integrated organizational knowledge can explain many issues to the various teams. The teams can then collaborate and know how sales

Figure 2. Representation of organizational knowledge using cognitive maps



are affected by delivery delay and how they can shorten delivery delay. That is, the organizational knowledge model regarding the target issue shows all the relationships among elements across all areas, and it helps decision makers understand the problem clearly and choose appropriate actions to achieve organizational goals. As such, organizational knowledge constitutes the core competency of management.

Although teams and individuals create their respective knowledge models, work that is shared among teams calls into use separate bodies of individual knowledge and generates an organizational knowledge model as well. The organizational knowledge model becomes a basis for understanding the dynamic complexity of the target situation. It enables decision makers and subunits to understand the entire structure of the target business problem (e.g., how to increase revenue). It also helps them assess the behavioural mechanism involved, thus facilitating the choice of appropriate actions to achieve organizational goals.

Formulating and Testing Knowledge Model

For the purpose of decision support, the most important thing is to identify several decision options and validate the best option for solving the problem at hand. For this purpose, the organizational knowledge model must be translated into an analyzable form. Although cognitive maps improve communication and comprehension among their users, they may not render an organizational knowledge model adequately analyzable.

There are various ways to analyse a cognitive model. One alternative is to investigate causal paths. This aims to identify the paths leading to either causes or effects for each causal factor. For this purpose, the organizational cognitive model should be analysed in terms of the strength of the impact between causal factors. The cognitive model includes the indirect causal paths as well as the direct causal paths. Direct causal paths easily can be identified from the cognitive map, but it is difficult to do so with indirect causal paths. In addition, there are usually multiple indirect causal paths. In this context, the aim is to identify the causal paths that have the maximum causal impact among all causal paths, regardless of whether the impact is direct or indirect. To capture those causal paths, some studies have proposed methods that combine heuristic algorithms with the cognitive model (Kwahk & Kim, 1999; Zhang et al., 1994).

Table 2 illustrates how to create and analyse a knowledge model. This method is helpful in analysing the organizational knowledge model because it takes into consideration both the qualitative and quantitative aspects of the cognitive model.

Table 2. Creating and formulating a knowledge model

Objective	Task	Output	Tools
Cognitive model generation	Specify goals	Goal statement	Brainstorming Interview Document analysis Survey Eigenvector algorithm
	Identify causal factors - List all causal factors - Cluster the causal factors	Causal factor list	
	Identify causal connections - Identify the relationships between clusters - Identify the relationships between causal concepts	Cluster relationship diagram Causal factor relationship diagram	
	Assign causal values - Conduct pair-wise comparison - Compute eigenvectors	Pairwise comparison matrix Causal values	
Causal path identification	Initialize cognitive matrix	Cognitive matrix	Matrix operation Causal path computation algorithm
	Compute causal impact paths and values	Causal impact paths and values matrix	

A cognitive map is composed of three components: causal factor, causal value, and causal connection. The main difficulty lies in determining the causal value component. Specification of the causal value is the most challenging problem in generating a cognitive map because it has a qualitative property reflecting people's cognitive status, which cannot be directly measured. Besides, human perception is often inconsistent. Direct scale values have been used by most of the methods for cognitive modeling (Eden & Ackermann, 1989; Zhang et al., 1994). However, this direct assignment approach has limitations in that the procedure is not systematic and the result heavily depends on the analysts' or participants' subjective judgment.

For this method, an eigenvector approach through pairwise comparison was chosen for more systematic determination of causal values. This approach is based on the analytic hierarchy process (AHP) method developed in the 1970s (Saaty, 1980). Strength of the AHP method lies in its ability to structure a complex problem hierarchically and to evaluate the relationships between entities systematically. In the application of AHP method, the eigenvector assignment approach is conducted through pairwise comparison and eigenvector computation.

Pairwise comparison technique starts from the idea that the measurements based on experience and understanding are obtainable only from relative comparisons and not in an absolute way (Saaty, 1980). The intensity of our feelings serves as a scale adjustment device to put the measurement of some objects on a scale commensurate with that of other objects. The results of pairwise comparisons are represented in a form of matrix, called pairwise comparison matrix. A pairwise comparison matrix has cell entries as a scale indicating the relative strength with which elements in one cluster influences other elements in other clusters. This scaling process can then be translated into impact weights. The eigenvalue method is the most preferred approach for the estimation (Saaty, 1980). When a pairwise comparison matrix has a maximum eigenvalue and the corresponding eigenvector whose components are all positive, this eigenvector becomes a ratio scale that are the estimates of relative impact values of elements under comparison. Eliciting causal values in a cognitive map can be viewed as a process that transforms qualitative mental status into quantitative numerical scale. The eigenvector approach provides a way for calibrating a numerical scale, particularly in areas where measurements and quantitative comparisons do not exist.

The completed global cognitive map is analyzed in terms of the strength of the impact between causal factors. Our concern is to identify the causal paths with the maximum causal impact among all causal paths regardless of the direct or indirect impact. These causal paths take negative or positive path values, depending on their causal values. In order to identify the causal path(s) with the maximum causal impact, we adopted the algorithm proposed by Zhang et al. (1994) and extended it to find the paths and values simultaneously. The algorithm produces an n x n matrix called the causal impact path and a value matrix consisting of X_{ij}, where X_{ij} is the set of $\{+p_{ij}, -p_{ij}, +v_{ij}, -v_{ij}\}$: $+p_{ij}$; is a positive causal impact path from element i to j, $-p_{ij}$; is a negative causal path, $+v_{ij}$; is a maximum positive causal impact value corresponding to $+p_{ij}$, and $-v_{ij}$; and is a maximum negative causal impact value corresponding to $-p_{ij.}$ The algorithm is applied iteratively, while either maximum positive value ($+v_{ij}$) or maximum negative value ($-v_{ij}$) can be improved; in other words, until new dominant values cannot be identified (refer to Appendix 1 for the simplified algorithm).

Decision Support

The analyzed knowledge model should suggest guidelines for decisions on managerial problems. A decision guideline can be generated in view of the organizational goal, based on the organizational knowledge model (or cognitive model) and the causal path analysis. An organizational goal is a desired future state of affairs that the organization attempts to realize (Etzioni, 1964). A goal pertains to the future, but it influences current activities. Because organizations are goal-attainment entities, goals play a role in setting directions for its members' activities, leading their thoughts and actions to a specific result (Hamner, Ross, & Staw, 1983). Decision guidelines thus can be identified by analyzing people's thoughts and actions with respect to their organizational goals.

To facilitate decision support, we propose analyzing the organizational knowledge represented in cognitive maps in terms of the causal paths and strengths among the causal factors. The causal impact paths and values among the causal factors can be computed based on the proposed methodology, as mentioned in the previous section. The derived matrix includes the negative path and value as well as the positive path and value for each relationship among the causal factors.

Regardless of the polarity of the impact, it is first necessary to focus on the most effective causal factor in achieving the goal. This factor can be an opportunity, if it has a positive impact, but it can be a problem, if it has a negative impact. It is then necessary to identify the relevant feedback loop paths that strengthen the positive impact and weaken the negative one. For a causal factor with a positive impact, this involves making its positive loop more positive and making its negative loop less negative. For a causal factor with a negative impact, this involves making its positive loop less positive and making its negative loop more negative.

The output from such a process enables a decision to be made on a managerial problem. There are many reasons that update individual and organizational knowledge and upon which the selection of an appropriate option can be made. That is, there is a feedback process from integrated knowledge and decision support to individual knowledge and mental models. This is a kind of organizational learning process. Although decision makers cannot apply the same option and the same knowledge to similar problems in the future, they can now understand the dynamic complexity of the target problem, the structure among the elements, and the behavioural patterns. Decision making via understanding dynamic complexity, based on a cognitive model, enables the acquisition of real leverage in managerial problems (Fiol & Huff, 1992; Senge, 1990; Sterman, 2001).

COMPARISON WITH OTHER APPROACHES

The proposed approach can be compared with other KM methods. Our research focuses on enterprise wide improvement by enhancing managerial decision support by means of organizational knowledge, whereas other KM methods (Davenport, 1998; Davenport et al., 1998; Kankanhalli et al., 2005) aim to obtain better efficiency and effectiveness in task processing by knowledge attainment and knowledge repository management. Due to this difference in approach, other KM methods are more concerned with individual or departmental tasks at the operational level. They highlight declarative knowledge (which is related to each employee's cognitive model) and procedural knowledge (which is stored as document- or database-type knowledge). In contrast, the proposed method that we have presented emphasizes integrating the partial knowledge of different departments and employees into organizational knowledge. By doing so, our method facilitates effective business decision making and strategic planning.

The proposed approach can be compared with other cognitive modeling methods. Several cognitive modeling methods and tools using the cognitive map have been developed in various domains, including business policy establishment, organizational learning, and strategic option development (Eden & Ackermann, 1989; Hall, 1984; Lee, Courtney, & O'Keefe, 1992). However, most cognitive modeling methods emphasize map representation as a knowledge representation scheme rather than as a problem-solving tool (Kwahk & Kim, 1999). The proposed approach provides a representation scheme as well as some guidelines for problem solving, by further investigating the knowledge represented in the cognitive map, based on the analysis of the most effective paths.

The proposed matrix approach also can be compared with system dynamics (Sterman, 2001). System dynamics is a methodology aimed at designing better behaved system, by understanding the target system, especially with feedback loops among system components and behaviour patterns over time. System dynamics attempts to conceptualize any business problem with a causal loop diagram, and formulate and test it after transforming the causal loop diagram into a stock-flow diagram. The standard application of system dynamics includes identifying the core loop and core factors as part of policy development. However, identifying the core loop and core factors relies on either the intuition of the modeler or user, or the somewhat cumbersome simulation testing of several alternatives. While the identification of the core loop and core factors is very critical to the application of system dynamics and effective policy development, little research has been done in the area. By proposing a new method for identifying the core loop and core factors, this study has contributed to system dynamics literature.

APPLICATION CASE

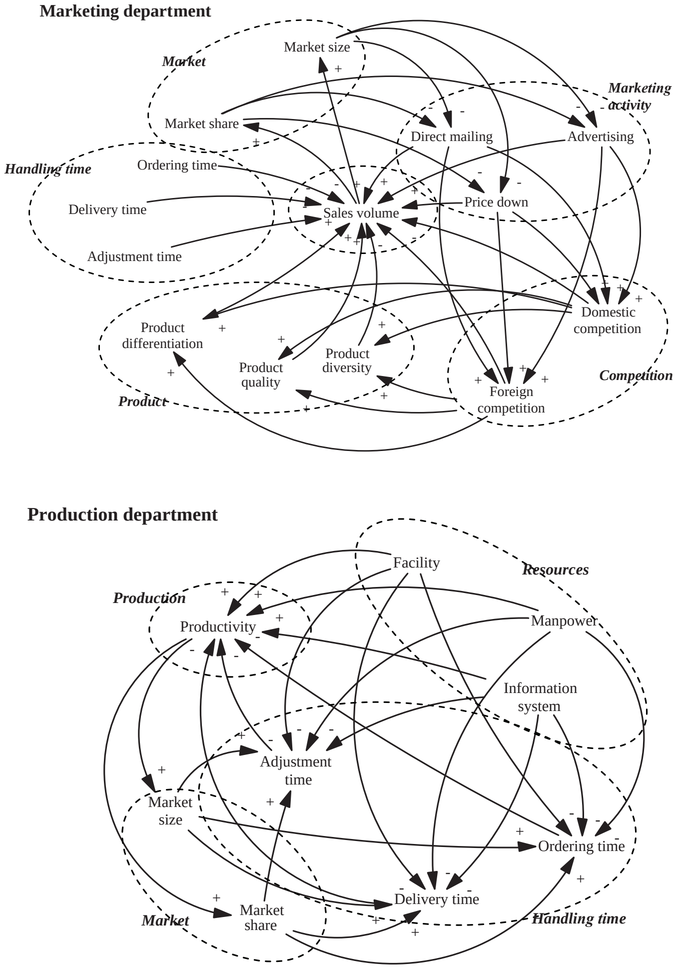
We applied the proposed decision support loop to a beverage company with an annual sales volume of about $600 million. The company was about to start a business process redesign implementation project, and before that, the management wanted to know the main target of the process redesign, especially across the marketing and production departments. Accordingly, we applied the proposed approach in finding the leverage points in decision making for increasing profit by identifying core factors and core activities.

The application of the proposed method was carried out by two researchers who had knowledge about the proposed method and cognitive map, along with the company's project team, which mainly consisted of members of related departments. Two researchers educated the project team about the procedure and the use of cognitive map, particularly, focusing on the knowledge elicitation of individual department. This study lasted for a month until the business process redesign implementation project started.

Individual Knowledge

Individual knowledge was gathered from the marketing and production departments. To generate a cognitive map for each department, a brainstorming session and interviews with participants from each department were held. Following the discussion and interviews, the participants established the goals for their respective departments. The marketing department set increasing sales as its goal, while the production department decided on improving productivity. Next, we attempted to extract all the causal factors for each department, including business-related activity concepts. The brainstorming technique again was used. When all the causal factors had been listed, they were clustered according to their functional similarity and behavioral homogeneity. Based on these clusters, the relationships between clusters were identified, along with their directions and polarities. A cognitive map was derived from the list of causal factor clusters and the cluster relationships; this was done by replacing clusters with their corresponding causal factors and making

Figure 3. Individual knowledge models of two departments



appropriate connections among causal factors. Then cognitive maps were generated from the two departments along with the relevant goals, as illustrated in Figure 3.

Organizational Knowledge

Knowledge related to organizational goals is dispersed across a company, and it is kept by the top management, departmental managers, and departmental staff members of the firm. This knowledge is identified and organized through "externalization" and "combination." Although some information or knowledge can be obtained from documents or databases, large portions of knowledge reside in mental models. In our case application, we conducted interviews with the top managers and the middle managers of the two departments to identify partial knowledge. By having these interviews, we could detect and resolve discrepancies between the cognitive maps of the two departments.

Combining the individual knowledge models of the two departments generated the organizational knowledge model as depicted in Figure 4. The synthesizing process revealed organizational knowledge that was not known explicitly to the departments. The two departments became aware of how elements in one department could affect the other department. For example, efforts to increase market share by the marketing department could lead to increasing ordering time and delivery time, thus resulting in diminished productivity, which is of interest to the production department.

Formulating and Testing the Knowledge Model

The organizational knowledge represented in the cognitive map was analyzed in terms of the causal paths and strengths among the elements to identify the leverage points in decision making. The causal impact paths among the causal factors as well as their values were computed. In this application case, core business activities were identified from the causal impact paths and values matrix, as illustrated in Table 3 (and also in Figure 5).

Figure 4. The organizational knowledge model between the two departments

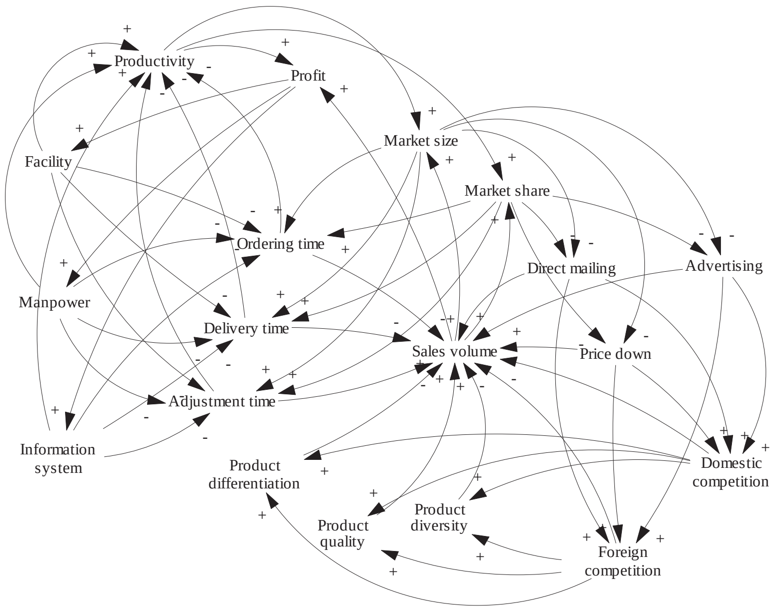
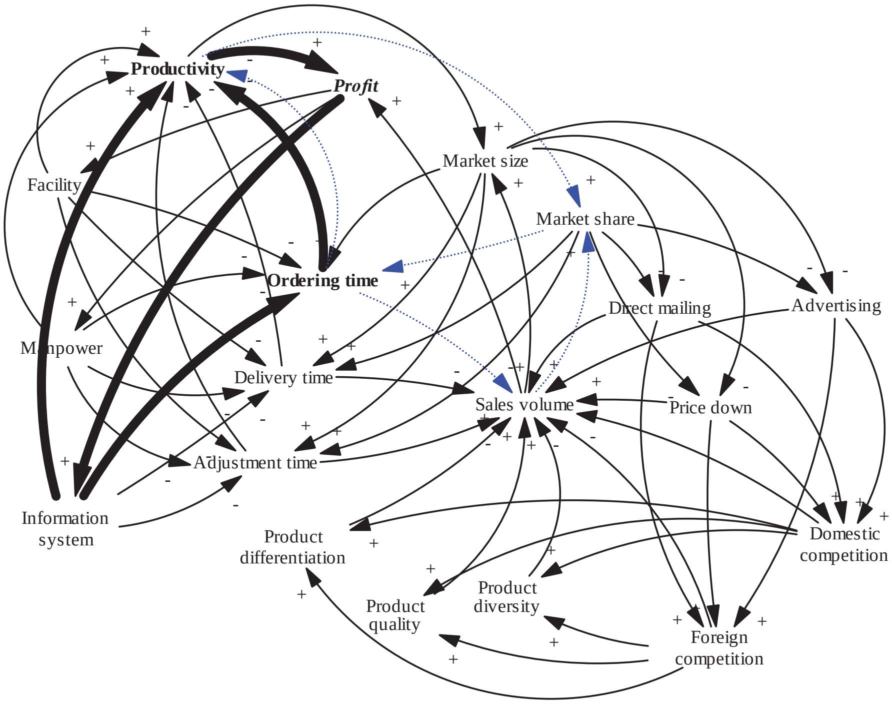


Table 3. Analysis of core business activities

Causal factor		Feedback loops
The most positive impact factor: Productivity	Positive	Path = {Productivity - Profit – Information system - Productivity} Value = +0.52*
	Negative	Path = {Productivity - Market share - Ordering time - Productivity} Value = -0.19*
The most negative impact factor: Ordering time	Positive	Path = {Ordering time - Productivity - Profit - Information system - Ordering time} Value = +0.36*
	Negative	Path = {Ordering time - Sales - Market share - Ordering time} Value = -0.32*

** Values can be calculated based on the path of feedback loops and the corresponding causal values as follows: +0.52=(+0.67)*(+1.0)* (+0.77); -0.19= (+0.33)*(+0.83)*(-0.70); +0.36= (-0.70)*(+0.67)*(+1.0)*(-0.77); -0.32=(-0.57)*(+0.67)*(+0.83) (refer to Appendix 2).*

Figure 5. Feedback loops related to the target goal



When increasing profit was considered as a target goal, the two most effective causal factors were identified from the causal impact paths and values matrix (refer to Table 4). One was productivity, which was the most positive causal factor. It represented an opportunity to accomplish the organizational goal because productivity enhancement contributes most to increasing corporate profit. The other one was ordering time, which was the most negative causal factor. It represented a problem for the attainment of the goal because an increase in ordering time undermines profit increases through a decrease in sales volume. The objective was, therefore, to strengthen the positive causal factor ("productivity") and weaken the negative casual factor ("ordering time").

As can be seen in Table 3 and Figure 5, the causal factors—productivity and ordering time—possessed *positive* feedback loops of {Productivity–Profit–Information system–Productivity} and {Ordering time–Productivity–Profit–Information system–Ordering time}, respectively. In addition, the two factors possessed *negative* feedback loops of {Productivity–Market share–Ordering time–Productivity} and {Ordering time–Sales–Market share–Ordering time}, respectively. It seems clear that the paths, {Productivity–Profit–Information system} and {Ordering time–Productivity}, were the main drivers that could accelerate an improvement in productivity and a decrease in ordering time. Thus, by designating the above two paths of related activities as core business activities, it would be possible to focus on how to use information technologies in redesigning the processes related to productivity and ordering time.

Table 4. Part of causal impact paths and values matrix (causal factor "profit" column)

Cell	**Positive**		**Negative**	
(*i, j*)	**Value**	**Path**	**Value**	**Path**
(01, 01)	+0.516	1- 14- 11- 1	-0.114	1- 14- 15- 2- 19- 15- 11- 1
(02, 01)	+0.330	2- 1	-0.261	2- 19- 15- 11- 1
(03, 01)	+0.026	3- 2- 1	-0.021	3- 2- 19- 15- 11- 1
(04, 01)	+0.198	4- 2- 1	-0.156	4- 2- 19- 15- 11- 1
(05, 01)	+0.160	5- 7- 9- 2- 1	-0.159	5- 6- 2- 1
(06, 01)	+0.175	6- 2- 19- 15- 11- 1	-0.221	6- 2- 1
(07, 01)	+0.211	7- 9- 2- 1	-0.167	7- 9- 2- 19- 15- 11- 1
(08, 01)	+0.056	8- 2- 1	-0.044	8- 2- 19- 15- 11- 1
(09, 01)	+0.254	9- 2- 1	-0.201	9- 2- 19- 15- 11- 1
(10, 01)	+0.020	10- 2- 1	-0.016	10- 2- 19- 15- 11- 1
(11, 01)	+0.670	11- 1	-0.128	11- 19- 15- 11- 1
(12, 01)	+0.114	12- 11- 1	-0.022	12- 11- 19- 15- 11- 1
(13, 01)	+0.080	13- 15- 11- 1	-0.025	13- 15- 2- 19- 15- 11- 1
(14, 01)	+0.516	14- 11- 1	-0.114	14- 15- 2- 19- 15- 11- 1
(15, 01)	+0.149	15- 2- 19- 15- 11- 1	-0.469	15- 11- 1
(16, 01)	+0.026	16- 2- 19- 15- 11- 1	-0.040	16- 11- 1
(17, 01)	+0.086	17- 2- 19- 15- 11- 1	-0.161	17- 11- 1
(18, 01)	+0.025	18- 15- 2- 19- 15- 11- 1	-0.080	18- 15- 11- 1
(19, 01)	+0.138	19- 5- 6- 2- 1	-0.389	19- 15- 11- 1

Note: 1 represents-profit; 2 represents sales amount; 3 represents DM; 4 represents advertising; 5 represents price down; 6 represents domestic competition; 7 represents foreign competition; 8 represents product differentiation; 9 represents product quality; 10 represents product diversity; 11 represents productivity; 12 represents facility; 13 represents manpower; 14 represents information system; 15 represents ordering time; 16 represents delivery time; 17 represents adjustment time; 18 represents market size; and 19 represents market share.

Decision Support

Based on the above organizational knowledge and consensus, the ordering process was identified as a candidate target process for possible redesign. The existing ordering process depended heavily on manual handling and required the intervention of the sales branches. This resulted in long ordering time and inefficiency in production and delivery. Including a new client-server system in the redesign of the ordering process could significantly reduce total ordering time.

In the redesigned ordering process, every agency could send its orders directly to the factory through the network without the intervention of the sales branches. Reducing the branches' role in order taking was expected to result in shorter ordering time, which in turn was likely to increase efficiency in production and delivery and, in the long run, contribute to profit. In addition to discovering the best decision option, the top management and managers at other levels came to understand the elements involved in the business process, the relationships among them, and the behavioural mechanism of the target business problem.

At the end of the application of the proposed method, the results and insights were presented to the top management of the firm and the two departments. The top management came to understand what factors affected organizational profit and how the factors were related across the two departments. In addition, the management could now perceive why the proposed decision guidelines would be effective. The two departments and the individual employees also could expand their department-constrained knowledge into cross-department knowledge. Thus, the proposed method facilitated understanding of the behavioural mechanism regarding the target managerial problem by linking knowledge integration to decision support.

In summary, the goal in the application case was to identify the decision options to increase profit. For company-level decision making, such as in the application case, knowledge integration (regarding how to increase profit and what factors affect profit) across functional areas is essential. As part of knowledge management, the proposed approach facilitates the identification and integration of partial knowledge (as in Figure 3) into organized knowledge (as in Figure 4). In decision making, there could be several decision options. Identifying the best option or core factors is one of the main goals in decision support (as in Figure 5). Thus, the matrix method enabled us to identify the core factors regarding the goal of decision making based on the combined knowledge model. In the case study, the management and the two departments gained newly identified knowledge through our proposed process.

DISCUSSION

Any problem is characterized by its complexity type: detail complexity and dynamic complexity (Senge, 1990; Sterman, 2000). Detail complexity arises when it focuses on the static aspect of a structured problem by highlighting the correctness of selected variables. Dynamic complexity arises when it focuses on the dynamic aspect of an unstructured problem by highlighting the interactions among the variables. Any problem characterized by detail complexity tends to entail mathematical modeling approach to find an optimal solution. In contrast, any problem characterized by dynamic complexity tends to entail the cognitive modeling approach to design a better behaved system by understanding the behavior mechanism. Organizational problems (or business management problems) are characterized by dynamic complexity, tacit knowledge factors, feedback effects over time, and unstructuredness (Sterman, 2001).Organizational problems especially require (tacit and explicit) knowledge gathering and integration across employees and organization units (Argote, McEvily, & Reagans, 2003; King, 2006). In addition, a systematic approach is needed to identify and capture knowledge within the organization (Cai, 2006; Nah, Siau, & Tian, 2005). Based on these needs, this study proposed a knowledge integration approach for organizational decision support by developing a cognitive modeling methodology together with the decision support loop. We believe the developed decision support loop and the methodology (including tasks and relevant methods in each step over the two common stages) is unique compared to other decision support approaches.

The case described in the previous section may be best discussed as an exercise in knowledge conceptualization. During the conceptualization process, the knowledge related to the target problem was identified and structured from the causal relationship perspective using cognitive maps. The analysis enabled decision makers to: (1) trace the basic causes of unexpected outcomes; (2) understand which decision factors had more significant impacts on performance; and (3) make trade-offs between decision alternatives. The reasoning process had effects on both the value of decision factors and the causal relationships.

Our proposed approach is characterized by its learning process and organizational memory. Learning allows individuals to obtain knowledge and insight from the results of experiences, and facilitates the application of this knowledge to future circumstances (Fiol & Lyles, 1985). Organizational learning aims to obtain knowledge, store it in the organizational memory, and revise it by experience; the accumulated organizational knowledge is thus diffused (Huber, 1991; Senge, 1990). Organizational memory refers to "the means by which knowledge from the past [is] brought to bear on present activities, thus resulting in higher or lower levels of organizational effectiveness" (Stein, 1995 p. 22). Ramesh (1999) suggested the development of organizational memory through the identification of information that should be provided as part of cognitive feedback, together with the interdependencies within this information. Organizations update their respective organizational memories that consist of knowledge through learning. Our proposed approach enables an organization to obtain of previous knowledge from individuals or organizational knowledge models, allows for the creation of new organizational knowledge, and allows for its revision by reasoning and new experiences. The management and teams of an organization can share the collective tacit/explicit knowledge to improve their understanding of the target situation, which will enable them to be more cooperative in their dealings with each other. The organizational knowledge model, thus, plays a role in organizational memory.

Compared to other general decision support approaches, our approach would be more appropriate to the decision-making context with highly constrained tasks involving resource allocation. Highly constrained tasks can be classified as mixed-motive negotiation tasks in which participants have mixed motives to compete and cooperate (McGrath, 1984; Rees & Barkhi, 2001). It is, therefore, important to understand the overview of the system, and this should be shared among participants with respect to how one part of a decision can affect other parts. Decision-making support should aid individuals or subunits in an organization in exchanging information and making coordinated decisions (Barkhi, 2001–2002). The proposed approach enables individuals or subunits in an organization to make decisions consistent with the organizational goals, leading them to collaborate with each other by linking organizational knowledge to decision support.

As part of the proposed approach, the matrix method seeks to provide problem-solving guidelines in a systematic way that is lacking in most cognitive map methods. The merit of our approach is that it quantifies the knowledge represented in the map and identifies core factors and the relationships among them. The identified factors and relationships are new knowledge that comes with the application of our method. Their importance is reflected in the fact that they are the main target for decision making. Therefore, our matrix method plays an important role in the proposed organizational decision support through knowledge integration across organizational units.

Our proposed matrix approach is more appropriate for testing linear problems, but many real-world problems (or systems) are characterized by nonlinearity. The main focus of system dynamics is to conceptualize and test the effect of nonlinearity over time. While our proposed approach captures nonlinearity in structuring a problem, the matrix method has its limitations in testing nonlinearity effects over time. Nevertheless, the limitation can be eased by combining the proposed matrix approach with the typical system dynamics approach. Based on the identified core loop and factors from the matrix approach, we can further test the model (or business problem) with the format of the stock-flow diagram of the system dynamics approach. In the testing, we could consider nonlinearity in the system; and we could validate whether the identified core loop and factors produce real leverage effect in the nonlinear system.

CONCLUSION

The core contribution of our study lies in proposing a methodology for organizational decision support based on knowledge gathering and integration across organization units and people. While most previous research on knowledge management has focused on identifying and sharing knowledge mainly for transaction processing in an organization, this study explains how organizations can apply knowledge management (i.e., knowledge gathering and integration across multiple individuals and organizational units) for organizational decision support. For this, we have developed and proposed the decision support loop. The decision support loop facilitates integrating individual knowledge into organizational knowledge, then formulating and testing it for decision support. For the knowledge representation, formulation, and testing, we used the cognitive modeling method, which enables decision makers to estimate the strength of the impact between causal factors. The generation of alternatives and the testing of those alternatives enable decision makers to appreciate the behavioural mechanism and the inherent structure of the target business problem. The application case showed the validity and usefulness of the proposed method.

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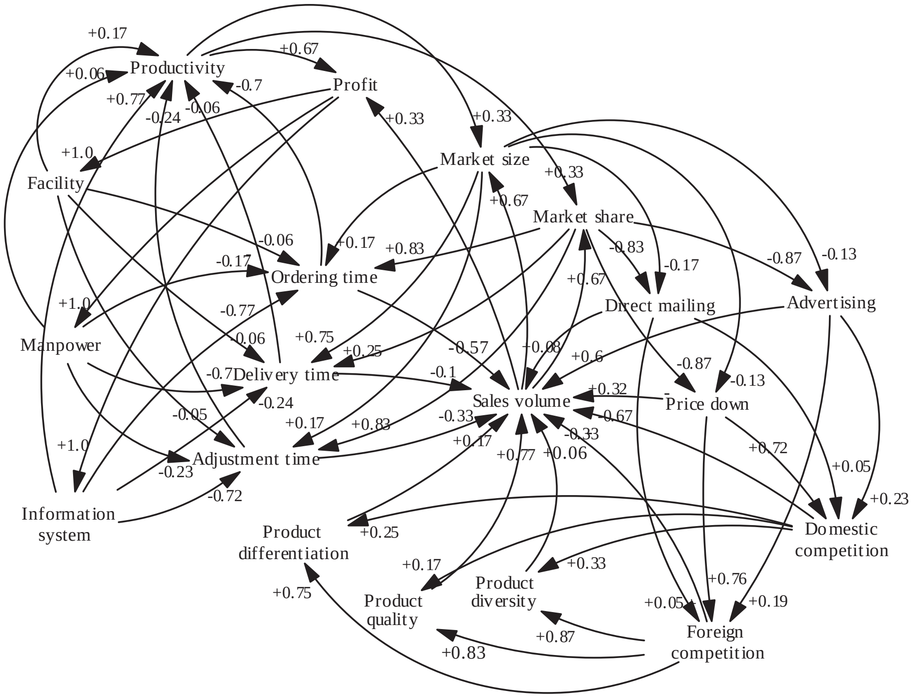
APPENDIX

1. Simplified algorithm for computing causal impact paths and values

```
Initialization
Set $X_{ij}$ such as
        $+p_{ij} = \{i, j\}$, $-p_{ij} = \{\phi\}$,   $+v_{ij} = u_{ij}$,  $-v_{ij} = 0$,   If $u_{ij} > 0$
        $+p_{ij} = \{\phi\}$,  $-p_{ij} = \{i, j\}$,  $+v_{ij} = 0$,  $-v_{ij} = u_{ij}$,   If $u_{ij} < 0$
        $+p_{ij} = \{\phi\}$,  $-p_{ij} = \{\phi\}$,   $+v_{ij} = 0$,   $-v_{ij} = 0$,   If $u_{ij} = 0$

Main procedure
Do while being improvement
  For $i$ = 1 To n
     For $j$ = 1 To n
        For $k$ = 1 To n
           Read $-v_{ij}$, $+v_{ij}$, $-v_{ik}$, $+v_{ik}$, $-v_{kj}$, $+v_{kj}$
           If $-v_{ij} > (-v_{ik}) * (+v_{kj})$
              Set $-v_{ij} = (-v_{ik}) * (+v_{kj})$
              Set $-p_{ij} = (-p_{ik}) \cup (+p_{kj})$
           End If
           If $-v_{ij} > (+v_{ik}) * (-v_{kj})$
              Set $-v_{ij} = (+v_{ik}) * (-v_{kj})$
              Set $-p_{ij} = (+p_{ik}) \cup (-p_{kj})$
           End If
           If $+v_{ij} < (+v_{ik}) * (+v_{kj})$
              Set $+v_{ij} = (+v_{ik}) * (+v_{kj})$
              Set $+p_{ij} = (+p_{ik}) \cup (+p_{kj})$
           End If
           If $+v_{ij} < (-v_{ik}) * (-v_{kj})$
              Set $+v_{ij} = (-v_{ik}) * (-v_{kj})$
              Set $+p_{ij} = (-p_{ik}) \cup (-p_{kj})$
           End If
        Next $k$
     Next $j$
  Next $i$
Loop
```

2. Organizational knowledge model with causal values



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Chapter 3.19

System Characteristics, Perceived Benefits, Individual Differences and Use Intentions:

A Survey of Decision Support Tools of ERP Systems

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ABSTRACT

Limited research has considered the value derived from using enterprise resource panning (ERP) systems for decision making support. This paper aims to evaluate the impact of a set of individual differences, system characteristics, and perceived benefits of the system, on the intentions to use ERP systems for decision support. A field study was used to collect data from managers working in Bahraini enterprises that use ERP systems. The results indicate that individual differences concerning age, gender, level of education, and even computer self efficacy did not influence intentions of using the decision tools of ERP systems. The only individual difference that showed significant influence is the degree of knowledge of the system. In addition, both perceived shared benefits and system characteristics had significant influence on the intention to use the system for decision support tasks, through perceived ease of use and perceived usefulness. The paper discusses the implications of these findings and ends with possible extensions of the study.

INTRODUCTION

Over the past decade, organizations around the world have spent billions of dollars implementing ERP systems. Motives of adopters of ERP systems have focused primarily on revolutionizing transaction handling by improving business processes and integrating operations and data. The current generation of ERP packages holds the promise of improving online analytical capabilities to enhance the organization's business intelligence as well.

ERP systems could be defined as comprehensive software packages that seek to integrate the complete range of business processes and functions in order to present a holistic view of the business from a single information and information technology architecture (Gable, 1998). Implementing an ERP system is a costly and risky project. The cost of a full implementation in a large international organization can easily exceed $100 million. A recent survey of 63 companies—with annual revenues ranging from $12 million to $63 billion—indicated that ERP projects cost $10.6 million and take 23 months on average to complete (Umble & Umble, 2002). Moreover, their implementation environments are often very complicated. They usually require large-scale business process reengineering (BPR) undertakings, complex technical arrangements for integrating the core ERP technology with any existing or future software, as well as careful management of the contributions of several participants in the projects such as: functional departments, consultants, business partners, and vendors. All these requirements and more, magnify project management challenges for such projects, making them prone to implementation failure.

Despite these challenges, investments in these systems are increasing, making the ERP software one of the fastest growing markets in the software business. In the 1990s some statistics projected its eventual market size to be around $1 trillion by the year 2010 (Bingi, Sharma, & Golda, 1999). Moreover, expectations for keeping these interests in ERP investments are even bigger in the 2000s. This is because, though they were originally developed and implemented for transactional aspects, a growing need to use these systems for decision support has recently become clear. Lately, these software packages are incorporating decision support tools in order to take advantage of data storage, access, scrubbing, and integration capabilities facilitated by ERP systems (Turban, Aronson, & Liang, 2005). On the other hand, the confluence of ERP and decision support technology has begun to draw the attention of academia as well (Shafiei & Sundaram, 2004). Obviously ERP vendors, implementers, and researchers need to understand the factors that affect their usability. Based on this need, this article's main objective is to identify the main contextual variables that influence the acceptance of decision support tools of ERP systems. Three groups of variables were introduced in our theoretical model: (1) individual differences, (2) perceived shared beliefs of the decision support benefits of these systems, and (3) system characteristics.

The second section of this article reviews prior literature on ERP and decision support. In addition, it provides a brief explanation of TAM as the guiding basis for the theoretical framework of this research. The third section introduces the research model along with a discussion of the model variables. The fourth section describes the study's methodology. The fifth section reports findings on the factors that are found to be influencing the use of these systems. The last section concludes the study with a discussion of the main findings and suggestions for future investigations.

LITERATURE REVIEW

ERP and Decision Support

Very few studies have addressed issues related to incorporating ERP systems and decision support tools. This is mainly because ERP and decision support systems (DSSs) have independently evolved and adopted in the marketplace as well as in academia. Consequently, each subject has its own separate studies. On the other side, plenty of research efforts have been introduced for technology/information systems acceptance or usability. In the following paragraphs, we tried to briefly present the research most related to our study's main objective.

Starting with the ERP aspect, many researchers have provided frameworks and insights that tried to explain success of ERP systems implementation. We thought that these success factors' frameworks could be helpful in providing a basis for synthesizing an initial acceptance theory for incorporating ERP and DSS tools for our research. Akkermans and Van Helden (2002) and Al-Mashari, Al-Mudimigh, and Zairi (2003) for example, used a case study approach to provide rich accounts of the implementation processes for some selected individual companies. Other studies used a statistical approach to develop and test different theoretical models that identify several critical success factors, using samples of firms that have recently implemented ERP systems (Bradford & Florin, 2003; Hong & Kim, 2002). Examples of factors tested in such studies are: top management support; effective communication; project management; business plan and vision; software testing and trouble shooting; and monitoring and evaluation of performance. Another important direction this literature has tried to examine is how such critical factors differ in their impact or contribution to success, according to the different stages in the life cycle of the ERP implementation project (Markus, Tanis, & Van Fenema, 2000; Rajagopal, 2002).

Previous studies concerning DSSs use or adoption had other streams that could be used as well for building a relevant background for this study. For example, some researchers paid great attention to issues such as patterns of use or areas where such DSS tools are used and how these patterns affect perceived value and satisfaction (Vlahos, Ferratt, & Knoepfle, 2004). Others concentrated on how acceptance levels of these systems differ according to managers' individual differences, such as gender and cognitive and decision style (Bruggen & Wierenga, 2001; Lu, Yu, & Lu, 2001). One important development in this area is the steady growth of business intelligence and business analytics technologies' industry, with revenues reaching into low billions, according to some statistics (Turban et al., 2005). Moreover, tools concerning data mining, data warehousing, and knowledge management systems are becoming easier to use and consequently more promising for higher levels of usability. One of the surveys concerning these developments showed that approximately 35% of corporate management and staff directly used data mining tools (Nemati & Barko, 2001).

The confluence of ERP and DSSs is still in its initial stage, though clear interests could be cited. For example in a field study of six ERP implementations, Palaniswamy and Frank (2000) described organizations' need to digest the vast amount of information from the environment and make fast decisions. Shafiei and Sundaram (2004) explained that DSS tools take advantage of the data resident in ERP systems. Holsapple and Sena (2005), in their survey that examined the connections between ERP systems' objectives and decision support benefits, found that organizations did consider four objectives for decision support to be fairly important while planning their ERP projects. These objectives are: (1) shifting responsibility of decision making, (2) supporting interrelated decision making, (3) supporting multiple persons working jointly on a decision, and (4) supporting individual decision makers. On the other side, the survey showed that ERP systems do indeed provide substantial decision support benefits concerning the following: enhancing knowledge processing, improving competitiveness, reducing decision costs, and supporting multi-participants' decision making.

Technology Acceptance Model

Identifying factors that determine user's adoption of IS has drawn much attention in the last two decades. This is due to the realization that millions of dollars could be spent on these systems, while potential users may not even use them. TAM is an established model in explaining IS adoption behavior. It is based on theories in social psychology such as theory of reasoned action (TRA), and the theory of planned behavior (TPB). TAM has been frequently found to have better explanatory power than other models or theories used in the IS adoption subject (Davis, Bagozzi, & Warshaw, 1989; Taylor & Todd, 1995).

According to TAM, usage of an IS is determined by users' intention to use the system, which in turn is determined by users' beliefs about the system. There are two kinds of salient beliefs involved: perceived usefulness and perceived ease of use of the system. Perceived usefulness (PU) is defined as the extent to which a person believes that using the system will enhance his job performance. Perceived ease of use (PEOU) is defined as the extent to which a person believes that using the system will be free of effort. Furthermore, both types of beliefs are subjected to the influence of external variables. By manipulating these external variables, system developers can have better control over users' beliefs of the system, and subsequently, their behavioral intentions and usage of the system. A good review of this stream of research is provided by Lucus and Spitler (1999), and Legris, Ingham, and Collerette (2003).

TAM has been applied to a wide range of IS applications. However, very few have used it for complicated systems such as ERP. Amoako-Gympah and Salam (2003)—probably the first to extend using TAM in an ERP implementation environment—have examined the impact of training and project communications on shared beliefs about the benefits of the ERP technology and how these shared beliefs influence the TAM core framework. Amoako-Gympah (2005), in another study, looked at the influence of prior usage, argument for change, intrinsic involvement, and situational involvement on PU and PEOU of TAM. Also Calisir and Calisir (2004), based on data obtained from 35 end users in 24 companies, found that PU and learnability could be significant determinants of end-user satisfaction with ERP systems. In addition, PEOU and system capability seemed to affect PU, while user guidance seemed to influence both PU and learnability.

This article represents an extension to this line of studies. From one side, it tries to contribute to the current interests in integrating ERP and the decision support tools body of research. From the other side, it tries to meet the need to understand the main factors that affect the use of this side of the system. The few current studies, which investigated the acceptance of ERP systems, concentrated on the general use of ERP systems, which is more oriented towards the classical transactional part of these systems. We believe that the decision support part of ERP systems requires separate investigation concerning its usability.

It is important to note here that using TAM for this research was not for the sake of introducing another TAM example. We came to a belief in the beginning of this study that measuring the intentions to use the system is more appropriate than measuring its real use. We expect that the use of the decision support tools accompanying ERP systems is still relatively limited, as these systems are traditionally considered as transactional systems. Moreover, using TAM had many advantages for such research studies. Firstly, it informs researchers of what types of contextual factors could be included and how their relationships might be. Secondly, it provides an important basis for comparisons and extensions with previous research in IS. Thirdly, many of the academics feel comfortable with TAM, though some still do not feel relaxed with the link between intentions to use the system and its real use. However the big previous bulk of research concerning TAM, indicates a high level of acceptance of the model, which eases understanding of any future extensions.

RESEARCH MODEL AND HYPOTHESES

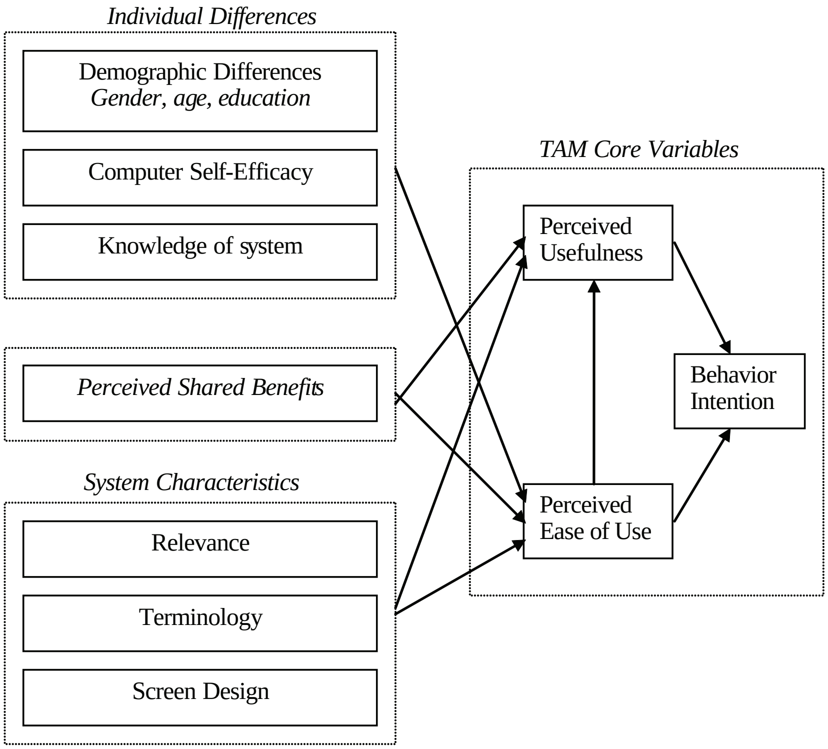
Many factors have been selected by prior studies as potential predicators for IS use intentions. Examples are: top management support, project management capabilities, and BPR competencies. However, our main concern was to include only those that are specifically related to the decision support part of the system. This criterion made us eliminate many factors that seemed more appropriate to the traditional transactional aspect of the system. In the end, three main categories of external variables have been selected, namely: (1) individual differences, (2) system characteristics, and (3) shared beliefs about the benefits of the system. We thought that it is fairly logical to expect that managers' intentions to use such a system rely more on how they perceive its specific benefits to their work, how friendly and relevant this system is to use, and other items related to their individual characteristics. These three groups of variables have been emphasized in most of the classical TAM research studies (Agarwal & Prasad, 1999; Davis, 1989; Igbaria & Iivari, 1995; Venkatesh, 1999). The proposed research model includes three individual difference variables and three system characteristics, besides shared beliefs items about the benefits of ERP for decision support (see Figure 1) and the selection of which are supported by prior studies in the IS literature. The following is a discussion for these variables.

Individual Differences

Individual differences are believed to be most relevant to both the decision-making process (Klenke, 2003; Lu et al., 2001; Smith, 1999) and ISs' use intentions (D'Ambra & Wilson, 2004; Kotey & Anderson, 2006; Lai & Li, 2005; Mafe & Blas, 2006; Olson & Boyer, 2003). In this study, we examined three variables concerning individual differences: demographics, computer self-efficacy (CSE), and knowledge of system.

The demographic variables or the personal characteristics selected for this research are: gender, age, and education. Previous research

Figure 1. Research model



efforts showed how information systems' use intentions differ between men and women (Lai & Li, 2005; Mafe & Blas 2006); how differences in age influence users' levels of computer anxiety and consequently use intentions (Kotey & Anderson, 2006; Lu, Yu, Liu, & Yao, 2003); and how computerized ISs' use is related to the users' level of education (Mafe & Blas, 2006; Olson & Boyer, 2003).

Besides demographics, CSE is one of the classical individual differences, usually found as an important predicator for IT usage (Compeau & Higgins, 1995) and PEOU of information systems (Agarwal, Sambamurthy, & Stair, 2000; Igbaria & Iivari, 1995). Knowledge of the system is another important individual difference that has been found as a significant contextual variable for IT/IS use intentions (Benbasat, Dexter, & Todd, 1986; Hong, Thong, Wong, & Tam, 2002). Apart from TAM suggestions of what variables to include in the research model, considering individual differences is especially important for DSSs, where higher levels of interactivity and mutual learning are expected to exist between the system and the user (Turban et al., 2005). Differences in individual characteristics will then influence how users interact with the system and consequently their use intentions.

According to TAM, individual differences usually influence PEOU, but not PU (Hong et al., 2002; Igbaria & Iivari, 1995), as shown in Figure 1. Based on the previous discussion, our related hypotheses are:

H1a: *Using ERP systems for decision making will be perceived easier for male than for female managers***.**

H1b: *Using ERP systems for decision making will be perceived easier for younger managers.*

H1c: *Using ERP systems for decision making will be perceived easier for managers with more education.*

H2: *Using ERP systems for decision making will be perceived easier for managers with higher levels of computer self-efficacy.*

H3: *Using ERP systems for decision making will be perceived easier for managers with higher levels of knowledge of the system.*

System Characteristics

The main logic behind including system characteristics in this framework is that the study deals with a relatively complex system. Consequently, we expected higher influences on factors related to how friendly their interfaces are and how relevant their functions are to the users' main tasks. The relationships between system characteristics and TAM beliefs' constructs have been investigated in many studies (Hong et al., 2002; Venkatesh & Davis, 2000). Researchers usually use a general construct that represents this variable, such as "perceived system quality" (Igbaria, Gumaraes, & Davis, 1995) or "output quality" (Venkatesh & Davis, 2000). This study relied on Hong et al.'s (2002) three system characteristics to be investigated in this research, namely: relevance, terminology, and screen design.

Relevance can be interpreted as the degree to which the system matches users' information needs. Terminology refers to the words, sentences, and abbreviations used by a system. Screen design is the way information is presented on the screen. Similar to individual differences, system characteristics are especially important for DSSs, to facilitate higher levels of interactivity between the system and the user.

However, the difference between system characteristics and the individual differences variable, according to TAM previous studies, is that it is expected to influence both PEOU and PU of TAM core constructs and not only PEOU as depicted in Figure 1 (Davis, 1989). According to the previous arguments, we expect that:

H4a: *Relevance of the ERP system will have a positive effect on perceived ease of use of the decision support tools of the system.*

H4b: *Relevance of the ERP system will have a positive effect on perceived usefulness of the decision support tools of the system.*

H5a: *Terminology clarity of the ERP system will have a positive effect on perceived ease of use of the decision support tools of the system.*

H5b: *Terminology clarity of the ERP system will have a positive effect on perceived usefulness of the decision support tools of the system.*

H6a: *Screen design of the ERP system will have a positive effect on perceived ease of use of the decision support tools of the system.*

H6b: *Screen design of the ERP system will have a positive effect on perceived usefulness of the decision support tools of the system.*

Perceived shared beliefs of benefits

A shared belief about the specific benefits of the system in the organization may play a significant role in shaping the usage intentions of that system. Obviously, this factor is important because the main benefits of ERP are traditionally referred to their transactional aspects. Therefore, it was included to investigate the items specifically related to the decision-making benefits that the system may bring. It is different than the PU variable in the TAM construct, which is usually used to measure the general usefulness of the system in question. Thus:

H7a: *Perceived shared beliefs of the decision-making benefits of ERP systems will have a positive effect on perceived ease of use of the decision support tools of the system.*

H7b: *Perceived shared beliefs of the decision-making benefits of ERP systems will have a positive effect on perceived usefulness of the decision support tools of the system.*

TAM Variables

Extensive research over the past two decades provided evidence of the significant effect of PEOU and PU on users' intentions to use an information system (Agarwal & Prasad, 1999; Davis et al., 1999; Hu, Chau, Sheng, & Tam, 1999; Venkatesh, 1999). These studies also showed that while PU has direct impact on use intentions, PEOU has direct and indirect impacts. Hence, we hypothesize that:

H8: *Perceived usefulness will have a positive effect on behavior intention to use the decision support part of the ERP system.*

H9a: *Perceived ease of use will have a positive direct effect on behavior intention to use the decision support part of the ERP system.*

H9b: *Perceived ease of use will have a positive indirect effect on behavior intention to use the decision support part of the ERP system through its effect on perceived usefulness of the system.*

METHODOLOGY

Study Context: The Kingdom of Bahrain

The Kingdom of Bahrain is a small Arabian island centrally located in the Arabian Gulf, with a monarchy rule form. Its economy depends on oil revenues. Facing declining oil reserves, Bahrain has turned to petroleum processing and refining imported crude. Also, it has transformed itself into an international banking center. Other important industries are aluminum smelting and tourism. Current population is approximately 688,000 residents of whom approximately 235,000 are not nationals. (For more details about the Kingdom of Bahrain, see http://www.odci.gov/cia/publications/factbook/geos/ba.html)

Measures

A survey methodology was used to gather data for this study. Straub's (1989) guidelines to validate the instrument of this research were followed. Items used in the operationalization of the constructs were drawn from relevant prior research and provided in Appendix A. One advantage of using TAM to examine the adoption of a specific IS is that it has well-validated measures. PEOU, PU, and behavior intentions constructs were measured by items taken from the previously validated inventory of measures and modified to suit the current context (Agarwal & Prasad, 1999; Hong et al., 2002).

The CSE instrument developed by Compeau and Higgins (1995) was used in this research. Knowledge of the system was assessed by two items suggested by Davies (1997): familiarity with using the system and knowledge about using the system for the users' specific decisions problems. Items for measuring the three system characteristics were taken from Hong et al.'s (2002) user survey and were rephrased for the context of the study's specific ISs. Perceived shared benefits were self-developed based on related previous studies such as Holsapple and Sena (2005) and Amoako-Gympah, (2005). Likert scales (1~7), with anchors ranging from *strongly disagree* to *strongly agree*, were used for all questions except for the items measuring CSE. The anchors of the items measuring CSE ranged from *not at all confident* to *totally confident*. The mean of the scores over all questions provided the composite score for each variable. The adopted instrument, along with all its items, was discussed with three industry executives from three different organizations experienced with using ERP for decision making and with two faculties. Based on their feedback, minor changes to reflect the research settings were made in the instructions and wording of some of the items. The subjects who had participated in this convenience pre-test were excluded from the final data collection and subsequent study.

Sample and Procedure

Only 10 companies were found to have prior experience in ERP systems in Bahrain. To come up with this list of companies, Vendors' Web sites (Arabian branches) were reviewed and brief telephone interviews were made with their representatives in Bahrain. The IT manager of each company was contacted to help us come up with a list of potential interviewees for the study.

The targeted informants are all the managers who use ERP systems to assist him/her in decision making. There were no restrictions on the organizational level of the manager, whether in top, mid-management, or operational level in the organization. Also, no restrictions were imposed on the functional activity where the decision makers work. The list of the potential informants had approximately 20 informants for each company. Consequently about 200 copies of the questionnaire were sent to the IT managers of these companies, who forwarded them to the targeted informants in their companies.

Before answering the questionnaire, respondents were asked whether they have enough experience in using the system for some decision-making activity or not. Only 84 interviewees returned the questionnaire (a response rate of 42%) from 8 companies. Nine of the questionnaires were dropped because seven of them had incomplete answers. The other two came from two managers who have not used the system yet, as was indicated by one of the questions in the questionnaire. Table 1 shows the companies participating in the study, while table two provides a profile of the respondents.

Table 1. Sample description: companies profile

Company	***ERP Vendor***	***Use period***	***No. of employees***
Batelco (Bahrain Telecom co)	SAP	3	1600
Asary (Arab Ship-building & Repair Yard)	Oracle	5	1200
Bahrain flour mills	Orion	1	100
Bapco (Bahrain Petroleum)	Oracle	3.5	3000
Aldhaen Craft	Oracle	3	200
GFH (Gulf Financial House)	Oracle	2	100
Alba (Aluminum Bahrain)	SAP	5	3000
Midal Cables	Oracle	4	310

Table 2. Sample description: Respondents profile

	Frequency	***Percentage***[a]
Gender		
Male	61	81
Female	14	19
Age		
Mean = 37. 7		
SD = 9.2		
Department		
Accounting & finance	25	33
Information technology	11	15
Product managers	7	9
Product marketing	7	9
Planning and project management	6	8
Other departments (engineering, logistics and procurement, production and maintenance, human resources)	19	25
Experience in management positions		
Mean = 9.3 years		
SD = 6.8		
Experience in using ERP in Decision making		
Mean = 4 years		
SD = 2.9		
Educational level		
Master's degree	22	29
Post graduate diploma	7	9
Bachelor degree	38	50
Diploma (associate degree)	9	12
Respondents from each type of business		
Manufacturing (5 companies)	33	44
Oil (1 company)	19	25.3
Telecommunication (1 company)	16	21.3
Banking and finance (1 company)	7	9.3

[a] *Due to rounding the percentage may not add up to 100*

Validity and Reliability

Reliability

Reliability is the consistency or precision of a measuring instrument that is the extent to which the respondent can answer the same or approximately the same questions the same way each time (Straub, 1989). The internal consistency reliability was assessed by calculating Cronbach alpha values. The results of the reliability test conducted for the study's constructs are summarized in the fifth column of Table 3. All alpha scores were above 0.70, which suggest an acceptable level of reliability for the study's constructs (Field, 2000).

Discriminant Validity

Since each variable was measured by multi-item constructs, a discriminant analysis should be employed to check the unidimensionality of the items. Discriminant validity was checked by conducting a factor analysis. In Table 3, discriminant validity was confirmed when items for each variable loaded onto single factors with loadings of greater than 0.5 (Nunnally, 1978). Table 3 provides the loadings of each item of the independent and the dependent variables. Nine factors emerged with no-cross construct loadings above 0.5, indicating good discriminant validity.

Based on these examinations of the psychometric properties of the scales, we conclude that each variable represents a reliable and valid construct (Field, 2000).

RESULTS AND ANALYSIS

The means and standard deviations of all the variables of the study are summarized in Table 3. A multiple regression analysis was employed to identify which variables made significant contributions to predicting the dependent variables: use intentions, PU, and PEOU, to test hypotheses H1-H9a. Also, a path analysis was used for hypothesis H9b. Path analysis is a regression-based technique widely used for studying the direct and indirect effects in models encompassing mediating variables, similar to the research model proposed in this study. The intercorrelation matrix (Table 4) was first examined to assure the validity of the regression analysis, looking for possible multicollinearity problems. All intercorrelations among

Table 3. Summary statistics, and reliability and validity analysis

Measures	*Items*	*Mean*	*SD*	*Reliability (Cronbach's Alpha)*	*Validity:(Items loadings on single factors*[a]
Behavior intention	2	5.7	0.9	0.82	0.57; 0.70
PU	3	5.6	0.9	0.91	0.79; 0.84; 0.83
PEOU	3	5.2	1.1	0.79	0.64; 0.60; 0.81
Relevance	2	5.0	1.3	0.86	0.74; 0.79
Terminology	2	4.9	1.1	0.73	0.82; 0.61
Screen design	2	4.7	1.5	0.89	0.54; 0.72
Perceived shared benefits	8	5.4	0.8	0.88	0.77; 0.78; 0.59; 0.65; 0.59; 0.60; 0.82; 0.76
Knowledge of system	2	5.4	1.0	0.85	0.74; 0.75
Computer self-efficacy	8	4.9	0.9	0.78	0.71; 0.56; 0.90; 0.57; 0.76; 0.79; 0.87; 0.81

[a] *Extraction method: Principal component analysis; rotation method varimax with Kaiser normalization; egienvalue = 1*

Table 4. Correlation matrix between variables

Measures	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*
Behavior intention (1)	1											
PU (2)	.59**	1										
PEOU(3)	.49**	.53**	1									
Relevance (4)	.33**	.46**	.35**	1								
Terminolog7 (5)	.40**	.44**	.50**	.49**	1							
Screen design (6)	.38**	.35**	.48**	.68**	.69**	1						
Perceived shared benefits (7)	.39**	.39**	.50**	.38**	.33**	.40**	1					
Knowledge of system (8)	.25*	.40**	.35**	.49**	.68**	.59**	.25*	1				
Computer self-efficacy (9)	.11	.21	.14	.16	.06	.03	.22	.24*	1			
Gender (10)	-.02	.01	-.02	-.16	.00	-.10	.01	-.05	.04	1		
Age (11)	-.03	.04	.03	.04	.06	-.03	.04	.01	-.17	-.31**	1	
Education (12)	.04	-.12	-.16	-.05	-.03	-.12	-.09	-.04	.14	-.02	-.15	1

* $p < 0.05$; ** $p < 0.01$

exogenous variables were reasonably low. Hair, Anderson, Tatham, and Balck (1995) suggest that values of $r > 0.80$ indicate a multi-collinearity problem.

The results of the regression analysis, including *B* coefficient, *t*-statistic, and significance level for each independent variable, are reported in Table 5. The first regression model showed that both PU and PEOU were found to be significant determinants of the dependent variable namely, the intentions to use the decision tools of ERP systems. Also R^2 value of the model indicated that it explains 39% of the dependent variable total variance. However, the relative strength of their explanatory power was different. PEOU ($B = 0.46$, $p < 0.001$) was a much stronger predictor of managers use intentions as compared to PU ($B = 0.25$, $p < 0.05$). The results provided support for H8 (PU—use intention relationship); and H9a (PEOU—use intention relationship).

In the second regression model, PU was regressed on perceived shared benefits, system relevance, system terminology, and system screen design. This analysis yielded a regression function ($R^2 = 0.32$, $p < 0.001$) with three significant predicators: (1) perceived shared benefits ($B = 0.23$, $p < 0.01$), (2) system relevance ($B = 0.34$, $p < 0.05$), and (3) system terminology ($B = 0.33$, $p < 0.05$). The results provided support for H4b (systems relevance—PU) H5b (system's terminology—PU); and H7b (shared benefits—PU). The findings however, failed to support H6b concerning the relationship between system screen design and PU.

Also a multiple regression method was applied to determine variables influencing PEOU. The results reported in Table 5 showed that only system terminology ($B = 0.33$, $p < 0.05$), and perceived benefits ($B = 0.36$, $p < 0.01$) have significant effects on PEOU. These variables explained approximately 40% of the variance in PEOU. Based on these results, H5a (system terminology—PEOU), and H7a (perceived shared benefits—PEOU) were also supported. The analysis failed to support H1a, H1b, H1c, H2, H3, H4a, and H6a. These concern the relationships between gender; age; education; CSE; knowledge of the system; system relevance; and system screen design, and PEOU.

Following the suggestions of Cohen and Cohen (1983), a hierarchical multiple regression was used to test the mediation hypothesis (H9b). I regressed behavior intention on PU in the first step, with

Table 5. Multiple regression results

Dependent variables	*R^2*	*Independent variables*	*B*	*t*	*Sig.*
Behavior intention	0.39***	PU	0.25	2.26	0.027*
		PEOU	0.46	4.25	0.000***
PU	0.32***	Perceived shared benefits	0.23	2.07	0.002**
		Relevance	0.34	2.51	0.014*
		Terminology	0.33	2.43	0.018*
		Screen design	-0.27	-1.27	0.210
PEOU	0.40***	Perceived shared benefits	0.326	2.95	0.004**
		Relevance	-0.054	-0.395	0.694
		Terminology	0.33	2.155	0.035*
		Screen design	0.175	1.04	0.302
		Knowledge of system	-0.066	-0.466	0.643
		Computer self-efficacy	0.082	0.756	0.452
		Gender	-0.028	-0.267	0.791
		Age	-0.004	-0.33	0.974
		Education	-0.116	-1.154	0.253

$* p < 0.05$; $** p < 0.01$; $*** p < 0.001$

Table 6. Hierarchical regression results

Regression step 1		***Regression step 2***		***Change in R^2***
R^2	*p*	R^2	*p*	
0.349	0.000	0.392	0.027	0.043

PEOU in step two. The unique contribution of PEOU (in explaining behavior intention) was examined over and above the PU variable. Table 6 showed that the change in R^2 after introducing project success into the equation is significant (R^2 change = 0.043, $p = 0.01$), giving support to the proposed mediation hypothesis (H9b). Table 7 summarizes hypotheses testing results.

DISCUSSIONS, CONCLUSIONS, AND LIMITATIONS

This study tried to contribute to the emerging research efforts concerning the convergence of ERP systems and decision support tools. We tried to provide an understanding of the different variables that influence manager's use intentions, which expectedly impact their level of adoption and usability of these systems. Following the research main framework and its groups of variables, we discuss the results as follows.

Individual Differences

In contrast with our hypotheses and most of the prior research, all the individual differences that have been considered in the research model did not influence Bahraini managers' perceptions concerning ease of use of these systems. It is interesting to find that CSE was a nonsignificant factor in this study. This might mean that man-

Table 7. Hypotheses testing results

	PEOU		*PU*		*Behavior intention*	
	No.	Support	No.	Support	No.	Support
Gender	H1a	No	---	---	---	---
Age	H1b	No	---	---	---	---
Education	H1c	No	---	---	---	---
Computer self-efficacy	H2	No	---	---	---	---
Knowledge of system	H3	No	---	---	---	---
Relevance	H4a	No	H4b	Yes	---	---
Terminology	H5a	Yes	H5b	Yes	---	---
Screen design	H6a	No	H6b	No	---	---
Perceived shared benefits	H7a	Yes	H7b	Yes	---	---
PU	---	---	---	---	H8	Yes
PEOU (direct)	---	---	---	---	H9a	Yes
PEOU (indirect)	---	---	---	---	H9b	Yes

agers do not see technical or computer skills as a significant obstacle anymore. Supporting this argument, the degree of managers' knowledge of the system was found to not be statistically influential as well. Using computer systems in the past might have been difficult or at least require significant training in order to convince users to adopt them. Even for simple systems such as e-mail, word processing, and spreadsheets, prior research showed that sufficient computer skills were required (Agarwal & Prasad, 1999; Harrison & Rainer, 1992). At the present time, a new generation of managers who are immune from the difficulties of using ISs have taken over, and computer systems have become much easier than they were in the past. Moreover, using professional assistants to help managers in using advanced DSSs is one of the common ways for bypassing the difficulty of directly dealing with such systems (Turban et al., 2005).

Besides the technical skills, the results showed that demographic differences were also not statistically influential in this research. It seems that managers nowadays are more confident in using computers than they were in the past. Their intentions in using such systems do not differ whether they are old or young, male or female, having higher or lower degrees of education. One limitation for the finding concerning gender is that females represent only 19 % of the sample.

The previous findings simply suggest that implementation plans should not have different programs for enhancing system adoption according to such individual differences. This would save our time and efforts for other more significant factors.

System Characteristics

Not all three system characteristics had significant influence on TAM variables according to the results of this study. While system terminology had a significant effect on both PEOU and PU, system relevance had a significant effect only on PU. On the other hand, Screen design did not have any influence on either. These results suggest that the vendor of these packages should give more emphasis to the terms, language, and expressions that managers use in their decision-making activities, in order to enhance adoption levels of these systems. Although both screen design and terminology represent system interface, the results did not support the role of screen design on both TAM variables. This implies that what matters in these packages is the ability to reflect the language that managers use, and not imposing other technical or nonrelated terminology that might distract their use of these systems.

On the other hand system relevance was found to have influence on PU, but not PEOU. It seems logical to find this influence on managers' perceptions of the usefulness of the system, as relevance is more related to the content of the system—not to the interface, as in the other two system characteristics. This also supports prior studies concerning the effect of system relevance on system use (Venkatesh & Davis, 2000).

Perceived Shared Beliefs

Consistent to our hypotheses, we found significant support to our expectations that shared beliefs in the benefits of the decision tools of ERP systems affect TAM constructs. This finding is especially important as ERP systems are generally known for their transactional aspects. Managers need to know the specific benefits of these systems for decision making. If management can take appropriate steps to positively influence the belief structure concerning decision-making activities of these systems, this will then lead to more acceptance of ERP systems by the organization's managers.

It is clear from the results that this factor—besides system terminology—was found to be the most important influential factor of the study. Implementation programs should then give more attention to these two factors. Training and communication programs should help form these shared beliefs. Managers should directly understand how ERP decision tools provide such benefits.

The findings of this study have implications for developing usable ERP systems for decision-making tasks. Considering the millions of dollars that have been invested in such systems worldwide, it is of paramount importance to ensure that managers will actually use them. In order to achieve this goal, attention must be placed in designing user-friendly interfaces that emphasize manager-familiar terminologies. At the same time, developers of ERP systems should keep in mind that, although these interface-related system features may appeal to users in the early stages, their final decision on whether to use a system or not, depend on the content of the decision tools of these systems. Specifically, it depends on how relevant these systems are to managers' decision problems.

On the other hand, implementation programs for these systems should have a strong training and communication scheme in order to provide clear understanding of the specific benefits of these systems to decision makers.

This research has several limitations. First, we did not incorporate actual usage behavior in the proposed model. However, this is not a serious limitation as there is substantial empirical support for the causal link between intention and behavior (Venkatesh & Davis, 2000; Venkatesh & Morris, 2000). Second, there may be other individual and external variables that may affect the intention to use these approaches. Future research can incorporate other variables into the research model. Potential individual differences include managers' cognitive styles and decision styles, which have been repeatedly used in TAM applications in previous cases (Harrison & Rainer, 1992; Hong et al., 2002). Some other contextual factors, such as IT capabilities, outsourcing, and degree of strategic focus have been included in relevant research studies (Bhatt, 2000). Future research can examine whether these factors have any influence on the acceptance of decision tools of ERP systems.

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APPENDIX A. SURVEY INSTRUMENT

The different opinions are indicated by the numbers 1: strongly disagree; 2: disagree; 3: somewhat disagree; 4: neutral; 5: somewhat agree; 6: agree; 7: strongly agree.

Perceived Usefulness (PU)

1- Using the system in my job enabled me to accomplish tasks more quickly.
2- Using the system in my job increased my productivity.
3- Using the system enhanced my effectiveness on the job.

Perceived Ease of Use (PEOU)

1- I found it easy to get the system to do what I wanted it to do.
2- It would be easy for me to become skillful at using the system.
3- In general, I would find the system easy to use.

Use Intension

1- I intend to use the system.
2- I intend to increase my use in the future.

Computer Self-Efficacy (CSE)

1- I could complete the job using the software even if there was no one around to tell me what to do.
2- I could complete the job using the software if I had only the software manuals for reference.
3- I could complete the job using the software if I had seen someone else using it before trying it myself.
4- I could complete the job using the software if I could call someone for help if I faced a problem.
5- I could complete the job using the software if someone else had helped me get started.
6- I could complete the job using the software if I had a lot of time to complete the required job.
7- I could complete the job using the software if I had just the built-in help facility for assistance.
8- I could complete the job using the software if someone showed me how to do it first.

Knowledge of the System

1- I am familiar with using the system.
2- I am knowledgeable in using the system to make my decisions.

Beliefs about using ERP system for decision support

1- The system enhances decision makers' ability to tackle large-scale complex problems.
2- The system shortens the time associated with making decisions
3- The system reduces decision-making costs.
4- The system encourages exploration on the part of decision makers.
5- The system enhances communication among decision-making participants.
6- The system improves coordination of tasks performed by an individual making a decision.
7- The system improves satisfaction with decision outcomes.
8- The system improves organizational competitiveness.

Terminology

1- I understand most of the terms used throughout the system.
2- The use of terms throughout the system is consistent.

Screen Design

1- The system commands are well represented by buttons and symbols.
2- The layout of the screens is clear and consistent.

Relevance

1- The resources in the system relate well to my work
2- The system has enough resources for my work

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Chapter 3.20

Supply Chain Management and Portal Technology

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INTRODUCTION

The role of corporate portals as tools for managing organizational knowledge has been constantly changing throughout their short lifetime. An important recent advancement in the functionality of portals is their ability to connect companies together, joining internal and external knowledge sources to assist in the creation of valuable knowledge. Nowhere is this increased functionality and utility more evident than in the use of portals to manage the supply chain.

A common trend in supply chain management (SCM) is the formation of one central strategy for the entire production network, which involves going beyond an organization's external boundary. This represents a shift from a commodity-based approach to SCM to a more collaborative and relationship-building strategy. As this "extended enterprise" comes into being, an extended IT infrastructure is needed. Systems, such as portals, that assist in spanning organizational boundaries and ensuring a timely information exchange can help support this strategy. Portal technology allows the IT infrastructure of one firm to span multiple organizations and be utilized by many (Dyer, 2000). The globalization of supply chains also presents an opportunity for the utilization of portal technology (Tan, Shaw, & Fulkerson, 2000). Geographically dispersed organizations have an increasingly greater need to share information, even though they experience issues with systems spanning different processes, cultures, and vast distances. A portal's ability to utilize the Internet can assist in the networking of such distributed firms.

The fundamental resource required for these extended organizations is knowledge, whether it is knowledge of markets, supply conditions, manufacturing, and logistical strategies, or of a supply partner's needs and capabilities. As knowledge is a resource characterized by "perfectly increasing returns" (Dyer, 2000, p. 61), knowledge can flow within a supply network and dramatically add value for all members. A small innovation at one end can often have a ripple effect through the supply chain, and result in a significant development at the other end. All forms of supplier networks require supporting technology to facilitate the creation and utilization of supply knowledge, and portal technology is often fulfilling this need.

BACKGROUND

Supply chain management can be defined as " … a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system-wide costs while satisfying service level requirements" (Mak & Ramaprasad, 2003, p. 175). This, in essence, states that SCM must create an infrastructure of knowledge and information that facilitates the integrated operations of supply chains. Knowledge supply chains emerge that are "… integrated sets of manufacturing and distribution competence, engineering and technology deployment competence, and marketing and customer service competence that work together to market, design, and deliver end products and services to markets" (Mak & Ramaprasad, 2003, p. 175).

Handfield and Nichols (2002) stress the importance of relationships in a supply chain, which they define as " … the integration and management of supply chain organizations and activities through cooperative organizational relationships, effective business processes and high levels of information sharing to create high-performing value systems…" (Handfield & Nichols, 2002, p. 8). In this view, the supply chain should encompass the management of information and knowledge systems in order to be successful.

Simply, a supply chain consists of the following processes within the network: buying raw materials, making and designing products, inventory management, selling to customers, and delivery of products (Poirier & Bauer, 2001). Whether done by one stand-alone firm (known as a vertically integrated firm), or a network of firms (dispersed in their business functions), each of these processes contributes to the product design, manufacturing, selling, and delivery to the customer. Portals, through their unique enterprise-wide architecture, contribute to the information and knowledge-sharing needs of each process. The following sections will examine the potential contribution of portal technology.

THE DEVELOPMENT OF SUPPLY CHAIN PORTAL TECHNOLOGY

Portal technology has emerged as an enabler of supply chain strategies, offering increased distributed access to partners through standard technology applications and processes. Initially, many larger organizations adopted electronic data interchange (EDI), an electronic messaging standard defining the data formats for the exchange of key business documents across private networks or the Internet. The Internet became important during the mid 1990s with the emergence of the World Wide Web and the adoption of HTML. Companies began to convert their EDI information exchange technologies to HTML, and later standardized XML formats in order to take advantage of greater selection of business applications, and the increased availability to all partners offered by the Internet. But for many organizations, the Web connection has become a strategic tool that strengthens the buyer-supplier relationship through establishing broad information connections that have a major impact on the overall supply strategy (Zank & Vokurka, 2003).

Initially, portals were used as an intrafirm system linking various functional areas of an organization together to share information. Usually linking various modules of an enterprise resource planning system (ERP), they allowed information to flow between the traditional silos of a business. Purchasing, engineering, manufacturing, logistics, and accounting could now receive and utilize data from all points along an internal supply chain (Handfield & Nichols, 2002).

Supply chain portals evolved to become the first interfirm portals to be commercialized and are now central to addressing the challenges of interfirm portals. Facilitating the flow of information and knowledge through every supply chain business process, supply chain portals extend the capability of members to share information and plan operations based on each other's activities. As production supply chains become more integrated as a result of increased information flows, the initial stage in the production chain, the product design and development stage, is increasing its level of interfirm information and recently knowledge sharing. Both formal and informal sources of knowledge contribute to the successful design and development of new products and processes, and much of this information must come from sources external to the organization such as customers and supply chain partners (Paquette & Moffat, 2005).

COLLABORATION IN SUPPLY CHAINS

In a supply alliance or collaborative agreement between two companies, the goals may include a reduction in transaction costs, the maximization of profit or increased learning, and knowledge transfer (Kogut, 1988). This knowledge transfer allows for supplier knowledge, engineering, and manufacturer capabilities to be an input into the product design process, which impacts the performance of new product development (Hong, Doll, Nahm, & Li, 2004). Supply-chain knowledge transfer requires integrating the flow of information and knowledge between various members of the supply chain to allow for the optimal management of supply.

Two different models of SCM are currently practiced in most industries (Paquette & Moffat, 2005). In traditional commodity-based supply-chain management, as practiced by most North American firms, suppliers are kept at arm's length in order to minimize commitments and dependence on specific suppliers and to maximize bargaining power. This *commodities supply chain model* is widely used with the goal of achieving cost savings under competitive pressures. In this model, supplier relationships are very limited to minimize switching costs. Networking technologies (such as portals) may be used to overcome the barriers of supply cost and complexity (Williams, Esper, & Ozment, 2002) and make decisions based upon efficiency benefits.

The commodity model operates in contrast to the "close collaboration" supply-chain model, which is based on the Japanese practice of creating strong partnerships through close collaboration with long-term supply partners. In the *collaboration* model, supply partners share more information and coordinate more tasks, use relation-specific assets to maintain lower costs, improve quality and increase speed, and rely on trust to govern the longer-term relationship (Dyer, Cho, & Chu, 1998). A key factor in the success of the *collaboration* approach is the close task integration between supply partners, which is enabled by the transfer of information and knowledge.

In this model, closely integrated and strategically developed supply networks with well-connected relationships at the core of the supply structure can be used to produce a strategic advantage (Williams et al., 2002). The same interfirm networking tools, including supply chain portals, are becoming the key enablers of supply-chain integration. Knowledge becomes a valuable asset and is shared through the use of these portal technologies, along with critical supply-chain information. Toyota, who has established portal-linked supplier knowledge networks that create shared goals, promote knowledge-sharing activities, and exchange best practices, is an excellent example. Not only is valuable knowledge created through the use of technology, but relationships within the supply chain are strengthened. The results have been output per worker increasing 14%, inventories reduced by 25%, and defect rates 50% lower than operations that supply Toyota's rivals (Dyer & Hatch, 2004).

SUPPLY CHAIN COLLABORATION WITH PORTAL TECHNOLOGY

As previously discussed, a supply chain incorporates processes involving buying, making, inventory, selling, and delivery. Each of these processes can benefit from an extended enterprise structure supported by portal technology. Through the increased information and knowledge sharing provided by portals, these functions can evolve into mature processes offering an organization a competitive advantage.

The buying function of a supply chain procures the necessary materials required for the product of the goods and services. In order to lower costs by leveraging combined purchasing volumes, a portal can link the network's buyers into one central purchasing function, allowing for controlled costs and the ability to negotiate lower costs based on volumes from the entire network. Standardized items can be designated, allowing for further standardization throughout the network. Tracking information for purchases can be made available to the entire network, allowing for production and sales planning at the other end of the supply chain. Notification of supply shortages or delays can be shared with network participants, allowing them to plan their schedules accordingly. Ultimately, a purchasing partnership may emerge, which is "... an agreement between a buyer and a supplier that involves a commitment over an extended time period, and includes the sharing of information along with a sharing of the risks and rewards of the relationship" (F.-R. Lin, Huang, & Lin, 2002, p. 148).

The making of goods and services, which would include the product design and development functions, can gain a great deal of value from portal technology. In supply chains following the collaborative model, network partners face the challenge of connecting with their partners to exchange product requirements information (Lin, Hung, & Wu, 2002). Portal applications supporting production chain collaboration should allow for the acquisition, sharing, optimization, and utilization of these requirements between customers and partners to detect any discrepancies or gaps within the requirements. Concurrent engineering (McIvor, Humphreys, & McCurry, 2003) supports collaborative product design processes through connecting multifunctional teams comprising of design and manufacturing employees and customers and suppliers. Portal technology linking supply chain applications can play a major role in supporting such concurrent engineering. Collaborative work applications implemented by all partners across the supply chain can be instrumental in the development of specifications, creation of interchangeable parts, part standardization or simplification, and part exclusion, all of which contribute towards cost reduction. Huang and Mak (1999) describe such a system consisting of ”virtual consultants” in ”virtual teams” organized within a “virtual office” equipped with “virtual design board,” available to all participants no matter where they are located, whether internal or external.

Cycle time is a key measurement for determining the efficiency of inventory processes. The goal is to reduce the time raw materials are delivered to customers in the form of finished products. Location of inventory can be a factor in reducing cycle time and ensuring prompt responses to a customer's needs. As well, excess or safety inventory must be managed through demand forecasting and tracking. Information and knowledge sharing can easily locate needed inventory stocks that maybe have been "hidden" to other partners in the past, or highlight ways to reengineer processes in order to speed the movement of inventory through the supply process. Initiatives, such as a continuous replenishment program (CRP), vendor-managed inventory (VMI), or quick response program, all rely on the dissemination of shipping and manufacturing information to externally distributed parties (Tan et al., 2000). Recently, portals have begun to play a key role in facilitating this information and knowledge sharing and enabling such programs.

The selling and marketing processes of the organization's goods and services are a large benefactor of portal technology. To ensure the products are targeted towards the correct markets, knowledge must flow across an organization's external boundary from its customers. Knowledge on product uses, market information, and channel information is necessary for the development of new successful products and services (Paquette, 2005). Information contained within customer relationship management (CRM) applications can also be supplied through portal technology to all members of the supply chain, ensuring a focus on the customer and consistent information throughout. Many supply chains with a mature portal technology infrastructure can directly link customers into their systems, allowing for point-of-sale ordering that creates an instant response and a rich stream of information (Kahl & Berquist, 2000).

In processes involving product delivery, logistical issues such as shipping dates, route mapping, delivery costs, and the development of a physical supply network arise. Just-in-time delivery has become a goal for many companies who wish to not only minimize the costs of carrying inventory, but manufacture and deliver the product based on information received from a customer. This requires all partners within the chain to have access to the same customer and manufacturing information, and an efficient supply network capable of handling such timely requests. Portals support this information, as when a customer order is received, all aspects of the chain can prepare for manufacturing and delivering the item, reducing the time for delivery and increasing customer satisfaction. Companies evolve from make-and-sell strategies to sense-and-respond capabilities (Bradley & Nolan, 1998). Trends in orders can be identified through this information, and capacity plans, material allocation, and supplier notification can all be adjusted accordingly (Handfield & Nichols, 2002).

COLLABORATIVE CHALLENGES

A common challenge with the networking of a supply chain is the integration of many technologies and applications that must work together to share similar information and knowledge (Cohen & Roussel, 2005). This problem of systems complexity can be minimized through the use of portal technology that integrates multiple applications and platforms in order to eliminate "application islands."

Specifically, the network of partners must come to an agreement on system interfaces and standards. Three kinds of system interfaces can create issues: (1) the agreement on or standardization of the interfaces of business processes that facilitate supply chain integration; (2) the agreement on or standardization of the interfaces of the systems and components that together constitute the product and services the supply chain delivers to the markets; and (3) the agreement on or standardization of the interfaces of the information systems that support the collaboration and integration of the supply chain's operations. Portals have an advantage through their use of "portlets," or small applications, that manage the interface with other applications and portals to allow for seamless information and knowledge sharing. All aspects of the portal's system interface must be in agreement and well developed in order for the supply chain's collaborative effort to be cost effective and efficient (Mak & Ramaprasad, 2003).

Access and security becomes a challenge when dealing with such a distributive network. As the access points of the system increase, so does the possibility of unauthorized or improper access to confidential information. Portals utilizing proper security measures, including firewalls, digital certificates and encryption, and virtual private networks (VPNs) for transmitting across public Internet networks, can minimize the risk of revealing proprietary and strategic information to competitors (Lee & Wolfe, 2003).

FUTURE TRENDS

As the role of information and knowledge becomes more important in the management of a supply chain, so will the role of portal technology. The demand for information to be timely, accurate, and detailed allows a portal to connect various members of a supply chain and deliver such information.

Previous research on the portal industry and its role in supply chains (Paquette & Moffat, 2005) has demonstrated that portal vendors will have to continually improve the functionality that both supports secure high-volume interfirm interaction across large geographical distances, and also functionality that supports the exchange of tacit and experiential knowledge to enable learning. New portal functionality specifically for collaborative design development and real-time test during the creation of new products will enhance the ability of portals to improve the efficiency and effectiveness of a company's new product development and delivery processes. Creating a shared environment that supports white-boarding, 3-D drawing support, video conferencing, document coauthoring and sharing will be part of a portal's role in supporting the collaborative supply chain.

CONCLUSION

As supply chains continue to move away from a commodity-based and more towards a collaborative model, their need for timely and accurate information throughout the supply network will increase. This demand allows for portal technology to be deployed in order to meet the interfirm information and knowledge-sharing needs. From the design and development of new products to their marketing and delivery, portals can supply the supply chain with the information required to meet the cost and time requirements of customers.

Portal technology can create a competitive advantage for a supply chain by enabling its information and knowledge-sharing capabilities to provide organizations with up-to-the-minute information regarding new products, customer demand, inventory status, and production schedules. As Internet technologies, and in particular portal applications, become more common amongst supply-chain members, their ability to create, identify, and utilize critical supply information will lead them to new levels of service, innovation, and success.

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KEY TERMS

Collaborative Relationship: A form of supply-chain management relationships where supply partners share large quantities of information and coordinate many tasks, use relation-specific assets to maintain lower costs, improve quality and increase speed, and rely on trust to govern the longer-term relationship. A key factor in its success is the close task integration between supply partners that is enabled by the transfer of information and knowledge.

Commodity Relationship: A form of supply-chain management relationships where suppliers are kept at arm's length in order to minimize commitments and dependence on specific suppliers and to maximize bargaining power. It is widely used with the goal of achieving cost savings under competitive pressures by keeping supplier relationships very limited to minimize switching costs.

Just-in-Time Inventory: The process where inventory is delivered to the factory by suppliers only when it's needed for assembly. It facilitates the cost-effective production and delivery of only the necessary parts in the right quantity, at the right time and place, while using a minimum of facilities, equipment, materials, and human resources. Its purpose is to eliminate any function in the manufacturing system that causes overhead, slows productivity, or adds unnecessary expense.

Supply Chain: The integration and management of supply chain organizations and activities through cooperative organizational relationships, effective business processes and high levels of information sharing to create high-performing value systems.

Supply Chain Management: A set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system-wide costs while satisfying service level requirements.

Vertical Integration: A supply-chain strategy whereby one business entity controls or owns all stages of the production and distribution of goods or services. It is the extent to which a firm owns its upstream suppliers and its downstream buyers. Control upstream is referred to as backward integration (towards suppliers of raw material), while control of activities downstream (towards the eventual buyer) is referred to as forward integration.

Virtual Private Network (VPN): A data network that uses public telecommunications infrastructures, such as the Internet, but maintains privacy through the use of a tunneling protocol and security procedures. A VPN gives a company the same capabilities as a system of owned or leased lines to which that company has exclusive access.

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Chapter 3.21

CRM Practices and Resources for the Development of Customer-Focused Multinational Organizations

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ABSTRACT

This chapter aims to provide a complete characterization of the different perspectives of customer relationship management (CRM) and its potentialities to support knowledge management practices in a multinational context. It describes the strategic and technological dimensions of CRM and how its adoption supports the development of a learning and customer-focused organization, with special emphasis on multinational corporations. CRM strategic approach entails the adoption of customer-focused initiatives and the development of learning relationships with customers. On the other hand, its technological dimension integrates a variety of different information and communication technologies, which makes a powerful system for improving the process of knowledge acquisition. This way, different subsidiaries of a multinational corporation can develop their learning capability so that they can better identify local market demands. As a result, the corporation is able to more accurately create a global knowledge stock about its different markets in different regions of the world.

INTRODUCTION

The current world is witnessing profound developments in the areas of information technology and business strategy. In the technological area, recent developments have led telecommunication technologies to reach a high level of integration with computing technologies and vice versa. This trend has had a strong impact upon society, promoting, among other things, an enlargement of the conceptual focus of information technologies to embrace the notion of relationship technologies. Regarding business strategy aspects, companies are creating a sound and lasting competitive advantage by adopting "relationship" as the word of order. As a matter of fact, the confluence of changing customer demands, emerging marketing and business theories, and available information and communication technologies (ICTs) have been imposing a shift on the way organizations relate to customers. The gap between strategic marketing approaches and ICT deployment has been diminished over time, culminating in integrated business approaches that involve both strategic and technological dimensions at the same time. This chapter focuses on the integration of knowledge management (KM) and customer relationship management (CRM) approaches.

At the same time as the rise of new ICTs, there has been the development of CRM and KM approaches for enhancing both relationship strategies and organizational learning capabilities. For instance, the evolution and integration of different ICT over time enabled the adoption of different and more evolved marketing approaches, giving birth to the present CRM systems. These systems support the development of current relationship strategies, which, in turn, were delineated by the evolution of marketing relationship strategies over time. On the other hand, market knowledge—which is directly related to information about customers and other environmental elements—and internal knowledge have become a strategically important resource for an organization, serving as a basic source of competitive advantage (Cui, Griffith, & Cavusgil, 2005).

In practice, CRM systems provide the functionality that allows an organization to make its customers the focal point of all departments within the firm. This way, the organization will be able to respond to its customers on a continual basis. More specifically, customer information databases and integrated interactivity enable an organization to develop a learning relationship with its customers, creating organizational capability to differentiate customers and markets, and to develop personalized interactions so that tailored products or services can be offered. In the context of multinational organizations, the adoption of CRM practices and solutions can improve the process of knowledge acquisition in different local markets, allowing multinational corporations to define and develop both local and global strategies according to regional demands. For example, in a multinational environment, CRM allows different subsidiaries to develop long-term learning relationships with their local customers, which makes the creation of specific business intelligence concerning local market demands possible.

In other words, CRM can be considered as a key element for supporting knowledge management in multinational organizations. Its strategic approach entails the adoption of customer-focused initiatives and the development of learning relationships with customers. On the other hand, its technological dimension integrates a variety of different information and communication technologies, which makes a powerful system for improving the process of knowledge acquisition. This way, different subsidiaries of a multinational corporation can develop their learning capability so that they can better identify local market demands. As a result, the corporation is able to more accurately create a global knowledge stock about its different markets in different regions of the world.

The strategic and technological dimensions of CRM are extremely intertwined and, as a matter of fact, the emergence of CRM strategies, concepts, and practices would not be possible without the appearance of new and evolved ICT resources. This chapter aims to provide a complete characterization of the different perspectives of CRM, describing its origins, concepts, paradigms, technologies, and its potentialities to support knowledge management practices. Considering that the adoption of CRM practices and solutions can generate substantial knowledge about an organization's customers, this chapter aims to describe the strategic and technological dimensions of CRM and how its adoption supports the development of a learning and customer-focused organization, with some special emphasis on multinational corporations (MNCs).

By reading this chapter, the reader can get a better and deeper understanding of the following aspects:

- What CRM is
- The strategic and technological dimensions of CRM
- The main challenges of CRM implementation
- CRM measurement aspects
- Practical considerations regarding CRM adoption
- The main CRM supporting roles to KM in a multinational context

ORIGINS AND CONCEPTS OF CRM

The acronym CRM per se does not explicitly convey what it is about. Sometimes it represents an information system, other times it represents a strategic business approach. Different authors interchangeably use CRM to address one thing or another, which may cause some confusion as to whether they are talking about an information system or a business strategy. The problem is that CRM strategies have emerged together with the information and communication technologies that allowed their practical implementation and feasibility. In terms of technological developments, underlying technologies are becoming less operationally complex and less expensive, and so their facilities and resources are being increasingly used by people, enterprises, and governments. The Internet, for example, is a key information technology that can also be viewed as a relationship technology. It is perhaps as a consequence of the ubiquity of such technologies that organizations have been focusing on relationship strategies. Turning to the business strategy aspects, companies are creating a sound and lasting competitive advantage by developing long-term learning relationships with their customers. At the same time as the rise of new information and communication technologies, there has been the development of the CRM concepts for implementing relationship strategies that enable sound organizational learning capabilities.

The Origins of CRM

CRM has its roots in relationship marketing strategies and its antecedents. As a matter of fact, developing good relationships with customers is a very old practice; as Sterne (2000) well illustrates, since the mid-eighteenth century pharmaceutical retailers in Japan have been practicing relationship management with their clients. Individual families are regularly visited by sales representatives, who review the contents of their company-issued medicine cabinets. The items that have been used are replaced, and the items that have not are either removed or replaced according to their expiry dates. Of course, on a small-scale context, such practice is completely feasible; however, on a large-scale context it becomes unviable.

With the development of mass media communications such as the printed press, radio, and TV, companies became able to communicate to millions of people at once. Gummesson (1999) points out that, during the industrial era, mass manufacturing gave birth to mass marketing and mass distribution. There were no technologies to address individuals. As a result, the marketing focus has changed from customer to product and brand recognition. The approach of personalized services was disregarded until new technologies appeared to foster new approaches. Table 1 provides a complete view of the different evolutionary phases of marketing strategies over time.

Of course, direct sales force and telemarketing efforts have not vanished, nor have mass marketing strategies been totally discarded. Naturally, if a company is successful in acquiring new customers, then at some moment it will reach a large-scale context; consequently it will need mass approaches. In many companies, different

Table 1. Evolutionary phases of marketing strategies (Source: Adapted from Ling and Yen, 2001)

PHASE	TIME PERIOD	FEATURES	DRAWBACKS
Direct Sales	Since long ago	Small stores; personalized services; intimacy and knowledge about customers; developed loyalty and trust	Cost inefficiency; small scale of business
Mass Marketing	After industrial era	Centralized large-scale production; wide-geographic distribution; one-way communication; cost efficiency; measure of success: market share	Does not have the sense of connection; low loyalty
Target Marketing	Since mid-1980s	Use IT to target customers by mail or telephone; direct communication with the target; potential reception of direct responses; measure of success: response rate	Interaction at a superficial level, not far enough; lack of more detailed customer data
Relationship Marketing	Since 1990s	Develops intimacy by using IT and maintaining mass production and distribution; recognizes that both knowledge and personal interaction yield trust and loyalty	Difficult to implement; involves various business functions; mainly for consumers instead of industry

marketing strategies are being combined to approach customers. However, it has been reported that there is a lack of cohesion between these strategies, which sometimes leads to confusion as customers receive multiple and uncoordinated messages through separate channels (Ling & Yen, 2001).

Instead of perceiving CRM as a revolutionary business strategy that came to substitute all the ones that preceded it, it would be more coherent to perceive CRM as a business strategy that proposes personal interactions even in a mass context, taking advantage of the strengths of previous approaches. This kind of large-scale personalization is perfectly feasible through the application of current information and communication technologies. Indeed, the availability of highly evolved telecommunication and information technologies was crucial for enabling CRM practices.

Concepts of CRM

Generically speaking, CRM is a term interchangeably used to refer to ICT or business strategies that improve an organization's capability to develop lasting and learning relationships with its customers. These two perspectives of CRM (technological and strategic) are extremely intertwined; however, CRM is more than a different way of applying existing technological and marketing tools and managing them. From a strategic point of view, CRM can be understood as an organization's broad business strategy, which focuses on building customer-personalized interactions whatever the channel of contact between the organization and its customers (Business Guide, 2000). Given its amplitude, it is fundamental to be aware that the implementation of CRM strategy is not just the responsibility of the marketing department or other customer service sectors. For Ling and Yen (2001), CRM is a broad strategic business process that involves the organization as a whole, spanning across different business functions rather than just within a particular product or business unit. They also affirm that CRM comprises a set of enabling systems that supports a business strategy to build lasting and profitable relationships with customers. A better understanding of customer needs and preferences is the way to enhance customer value, and this aspect is one of the major objectives of CRM.

It can be argued that CRM concepts have also evolved alongside the evolution of information and communication technologies. Making an analogy with Peppers and Rogers' (1993) characterization of today's media, we can identify three important characteristics of today's information technologies: (1) they can address individuals, (2) they are two-way channels, and (3) they are economically accessible. These technological aspects support the implementation of a chief strategy that is at the core of CRM philosophy: the one-to-one approach, which is mainly based on the development of personalized interactions between an organization and its customers. This approach is considered by Kandell (2000), who affirms that CRM involves the use of technology to identify, interact, and track every transaction with individual customers, developing a learning relationship with them. A clearer and more straightforward definition of CRM is provided by Buttle (2004), according to whom:

> *CRM is the core business strategy that integrates internal processes and functions, and external networks, to create and deliver value to targeted customers at a profit. It is grounded on high-quality customer data and enabled by IT.* (p. 34)

Taking into account the definitions and concepts we have seen thus far, it is possible to notice that its holistic business approach and information technologies are elements usually present when the CRM subject is addressed. Therefore, it is imperative to further characterize these two dimensions of CRM in a more specific way for further discussion. In the next two sections, we are going to expand on the strategic and technological aspects of CRM.

STRATEGIC ASPECTS OF CRM

Marketing concerns have progressively shifted from developing, selling, and delivering products to developing and maintaining a mutually satisfying long-term relationship with customers, as enduring relationships with customers provide a unique and sustained competitive advantage that is hard for a competitor to duplicate (Buttle, 1996). This latter argument might explain the fact that recent surveys indicate that CRM is becoming a major element of corporate strategy for many organizations throughout the world, and its implementation is considered a key aspect for the future performance of organizations (Abbott, Stone, & Buttle, 2001; Hansotia, 2002). Looking at some statistics of CRM growth rates, according to a report from The Conference Board,[1] more firms are adopting CRM programs. Fifty-two percent of 96 global firms recently surveyed by The Conference Board have implemented a CRM system or solution. Among these, the top three strategic rationales for implementing CRM were to: (i) increase customer retention/loyalty (94%); (ii) respond effectively to competitive pressures (77%); and (iii) differentiate competitively based on customer service superiority (73%). Across all surveyed firms, half of the total marketing investments were toward driving revenue, while one-third went towards building relationships. The average strategic time horizon employed for the CRM project was almost three years, with an average estimated implementation time of four years. In terms of market value, the numbers show that CRM is a phenomenon not to be ignored. In 2000, Kandell (2000) commented that the CRM market would be worth more than $16 billion by 2003. Two years later, a Gartner Group report showed that organizations worldwide paid $23 billion for CRM services and software, and that amount was expected to rise to $76 billion in 2005 (Pang & Norris, 2002). It can be argued that the differences between the reported numbers were due to different analysis criteria. Despite the differences, the numbers showed that CRM is a billionaire market. The high amounts involved can be explained by the fact that the range of CRM solutions is very broad, and it requires integration and improvements in information and communication technologies to enable the adoption of customer-oriented strategies.

A central practice in CRM strategy is to exploit customer insight and information to create profitable customer relationships (Abbott et al., 2001). Indeed, each customer interaction produces extensive data; the purpose of CRM is to make inferences over this data in order to allow an organization to identify patterns of customers' consuming behavior as well as to identify customers' profiles, needs, wants, and preferences. To achieve continuous improvement, an organization should track the results of customers' interactions and use such knowledge to refine further actions (Ling & Yen, 2001). This practice is reputed to promote the following organizational benefits:

a. **Retention of existing customers** through the process of anticipating offers according to customers' expectations over time and delivering personalized goods and services according to the customers' profile (Sterne, 2000).
b. **Acquisition of new customers** by prospecting and analyzing peoples' first contacts so that potential customers' interests can be matched (Buttle, 2004).
c. **Building of customer loyalty** through the process of listening, understanding, and responding according to customers' needs, wants, and behavior (Business Guide, 2000).
d. **Raising of customer profitability** through the process of providing high targeted solutions according to the customers' value (Ling & Yen, 2001; Khirallah, 2000).

Other benefits such as the improvement of customer lifetime value, raising of customer satisfaction, execution of faster services, costs reduction, improvement of sales force, better response rates, and so forth are also claimed to be promoted by the adoption of CRM initiatives (Kandell, 2000; Khirallah, 2000; Sterne, 2000; Buttle, 2004). Besides, Silverman (2001) comments that successfully implemented CRM strategies can promote a high return on investment. He argues that statistics from different sources show that organizations that have successfully adopted CRM enjoy higher prices and profit margin, faster growth rates, lower customer turnover, and an increased market share.

The benefits addressed thus far constitute strong reasons for CRM adoption. In order to achieve the organizational benefits we previously commented on, an organization should develop the ability to efficiently and effectively leverage customer information so as to design and implement customer-oriented strategies. The development of customer-focused strategies represents the heart of CRM tenets. As Hansotia says, CRM strategies are:

> …*strategies that celebrate differences in customers' values, potentials, needs and preferences. It is about leveraging customer knowledge to get closer to customers by anticipating their needs and communicating intelligently with relevant offers and messages, while all the time nudging them to increase the breadth, depth and length of their relationship with the firm.* (Hansotia, 2002, p. 122)

Moreover, CRM entails the management of customer interactions so that an organization can leverage customer knowledge to design and provide unique services and memorable experiences that customers will value and will be willing to pay for. To have a long-term effect, each experience must exceed expectations adding to the customers' stock of goodwill toward the company. The interactions should be reasonably frequent, error free, and quickly meet customers' needs and wants (Hansotia, 2002).

It is important to point out that, in order to meet customer particularities at a maximum level, customers' differences and common patterns should be observed. These insights are obtained by developing segmentation schemes. As Hansotia (2002) describes, segmentation techniques can be used to characterize and help understand different customer groups. Segmentation methods aim to group customers according to their preferences for products, services, channels of interaction, and the magnitude and frequency of their interactions with an organization. Once different behavioral segments are identified, each segment can be further profiled with additional information, such as survey-based attitudinal and satisfaction data. In the end, the organization will be able to learn, for instance, what the most profitable customers look like, which customers have a high propensity to buy certain products or services, or who the high-risk customers are. Hansotia (2002) also warns that prior to selecting the basic variables and dimensions that will be used to construct the segments on which customers' differences are to be observed, significant discussions should take place.

Indeed, the adoption of CRM strategies requires the commitment of an organization's administrative first echelon, demanding wide organizational discussions that involve not only the chief executive officer (CEO), but also all his or her direct reports. This is because CRM adoption usually presses for fundamental cultural shifts within organizations as well as new forms of organizational structure that might challenge current norms and practices (Abbott et al., 2001). Therefore, it is paramount that an organization revisits its mission statement to certify that it clearly addresses the company's focus on the customer, ensuring that CRM strategies tie in with the overall organizational mission and related strategies (Hansotia, 2002). This latter aspect is further detailed next.

Further Strategic Considerations

Strategic management considerations are vital for successful implementations of CRM solutions. Knowing how to introduce strategic changes is the major challenge facing executives acting in a business environment characterized by rapidly advancing technology and fierce competitiveness.

Strategic management deals with the overall direction of an organization, involving decisions regarding very important issues such as financial investments, technological improvements, and the well-being of the people who might be affected by the firm's activities. According to Finlay (2000), the number of people contributing to strategic management has increased considerably over the past decade. This is because organizations are realizing that the implementation of successful change is easier when made by the people responsible for the implementation and by those affected by the change. In practice, lower-level managers interact much more with the organization's main stakeholders, picking up trends in the environment and marketplace, and passing the information to the senior managers who can authorize action. This way, strategic management can be seen as a process where each of an organization's sub-units initiates much of its own strategy, contributing to form the organizational strategy (Thompson, 1997). Despite the advantages, if the process is not conducted in a coordinated manner, the sub-units' initiatives will not be consolidated at a higher organizational level and the solutions will remain fragmented within the sub-unit silos. Another important aspect is that the sub-units' initiatives should meet and strengthen the corporate strategic goals.

Therefore, it is extremely important for an organization to establish and communicate its vision, mission, and strategic goals to all its stakeholders. Basically, the organizational vision can be understood as a view of a future intended by an organization. Based upon this vision, the organization formally states its mission, which is a formal statement of the broad directions that the organization wishes to follow. The mission should contain a broad indication of the organization's offers and customers. Finally, the strategic goals are a formal establishment of an organization's purpose, setting out the scope of the organization's operations. Finlay (2000) warns that suitable goals should be relevant to the mission. This latter aspect is also addressed by Rowe, Mason, Dickel, Mann, and Mockler (1994) when they comment that organizational goals are chosen to align the organization more closely with its values and mission. They also point out that establishing goals and finding strategies that lead there [to the goals] are fairly straightforward tasks. However, there are difficulties when organizations attempt to take the stakeholders' interests into account. This latter concern is shared by Finlay (2000) when he positions the organization's relationships with stakeholders among the major strategic management concerns, namely:

- Matching the organization and its environment
- Initiating and handling both evolutionary and transformational change
- Managing the organization's relationship with stakeholders
- Balancing short- and long-term considerations

Increasingly, diverse groups are making claims as stakeholders in organizations. A stakeholder analysis should begin with the identification of as many relevant stakeholders as possible (Rowe et al., 1994). In the sequence, strategic managers should identify assumptions about the stakeholders in order to figure out the contribution that relationships with them can make to the well-being of the organization, and then to establish and maintain good relationships with them (Thompson, 1997; Rowe et al., 1994).

Buttle (2004) comments that a customer-centric firm is a learning firm that continuously adapts to customer requirements and competitive conditions. To develop customer-oriented strategies, organizations should put the customer first, collecting, disseminating, and using customer information to create better value propositions for customers. Appropriately dealing with massive customer information on a large-scale context is not a simple task; this is when information and communication technologies come onto the scene.

TECHNOLOGICAL ASPECTS OF CRM

Technology is a crucial factor in the move to CRM. It would not be possible to implement CRM strategies without the use of the current information and communication technologies. In order to implement relationship strategies and exploit their relationship technologies, companies are deploying and integrating CRM systems with their legacy systems, as well as integrating CRM systems with their network channels and the Internet. When well managed, these integrations are reputed to constitute a successful combination of technologies that provide the necessary resources to make the execution of the strategies that will situate a company in a much desired position possible: closer to its customers (Ling & Yen, 2001). Getting closer to customers means developing the ability to know customers' needs and wants in a more accurate, efficient, and effective way, which allows the development of positive, lasting, and learning relationships with customers, hence improving an organization's corporate reputation. The results are extremely significant and positive in terms of long-term strategies and business leveraging.

From a simple perspective, CRM is fundamentally a customer data intensive effort (Hansotia, 2002). We can say that CRM is grounded on generating knowledge from customer data, and the process of knowledge generation is enabled by the deployment of a highly integrated technological infrastructure and the integration of organizational processes. Integration is vital for CRM; without the integration of technological resources and organizational processes, the CRM mechanism will not provide accurate customer information and, as a result, the identification of customer needs and wants will become a helpless guessing game (Business Guide, 2000). The high investments required by CRM adoption can be explained by the fact that the range of CRM solutions is very broad, and it may involve integration and improvements in information and communication technologies. According to Pang and Norris (2002), such integrations and improvements may include:

- Integration of computer telephony that can support call centers' activities, such as voice recognition for directing calls and matching calls against names in a database.
- Customer self-service Web sites that allow the customers themselves to conduct online transactions such as searching for relevant information, downloading forms and software, and requesting services or goods. Reducing a call center's inbound calls by automating the self-service features within the CRM system can result in lower labor and training costs.
- Improvement of business intelligence using segmentation and analytical tools that identify customers' patterns and needs. Detailed customer profiles allow a customized delivery of services and products; these profiles can be generated by CRM analytical tools that allow an organization to quickly identify target populations, this way reducing significantly a marketing cycle time (Berry, 2001).
- Implementation of mass customization processes through which goods and services are individualized to satisfy specific customer needs.

Moreover, CRM systems provide the necessary level of integration to allow seamless coordination between all customer-facing functions. Hence, productivity enhancement can be achieved by customer-facing personnel being able to do customer-related work more quickly and less painfully, since they no longer have to re-type customer information several times and do not have to look up a customer's overall dossier in multiple computer systems (Goldenberg, 2002).

Regarding processes integration, understanding the mechanisms of relationships with stakeholders allows a better definition of organizational processes, which can be seen as the frequency and direction of work and information flows linking the differentiated roles within and between departments of an organization (Hammer, 1996). Indeed, business processes are generally linked together to form a set that delivers a product or service to satisfy a specific stakeholder target—most usually the customers. Competitive success depends on transforming an organization's key processes into strategic capabilities that consistently provide superior value to the customers (Rheault & Sheridan, 2002). Furthermore, Warboys, Kawalek, Robertson, and Greenwood (1999) warn that organizational processes cannot be considered in isolation from the information systems (systems as applications and tools, or systems as infrastructure) that are potentially available.

Regarding the latter issue, one important set of applications that automates and tracks customer processes, as well as integrating these processes with back-office systems, is known as "workflow applications." This characteristic makes workflow products ideally situated to address the demand for CRM solutions. Chambers, Medina, and West (1999) have conducted a comparative assessment of workflow products focusing on how well workflow vendors have adapted their technologies to provide CRM solutions. They found that many of the workflow vendors have indeed responded with product offerings that can handle many of the key application requirements of CRM scenarios. Analyzing four key customer-related scenarios—new order processing, customer complaint handling, new product development, and call center—they identified two main techniques with which workflow vendors began to provide workflow-enabled CRM solutions. These are: (1) providing tightly coupled workflow and CRM capabilities, or (2) offering workflow solutions that can be easily embedded in any CRM platform. According to them, with so many workflow vendors contributing to CRM initiatives, it is clear that workflow as a standalone technology is disappearing and moving toward products that embed productivity, efficiency, and competitive advantage—such as CRM systems.

In fact, as we are going to see next, workflow application is only one of the many technologies that can be involved in the scope of CRM systems.

Main CRM Components and Functionalities

We previously commented that CRM can be understood as an organization's broad business strategy, which focuses on building personalized interactions with customers whatever the channel of contact between the organization and its customers. Each customer interaction produces extensive data, and the purpose of CRM strategy is to make inferences over this database in order to promote organizational benefits such as retaining existing customers, building customer loyalty, raising customer profitability, and so forth. However, there is no way of implementing any CRM strategy without information technology support. This way, different software developers have been developing a broad number of CRM systems, applications, or tools that combine existing ICT in different ways.

Generally speaking, the broad categories of CRM solutions involve a set of integrated applications that embody different aspects and functionalities. The core of CRM technologies can be classified into three general areas according to their general roles or purposes (Dean, 2001; Miles, 2002):

1. **Operational:** Technologies that manage customer service activities in storefronts, call-centers, and field service databases. These databases store historical data necessary for the construction of a single view of the customer.
2. **Collaborative:** Technologies that support field self-service applications on the Web, enabling different types of customers to work across a single service channel. This area embraces many communications media, including fax, e-mail, voice calls, text chats, and so forth.
3. **Analytical:** Technologies that provide sifting facilities through data created during customers' interactions to find or generate useful business information. These technologies encompass a collection of tools where data is combined with logical rules in order to generate insight. This area also maintains specific rules for acting on insights.

As we can see, a CRM system is not a single program or technology; it is a set of software, hardware, and network technologies that are integrated together to provide a more complete organizational capability to generate customer knowledge. In a more specific way, McKendrick (2000) describes CRM system or application as an umbrella term involving the four categories of applications below:

- **Sales Force Automation:** This is a set of tools for sales professionals. The set has functionalities such as calendaring, forecasting, contact management, and configuration models.
- **Marketing Automation:** This is a set of tools for automating marketing departments' processes and operations, including Web and traditional marketing campaigns.
- **Customer Service and Support:** This is a set of tools for leveraging and managing information in customer contact centers, such as call-centers or internal helpdesk.

- **Channel and Partner Management:** Also referred to as a partner relationship management (PRM) system, this is a set of tools that supports and tracks activities with distributors, sales channels, resellers, and retailers.

It seems that McKendrick has included PRM systems in the core of CRM applications, considering that partners' demands somehow represent end users' demands and tracking these demands allows a more comprehensive view of customers' needs and wants in general. This aspect is strengthened by Buttle (2004), who comments that partners have access to end consumers; thus, they can provide information on changing customer profiles, customer expectations, or sources of customer satisfaction and dissatisfaction.

Another important category of application called "employee relationship management" (ERM) is also being involved in the reach of CRM solutions (Callaghan, 2002). The reasoning behind this idea is that by using a CRM approach, HR professionals are beginning to better understand employees in a whole new way. More specifically, ERM deploys solutions similar to CRM solutions such as analytical and segmentation tools, smart Internet tools, and interactive technology to care about employees, allowing HR professionals to more accurately identify employees' motivations, needs, and preferences as well as better aligning employment practices to real needs, which minimizes staff turnover and, at the same time, maximizes staff retention by the definition of more appropriate recruitment profiles. The final results promoted by ERM adoption are better-equipped managers, employee loyalty, empowered employees, improved employee satisfaction, preferred employer status, and reduced costs (Dorgan, 2003).

In terms of system support information technology, there are some computer technologies that should be allocated in order to fully implement a CRM system with all its functionality. It is important to point out that these technologies were not developed exclusively for implementing CRM systems; they were developed in different periods and for several purposes. Their link with CRM exists because their resources and functionalities made the implementation of CRM systems a feasible process. Therefore, they are fundamental to support CRM initiatives. Some of the main technologies that can be considered as core components of CRM systems are:

- **Data Warehouse:** This is a special kind of database that can manage a large amount of data with very high performance; it is generally used to store historical data, and its advanced functionalities allow more flexibility when retrieving information. Most often, the integrations with legacy and external data sources are made through data warehousing technologies. In CRM systems, a data warehouse is generally used as the central customer database that provides a single view of customers. For example, the database can provide key information on customers' orders, requests, problems, and so forth. This sort of information assists service representatives to resolve problems in a more efficient and effective way. Data warehousing technologies are also used as recommendation engines that store predetermined customer treatment recommendations, which are updated after each customer interaction (Todman, 2001; Hansotia, 2002).
- **Data Mining:** This technology combines concepts of statistics and artificial intelligence to help users analyze and extract predictive information from large databases such as, for example, data warehouses. In CRM systems, data mining software uses historical information stored in customer databases to build a model of customer behavior that could be used to predict which customers are more likely to respond to new services

and product offers. Such information can then feed other touch point systems such as call centers, e-mail systems, direct mail, and so forth, so that the right customers receive the right offers (Berry & Linoff, 2004). Data mining tools can predict future trends and identify behaviors; this way, businesses are able to make proactive, knowledge-driven decisions.

- **Online Analytical Processing (OLAP):** This technology transforms information stored in databases into a summarized format that allows managers to quickly drill-down on tables and graphics to analyze where a certain problem may have arisen. One of its strongest resources is that the analysis tools can also support decisions in real time; for example, a call-center agent may be promptly informed about customer scoring or predictive measures while the customer is on the telephone. Such a characteristic is called "real-time CRM" by some vendors. Another powerful OLAP functionality involves the setting of trigger points by the users so that they can be automatically informed when, for instance, a customer calls more than a certain number of times in a month (Buttle, 2004).
- **Segmentation Tools:** These technologies provide the functionalities that allow an organization to identify and group its customers according to key characteristics such as demographic, socioeconomic, housing, behavioral characteristics, and so forth. This way, organizations have a better understanding of their customers' market behavior, tailoring their products and services according to the different customer segments or types present in a database. Customer segments can also be targeted through their preferred media or channels of contact (Doyle, 2002). For Todman (2001), the capability to accurately segment customers is one of the important properties of a data warehouse designed to support a CRM strategy. However, there are other segmentation tools in the market.

Besides the technologies mentioned above, other complementary technologies such as campaign management tools (technologies that support the designing of marketing campaigns and strategies), interfaces to the operational environment, and interfaces to the communications channels can also be allocated by CRM systems.

In practice, customers can interact with organizations through several different channels or means of contact, namely: face to face, by telephone or fax, by post, through the Internet, and so forth. Customer interaction management solutions enable front-office integration, providing an appropriate environment with resources and facilities that allow customer-facing staff to deal with all customer interactions, regardless of the channel of contact. In another layer, workflow functionalities provide integration of front-office with back-office. Workflow solutions play a major role in enabling CRM initiatives to provide a higher quality of service to customers, allowing organizations to design automated processes to enhance the productivity and responsiveness of their workforce (Ling & Yen, 2001). A central data warehouse provides a single customer view, enhancing front-office integration with back-office and integration with legacy systems, and improving organizational performance at the back- and front-office. Data mining and segmentation resources provide the intelligence that allows organizations to better understand their customers' attributes and get better results. Among these technologies, the Internet is one of the most powerful. The adoption of Internet functionalities and capabilities by CRM systems constitutes a specific set of CRM applications termed "e-CRM."

e-CRM

Electronic CRM or e-CRM can be seen as a set of applications that takes advantage of the potentialities of the Internet environment to implement relationship practices. Indeed, the "Web" is a powerful channel available for organizations to develop and enhance interactions with customers; this is why the Internet has become crucial in supporting CRM efforts. McKendrick (2000) argues that a robust CRM site must have strong customer service functionalities; in addition, the site should also provide interactive chat, browser and application sharing, personalization, e-mail options, and content management. The implementation of such facilities significantly varies from one organization to another; generally speaking, Sterne (2000) describes different evolutionary stages of Internet sites according to the use of e-technologies by organizations:

- **Phase 1:** This is a basic level. Organizations use the Internet only to exhibit catalogs or brochures on their Web sites.
- **Phase 2:** At this phase, organizations include on their Web sites additional information for promoting and selling their products or services.
- **Phase 3:** At this stage, organizations begin to offer additional functionalities and services to assist customers in making decisions or finding solutions on their Web sites.
- **Phase 4:** At this level, the organizations' Web sites have facilities to promote effective customer relationship management through highly interactive mechanisms for both supplying customers with enough information and services, and getting strategic information from customers' interactions.

Based upon the phases above and taking into account the Internet resources, accessibility, and affordability, we can infer that the Web is a popular way for an organization to gradually build customer relationships (from phase 1 to 4). In order to respond to marketing demands and maintain competitiveness, organizations are increasingly considering the strategic value of the Internet as a means of enhancing relationship strategies. E-CRM solutions are situated at the most advanced level of e-technologies applications. Therefore, e-CRM initiatives require a more advanced level of computer and telecommunication organizational infrastructure.

Wireless CRM

It is important to consider that the evolution of wireless technologies, such as Wireless Access Protocol (WAP) and devices such as mobile phones and personal digital assistants (PDA), may potentially change the face of CRM applications. The rationale for this argument is that salespeople and mobile service personnel will be able to access customer data through Web-enabled handheld devices wherever they may be, cutting companies' expenses and increasing their efficiency. Furthermore, the customers themselves will be able to access service applications using wireless devices. As Songini (2001) illustrates, the General Motors Corporation has a wireless customer relationship management program available to let drivers know what to do when the "check engine" light goes on. McKendrick (2000) also addresses the wireless tendency of CRM systems, commenting that mobile devices will significantly alter the CRM market; the widespread use of wireless and remote technologies will require CRM applications to have multiple entry points and be available on a 24-hours-a-day, 7-days-a-week basis.

Summarizing, the confluence of the technologies we have mentioned thus far, systematically coordinated and integrated by CRM systems, has enabled organizations to sift through large amounts of data to extract invaluable information and knowledge about their customer base. Without these technologies, the adoption of CRM concepts and practices would not be possible. Moreover, the integration of these technologies with other operational systems at the front- and back-ends of organizations provides the necessary seamless collaboration of resources, which is one of the main objectives of CRM. Unfortunately, the integration of different technologies is just the source of the main difficulties that organizations face when adopting CRM initiatives.

CHALLENGES OF CRM IMPLEMENTATION

CRM is one of many technologies touted as the panacea that led to excessive expectations and a high rate of implementation failure. Previous surveys show that as many as 60% of CRM implementations fail the first time (Silverman, 2001). A close examination of the problem reveals that CRM is an extremely broad area, which involves several categories of solutions and hundreds of products and services that focus on a wide range of business problems and technological opportunities. For instance, CRM embraces a wide range of processes such as product configuration, field service, customer service, and customer analysis (Reddy, 2001). The greatest challenge of implementing CRM initiatives is the deployment and integration of a number of diversified technological resources in different ways so that an organization can ensure that all front-office activities and customer interactions appear seamless to the customers. As Kandell (2000) exemplifies, CRM adoption requires:

- **Integration across all type of interactions:** marketing, sales, service, and support;
- **Integration across all media for interaction:** in-person, telephone, fax, e-mail, web site, and so forth; and
- **Integration across all channels of interactions:** sales force, telemarketing, retail, e-commerce, and so forth.

Moreover, the integration of CRM systems with back-office and legacy systems is also a crucial point for successful implementations. Gartner Group's specialists said that many CRM projects fail because they do not fully leverage and integrate all potential customer channels, and they are not fully integrated with legacy systems and back-office solutions (McKendrick, 2000).

Reddy (2001) mentions that lack of executive sponsorship, too much organizational change, and mismatched technology infrastructure are usually cited as the potential suspects of CRM implementation failure. However, he argues that these symptoms are not the root cause of the failure. Instead, the main cause of failure is the lack of an actionable CRM strategy. This latter argument is strengthened by Silverman (2001) when he comments that CRM can be highly effective if it is implemented in a strategic, focused, and holistic manner. He argues that:

> *Typical missteps involve implementing a CRM suite with the hope that it will address all of a company's objectives, a strategy that often ends in disappointment; or implementing a specific solution that is ultimately applied to the wrong problem. Some companies immediately jump into the implementation of a CRM solution without truly understanding the business issue they are trying to address…The CRM battlefield is littered with failed project corpses resulting from the 'ready, fire, aim' approach. As such, it is important to fully understand and prioritize the business problems or objectives you are trying to address rather than leaping to buy a CRM solution based on a strong vendor demonstration or industry hype.* (Silverman, 2001, p. 90)

Another problematic aspect is the fragmented universe of CRM applications; this characteristic may mislead organizations to wrongly implement CRM solutions. Payne and Frow (2004) address this problem, commenting that many organizations are adopting CRM solutions on a fragmented basis through a range of activities such as help desks, call centers, direct mail, and loyalty cards; and these activities are often not properly integrated. Considering the integration of different channels of interaction as one of the key cross-functional processes in CRM strategy development, they conclude that the adoption of a strategic perspective is fundamental for successful CRM initiatives.

Cultural Considerations

Organizational values are abstract ideas that underlie beliefs that managers have about the business and about people. Although they are very abstract, vague, and difficult to define, values are revealed by the actions people take, what they think, and how they allocate their time, energy, and skills (Rowe et al., 1994). The shared mindset regarding the basic or implicit assumptions that members of an organization unconsciously carry around with them is the organizational paradigm. In other words, the organizational paradigm can be understood as a set of concepts and perceptions shared by a group that determines how the group views the world (Finlay, 2000). Since the introduction of new technologies almost always requires changes in an organization's strategy and processes, organizational cultural aspects such as values and paradigms may impact positively or negatively on the introduction of innovations. According to Rowe et al. (1994), implementation failures are often attributed to the inability of an organization to consider its cultural aspects in order to understand how they are influencing the implementation of new strategies or processes within the organization. A positive posture supports the organization's mission and helps achieve its strategies. Contrarily, a negative posture may run counter to the expressed mission and strategies.

Generally, organizational values or paradigms cannot be easily changed. There is evidence that, in some circumstances, people's resistance may slow down radically or even completely impede the adoption of new business models and technologies (Margetts & Dunleavy, 2002). Since CRM implementation entails strategic, procedural, and technological redesign, we may therefore expect organizations adopting CRM initiatives to face resistance problems due to cultural aspects. More specifically, the adoption of customer-oriented strategies requires: (1) revision of organizational mission, posture, and strategic objectives toward customers; (2) process redesign in order to enhance organizational performance; and (3) introduction of new technologies to improve customer experience and staff efficiency. Therefore, it is fundamental to be aware that cultural barriers are potential problems likely to emerge when an organization is adopting CRM concepts and practices.

Through and beyond this, it is important to consider that cultural aspects largely determine the experience of employees in a company, which in turn is reflected in their behavior when interacting with customers (Buttle, 2004). A consequence of this fact is that customer-facing behavior can have a major impact on customers' sense of satisfaction and future buying intentions. One important aspect that strongly impacts on employees' experiences is the accessibility and sharing of customer information across an organization. Buttle (2004) points out that customer-facing employees are in a position where they have significant influence on customer behaviors, perceptions, and expectations; hence, they need to have access to a considerable volume of customer information so that they will be able to tailor their selling efforts and service performance to a specific customer or segment requirements. A potential problem that can emerge from this context is addressed by Bond and Houston (2003), who warn that cross-functional communication can be inhibited by strong functional identities and different customer unit domains. Indeed, previous research has shown that managers from distinct functional areas are likely to perceive strategic decisions from perspectives that originate in different functional subcultures, different self-identities and self-interests, and different beliefs about desired ends and their means of achievement. These differences generate conflict and poor communication among functions and sub-units, hindering the enactment of strategic decisions (Frankwick & Ward, 1994).

CRM MEASUREMENT ASPECTS

Measuring CRM aspects is still a challenge for most organizations. There is not a common pattern for gauging CRM initiatives. One of the reasons for this difficulty is that the concept of CRM is rather broad and one who wants to measure it should specify very clearly whether what is going to be measured is CRM as a business strategy or CRM as an application system, or even both. Another reason is that the variables considered to be measured vary from one company to another according to the company's activity or business, and these variables can vary even more largely from private to public organizations.

Regarding CRM as a business strategy in the private sector context, most of the attention concerning CRM measurement is focused on return on investment aspects. Two of the most used metrics for measuring the success of CRM efforts are revenue growth and margin growth (Ness, Schroeck, Letendre, & Douglas, 2001). However, some companies still prefer to consider classical parameters such as decreased costs and increased sales to measure CRM benefits (Khirallah, 2000). Given the amplitude of CRM consequences and effects, we think that the variables or parameters above are insufficient to give us an appropriate measure of CRM benefits.

Other authors consider the impacts that the implementation of CRM strategies can cause on a company's performance, focusing on the main organizational benefits that are supposed to be reached via CRM initiatives. For instance, Sterne (2000) points out the following aspects linked to CRM's payoff:

- Faster service,
- Lower costs,
- Larger profits (profitability),
- Improved retention (loyalty), and
- Higher customer satisfaction.

Khirallah (2000) agrees with Sterne when she affirms that loyalty, profitability, and satisfaction are customers' demonstrations of CRM efficacy. She adds to the list of variables above, suggesting that the following aspects should be considered in the analysis of CRM results, which should also be analyzed in terms of customer segments:

- Customer profitability,
- Customer satisfaction,
- Relationship duration,
- System availability,
- Response time,
- Response rates,
- Cross-sell ratio,
- Market share, and
- Wallet share.

Khirallah (2000) also draws our attention to the analysis of customer satisfaction over time. She claims that the measurement of customer satisfaction would produce a better CRM gauge if the process implied the measurement of customers' satisfaction with the interactions. She justifies her assumption explaining that customer satisfaction is not a static parameter. Actually, the satisfaction of customers oscillates over time according to whether their needs are being attended to or not; moreover, even though previous needs are fully attended to (which raises the satisfaction level), the satisfaction of customers might go down as soon as additional unattended needs appear over time. Based on this aspect, we conclude that although customer satisfaction represents a good indicator of CRM effectiveness, other variables or indicators should also be taken into account in the analysis of CRM impact.

It is important to point out that the variables or indicators above mainly focus on the analysis of CRM results or, we could say, post-CRM adoption analysis. Besides those aspects, it is also important to consider the analysis of pre-CRM factors, which are organizational factors linked to organizational readiness to CRM adoption. Since CRM adoption implies the establishment of customer-focused strategies, enhancement of organizational integration, and improvement of customer interactions, it is crucial to look at the extent to which organization strategies are oriented to customers and how supportive the organizational infrastructure is to the development of such strategies.

PRACTICAL CONSIDERATIONS AND REFLEXIONS

In our global economy, people's knowledge has become a valuable asset for private companies and governments. Due to the availability of current information and communication technologies such as the Internet, and mobile and wireless resources, customers have more information than they usually had a few years ago and they usually know the companies from which they regularly buy well. The development of lasting and learning relationships between an organization and its customers fosters the creation of mutual trust so that they start sharing responsibilities and interests. For example, through self-service facilities, customers can verify the availability of products, order their purchases, and trace their orders. Online access to technical databases, chat resources, and bulletin boards put customers in contact with technical staff and with other customers so that they can mutually help each other.

The development of mass customization capabilities is as important as the ability to conduct personalized interactions. While customization capability refers to an organization's capacity to project and adjust its products and services according to customers' needs, personalized interactions refer to an organization's capacity to deal with customers' singularities and particular needs. Both aspects require the correct identification of every single customer's needs and preferences. Increasing "customer share" might be a better strategy than to increase "market share." The more you know about your customers' business, the better you can serve them. To convince your customers to give you more of their business, let them know much about your business. Do not limit customer relationships within the scope of salespeople only; give your customers access to experts from several areas of the company. Your experts are better able both to identify what your customers' needs and preferences are, and provide more complete and accurate information about your business.

To work with quality, it is necessary to continually observe the view and perception your customers have about the products and services you deliver (Seybold, 2002). According to Seybold (2002) different research has shown that while internal staff members or employees of an organization think their products and services have improved, the external customers think exactly the opposite.

The purpose of CRM solutions and systems is to allow organizations to work with their customers in a learning manner, which yields effective results for both sides. For example, it is becoming quite common for software developers to let their customers test unfinished versions of their products rather than conducting laboratory tests. The result is the creation of a product that more precisely meets users' preferences. Of course, taking advantage of customers' competencies requires some caution: it is necessary to mobilize customer segments according to specific criteria, engage the customers in an active dialogue, and manage their differences. By active dialogue we mean the development of "knowledge-rich" dialogues. Companies should promptly process and share what they learned from the customers to maintain existing dialogues and keep customers' interests alive (Prahalad & Ramaswamy, 2002).

CRM adoption requires deep cultural change, which should mobilize and embrace an organization as a whole. We should be aware that the employees are the people who really interact and establish relationships with customers. Hence, only a sound corporate culture promotes commitment. Many organizations have already realized that it is the internal customers—the employees—who are capable of "delighting" the external customers. Highly motivated employees project their motivation to the external public. This phenomenon helps to build the corporate image itself, which is highly influenced by what is projected by the employees (Davies, Chun, da Silva, & Roper, 2003). Organizations should see their employees as allies to attract, please, and maintain customers. The relationship of an organization with its customers can be seen as a service made by its internal customers to the external ones.

Whatever the strategy, it is important to bear in mind that managing customers' experiences is not the same as managing different products. Rather, managing customers' experiences is managing their interactions and interfaces or channels of contact. As customers' needs change over time, products and services ought to evolve as well and be adjusted over time according to new customers' needs, wants, and preferences.

Global CRM

Multinational organizations are getting more and more serious about globalizing their CRM programs and taking their CRM strategies to a multinational level. Important considerations should be taken into account by MNCs endeavoring to develop CRM initiatives on a multinational scale. A basic premise is that different countries have different cultures, traditions, symbols, expectations, processes, languages, laws, and so forth. They do business differently, therefore it should be expected that customer behavior or business practices are different across international boundaries. In this sense, the CRM applications and tools used in each country must fit the reality of that country. The reason for this is that cultural customs, language, customer expectations, and privacy laws, for example, all vary from country to country. For this reason, although it is extremely important that an MNC creates global standards for its CRM applications, the company should provide its subsidiaries' business leaders and customer-facing managers with decision-making power to adjust their local CRM applications (Dyche, 2001).

In the multinational arena, a strong global CRM deployment trend is the centralization of customer information. MNCs are creating global customer data infrastructure by implementing a corporate data warehouse that acts as a common repository of customer and business knowledge which is made available to subsidiaries worldwide (Dyche, 2001). This practice is illustrated by Case 1.

In short, multinational organizations are deploying global CRM solutions to better manage their sales and delivery channels worldwide. A usual implementation practice is to centralize customer data in a globally shared data warehouse, which is accessed through a global CRM engine that can interact with local CRM applications that may vary from country to country. This provides global understanding, identification, and tracking of appropriate customer contact channels in any given region, allowing MNCs to better manage their customer interactions around the world.

Case 1. Kelly Services connected sales network across 30 countries and five continents [Sources: Adapted from Kelly Services (n.d.) and Salesforce (Kelly) (n.d.)]

Kelly Services, Inc. is a Fortune 500 company headquartered in the U.S., offering staffing solutions including temporary staffing services, staff leasing, outsourcing, and vendor onsite and full-time placement. With clients ranging from small local businesses to blue chip multinationals in various markets from pharmaceuticals to telecommunications, Kelly Services operates in 30 countries and territories providing employment to more than 700,000 employees annually. To manage its highly diverse universe of customers, the company needed a central repository to share sales information between branch managers, sales reps, and recruiters spread throughout 30 different countries. Additional challenges included the need to better capture historical sales information due to staff turnover, and easy remote access to the central repository. Through the adoption of CRM practices and systems, Kelly standardized its tracking and management processes, and provided more than 100 users with anywhere online access to a fully documented sales history on every account anytime. CRM adoption enabled the company to network its global, large account sales force across 30 countries and five continents in a seamless and coordinated manner. Kelly Services now shares real-time data and key account information with minimal internal infrastructure. The solution, which includes multi-language and multi-currency functionalities, increased efficiency and better tracking of sales processes, and allowed easier identification of emerging opportunities and the ability to take action to help close deals. Also, it became smoother to preserve information during staff transitions.

CRM AND KNOWLEDGE MANAGEMENT IN MULTINATIONAL ORGANIZATIONS

Considering the CRM strategies, practices, resources, and systems commented on in the previous sections, it is possible to identify a number of potential roles CRM can play to enhance organizational learning capabilities that are also of KM concern.

In general, the development of KM practices entails three interrelated processes, which are mainly concerned with knowledge acquisition, knowledge conversion, and knowledge application (Gold, Malhotra, & Segars, 2001). The knowledge acquisition process is concerned with the development of organizational capabilities to obtain and accumulate knowledge; the knowledge conversion process is more concerned with making existing knowledge useful, which entails the development of organizational capabilities to organize, integrate, coordinate, and disseminate knowledge. Finally, knowledge application is mainly concerned with the use of knowledge; this entails the development of organizational capabilities to retrieve, share, and apply knowledge (Cui et al., 2005).

The development of these organizational capabilities is especially challenging for multinational corporations (MNCs), which continually seek to establish competitive positions in the global marketplace by developing strategic capabilities through subsidiaries (Kogut & Zander, 1993). To achieve such competitive positions, it is necessary for MNCs' subsidiaries to develop their strategies according to local market demands. As Cui et al. (2005) argue, instead of implementing standardized strategies, MNCs' subsidiaries should have strategic flexibility so that they can develop proactive strategies in accordance with their specific environmental conditions.

In order to efficiently identify and respond to different market conditions and demands, MNCs should develop the learning capability of their subsidiaries. In a global environment, we can see an MNC as a nested learning system in which the learning process occurs at several different but interconnected units at the same time. Monteiro, Arvidsson, and Birkinshaw (2004) point out that the knowledge generated by subsidiaries with strong learning capabilities becomes increasingly valuable to the rest of the organization. Therefore, the knowledge generated in the local environment becomes an essential part of an MNC's knowledge stock.

According to Schneider and De Meyer (1991), external sources are of the utmost importance for the generation of competences in a subsidiary. They argue that external sources can enhance the effectiveness and scope of learning processes. Furthermore, Andersson, Forsgren, and Holm (2002) have found a direct link between external sources and intra-organizational influence on MNC strategy. They argue that the degree of external relations determines the degree of influence. For example, an intensive and long-lasting interaction between a subsidiary and its customers regarding the development of a specific product or service might influence the process of product or service development in the whole MNC (Andersson et al., 2002). This aspect is strengthened by Gammelgaard (2000) when he comments that changes in the customers' taste and attitudes demand the development of entrepreneurial activity, as relationships with customers often lead to requests for modifications of existing products and services, and sometimes, the development of new ones (Gammelgaard, 2000).

Taking into account the aspects mentioned above, we can conclude that the adoption of customer-focused strategies and practices may significantly increase a multinational organization's capacity to generate knowledge. In this sense, CRM can be seen as an enabler for the development of learning capabilities, as the adoption of its concepts, practices, and learning techniques allow the development of business approaches that support knowledge creation and sharing mechanisms.

CRM Supporting Roles to KM

Knowledge management is a corporate process that involves the development of organizational learning capabilities. It is important to point out that the process of organizational learning is not limited to a mere information system, a data warehouse, or specific analytical tools. Although the adoption of technical solutions makes it feasible for an organization systematically to collect, analyze, process, and disseminate information, strategic and cultural aspects should be carefully observed prior to any technical investment. The adoption of customer-focused strategies is of crucial importance to the processes of knowledge acquisition, conversion, and application. In this context, CRM practices, systems, and tools provide powerful resources to enable effective organizational learning capabilities that can significantly increase a multinational organization's ability to recognize not only customer demands in specific regions of the globe, but also to identify global patterns and common marketing trends that can guide global strategies. In the sequence, we identify and describe the main aspects and areas where CRM can play crucial roles in supporting knowledge management in multinational organizations. Each description is illustrated with a real-life case that shows how different MNCs are deploying their CRM solutions globally.

Customer Segmentation

Segmentation strategy means that an organization seeks to group its customers according to common patterns and characteristics determined in conformity with previously identified criteria. Segmentation methods are often used to characterize and help with the understanding of different customer groups. More specifically, segmentation aims to group customers according to their preferences for products, services, channels of interaction, and the magnitude and frequency of their interactions with an organization (Hansotia, 2002). This way, organizations can have a better understanding of their customers' wants and needs, tailoring their products and services according to different customer segments or types. In a multinational perspective, CRM segmentation allows the generation of valuable customer knowledge to support the establishment of corporate strategies and services according to the reality of local markets. An example of segmentation practice is illustrated in Case 2.

Case 2. Hard Rock Cafe turned to CRM to help bring customers back into the fold (Source: Jessup and Valacich, 2005)

Founded in London in 1971, the now U.S.-based Hard Rock Cafe International, Inc. was among the first chains of themed restaurants to come into existence. With 138 venues in 42 countries, and over 30 million customers a year, Hard Rock has become a truly global phenomenon. With the rise of many thematic eateries around the world, Hard Rock turned to CRM to help solidify its footing. In 2000, the company estimated that of its 30 million customers who come to its 138 venues each year, only about 10,000 names were in the company's customer database. The company began a detailed two-year customer survey to build out its data resources and gauge its potential for using CRM. The survey was the backbone of the company's CRM strategy, and it helped to build a database to host about 100,000 names as preferred customers. The database provides real-time customer information for several applications including e-commerce operations. The CRM solution allowed analysis based on different customer segments, and the company was able to figure out how customers responded to e-mail or coupons. It was possible to identify what kind of people were buying and why. By targeting customer preferences, the company increased memorabilia sales by 75% and improved customer service response by 85%. Hard Rock Cafe intends to extend its CRM deployment to the point where it can identify and reward customers at point-of-sale locations (restaurants), rather than exclusively through its member-based programs.

Customer Personalization

CRM is also seen as an organization's broad business strategy that focuses upon building personalized interactions with customers, whatever the channel of contact between the organization and its customers (Dean, 2001). It proposes personal interactions even in a mass context. Such a large-scale personalization is perfectly feasible through the deployment of CRM systems, applications, and tools (Ling & Yen, 2001). Organizational capability to develop personalized interactions with customers is therefore a remarkable characteristic of organizational focus upon customers. A summary of customers' preferences and profiles in each MNC subsidiary may potentially enhance global strategies. Case 3 shows how the Chase Manhattan Bank is implementing personalization capabilities.

Channels of Customer Interaction

Customers can interact with organizations through several different channels or means of contact such as telephone, in person, fax, post, e-mail, and so forth (Kandell, 2000). Logically, an organization that offers a diversified number of different contact channels strategically increases the possibility of customer interaction. The integration of such channels in the front-office provides an appropriate environment with resources and facilities that allow customer-facing staff to deal efficiently with all customer interactions regardless of the channel of contact (Sterne, 2000). For Payne and Frow (2004), the integration of different channels of interaction is one of the key cross-functional processes in CRM strategy development. The analysis of the volume of customer interactions per channel is an important source of knowledge that can support MNCs to undertake timely and highly accurate forecasting. This aspect is illustrated in Case 4.

Workflow

Workflow is an important set of applications that enable the automation and tracking of different customer processes by the integration of front-office with back-office. This characteristic makes workflow products ideally situated to address the demand for CRM solutions (Chambers et al., 1999). Embracing workflow functionalities, CRM systems play a major role in the provision of a higher quality of service to customers, allowing organizations to design automated processes to enhance the productivity and responsiveness of their workforce (Ling & Yen, 2001). Therefore, *Case 3. Chase Manhattan Bank gets closer to its customers (Sources: Adapted from Ptacek, 2000 and "JPMorgan Chase" ,n.d.)*

JPMorgan Chase & Co. is a world-leading global financial services firm with assets of $1.3 trillion and operations in more than 50 countries. Under the JPMorgan and Chase brands, the firm serves millions of consumers in the United States and many of the world's most prominent corporate, institutional, and government clients. The U.S. consumer and commercial banking businesses serve customers under the Chase brand. The bank has adopted a CRM system to let its 4,500 relationship managers worldwide share and gain access to constantly changing information about the profitability of their corporate customers. The system makes the managers' jobs easier by keeping them up to date on all aspects of their multinational, multifaceted corporate clients. Chase was one of the first corporate banks to implement CRM techniques that the industry had applied to the retail side. The CRM system has different degrees of customization, allowing managers to use different benchmarks to gauge customers' profitability. Customers and bankers can enter and view relevant information through the Internet. Customers also can get a daily report card on their banking activities and are encouraged to give the bank feedback. The bank is also letting institutional customers send messages to their relationship managers as they observe market events. Video technology will be deployed so that customers and bankers can interact face to face wherever they are around the world. Through an increasing variety of channels, including wireless devices, customers can do online self-service and online tracking.

Case 4. InFact deployed CRM system to undertake timely and highly accurate forecasting. (Source: Adapted from Oracle, 2006)

InFact Group is a global technology consulting organization with a world-class portfolio of customers in three continents. The company provides end-to-end project services, and delivers outsourcing solutions based upon its dedicated development platform in India. After its founding in 2000, the company grew very rapidly, increasing its breadth of customers, extending its global reach, and recruiting more than 60 employees. As a consequence, the company needed to replace the existing legacy systems it relied on to manage a growing number of increasingly complex customer relationships. The company turned to a CRM system to face this challenge. InFact deployed CRM systems in Europe, the U.S., and India to create a single, comprehensive view of its customers and partners across multiple channels and touch-points. By introducing a standard sales, marketing, and service methodology worldwide, the company is able to optimize sales performance by efficiently tracking and qualifying every sales opportunity. InFact can also identify top-performing accounts and conduct rigorous analysis of customer interaction by region, industry, and revenue. CRM has reduced the time it takes to close a sales opportunity by 15%. The system allows the company to undertake timely and highly accurate forecasting. InFact trades in multiple currencies around the world, and it used to take one person up to four days each quarter to pull together all the different currency rates and fluctuation allowances into one consolidated spreadsheet forecast. The new CRM system automatically undertakes all currency conversion, historical exchange rates, and rollups. This saves InFact $33,000 each quarter in reduced overhead. Managers can also analyze customers and prospects by industry, region, and even city. The company has recently targeted 300 companies in Asia Pacific with a direct mail campaign and was able to track the calls coming in from this campaign. It was immediately apparent how many inquiries InFact received and the total cost per lead. By providing one view of the customer, greater visibility into the sales pipeline, and analytic insight into key performance metrics, CRM has helped to transform InFact into a more agile, proactive consultancy, with the tools needed to provide the highest levels of customer service.

the organizational capability to track and/or follow-up automated customer processes also represents integration towards customers. For MNCs, the adoption of workflow functionalities may significantly facilitate and optimize the execution of global business processes. Case 5 shows how an MNC is adopting a CRM system to integrate disparate customer touch points and focus its business processes across the company around customer needs.

Case 5. Air Products adopted CRM to support its operations in more than 30 countries (Source: Adapted from "Air Products", n.d.)

Founded in 1940, Air Products and Chemicals, Inc. has built leading positions in key growth markets such as semiconductor materials, refinery hydrogen, home healthcare services, natural gas liquefaction, and advanced coatings and adhesives. With annual revenues of $8.1 billion, operations in more than 30 countries, and more than 20,000 employees around the globe, the company lacked a common approach for its many divisions to manage the information critical to maintaining its relationships and growing revenue with customers. To allow its employees to focus more attention on customer needs, Air Products is putting into place a CRM system. Companywide access to accurate information about customers, production, and distribution will form the backbone of the company's customer care concept. The CRM system will ultimately integrate disparate touch points, raise the quality of customer interactions, and focus business processes across the enterprise around customer needs. The new system will serve as a repository of information and allow the company to build accurate customer profiles based on the products it sells and the services it offers. A customer portal is expected to strengthen the relationships with customers by making business more convenient and friendly. The portal will be integrated with the corporate CRM system and other business systems so that the new tools and processes will provide customers with a greater level of service than ever before. The ultimate objective is to provide managers with access to customer information all the way through the product cycle, from order commitment to production scheduling to delivery to invoicing, making sure the company gets it right for customers the first time.

Marketing Knowledge

Obtaining customer information is crucial for allowing MNCs' prompt acquiescence to market demands, which allows the development of better products and services according to local specificities. Also, the analysis of local market demands and trends allows the identification of common points of demand in different regions around the globe; this knowledge helps MNCs to define global strategies for their products and services, as well as target communication with customers and delineate more responsive marketing campaigns. Case 6 shows how Ford is taking its main marketing team to better deliver coordinated cross-border marketing campaigns.

Customer Information Sharing

This aspect is mainly concerned with customer information gathering and usage. Getting basic information about customers' needs, wants, and preferences allows the development of better strategies for providing immediate responses to different situations and scenarios, which improves MNCs' ability to make complementary plans to respond to different market expectations. The sharing of customer information throughout the MNC allows better transparency, reporting, and communication across global teams. This aspect is illustrated in Case 7.

Consistent Global Corporate Image

Employees are the people who really interact and establish relationships with customers. When interacting with customers, MNCs' employees are implicitly building their own corporate image. A positive image can be built when customer-facing employees are empowered to respond to customer needs and when they feel trusted to run the business. Enabling employees to consistently interact with customers in a standardized, but not inflexible manner is how International Business Machines (IBM) Corporation created a consistent corporate image worldwide (Case 8).

In all the illustrative cases presented above, CRM is implicitly supporting knowledge acquisition, knowledge conversion, and knowledge application processes within the multinational organizations addressed. For example, CRM supports knowledge acquisition processes by

Case 6. Ford's CRM strategy has increased sales and productivity (Sources: Adapted from Ford, n.d.; and IBM, 2006)

With a recorded net income of $2.5 billion in 2005, Ford Motor Company is a global automotive industry leader based in Dearborn, Michigan. The company manufactures and distributes automobiles in 200 markets across six continents. With about 300,000 employees and 108 plants worldwide, the company's core and affiliated automotive brands include Aston Martin, Ford, Jaguar, Land Rover, Lincoln, Mazda, Mercury, and Volvo. Ford wanted to project a consistent company and product message throughout Europe while ensuring national marketing campaigns were tailored to regional needs. The company also needed to track customer responses and implement a lead qualifying process to focus sales efforts. To achieve these goals, Ford implemented a pan-European CRM solution into its three largest markets—the German, Spanish, and UK operations. Ford then needed to implement a centralized version of its CRM solution into additional markets across Europe, including offices in France, Italy, and Austria. The standardized CRM solution was integrated with key business processes and designed to transform simple marketing campaigns into responsive, targeted communications. The solution included campaign management processes and supporting tools that meet marketing needs at both the local market and pan-European level. This approach works in tandem with the consumer lifecycle management application that tracks marketing campaign responses. The system allows the company to track different communications ranging from a brochure request via the Web site to test drive inquiries to a call center. Identifying and coding the different customer communications set the basis for the solution's lead qualification process that allows customer representatives to prioritize and offer the most appropriate follow-up based on the potential customer's level of interest. The centralized approach enables Ford's main marketing team to better deliver coordinated cross-border marketing campaigns. The CRM initiative has improved customer service with faster, tailored responses to queries. The solution has generated more than 500,000 qualified leads to date.

Case 7. Nokia customizes CRM solution to meet the needs of sales teams on three continents (Sources: Adapted from www.nokia.com and Salesforce [Nokia], n.d.)

During the 1980s, Nokia strengthened its position in the telecommunications and consumer electronics markets through a series of European company acquisitions. Since the beginning of the 1990s, Nokia has concentrated on enhancing its core business, telecommunications. Currently, Nokia is the world's largest manufacturer of mobile devices; a leader in equipment, services, and solutions for network operators; and a driving force in bringing mobility to businesses. In 2005, Nokia's net sales totaled EUR 34.2 billion. The company has 15 manufacturing facilities in nine countries, and research and development centers in 11 countries. At the end of 2005, Nokia employed approximately 58,900 people. As Nokia's sales teams used three different reporting systems ranging from spreadsheets to homegrown solutions, it became very difficult to provide real-time visibility into the sales cycle and preserve consistency across different regions and functions. Through the adoption of a CRM solution, Nokia provided its traveling sales force with a customizable system with real-time visibility into business anytime and anywhere. The company is able to customize its CRM system on the fly to respond to changes in business models and requirements. CRM has also provided deeper understanding of customer buying habits and allowed better transparency, reporting, and communication across global teams. This has streamlined sales organization for improved collaboration and productivity, which resulted in a shorter sales cycle and more consistency across different regions and functions.

providing resources to manage the customer interaction channels through which MNCs can obtain and store worldwide customer information in corporate databases. By providing global managers with sharing capabilities to access these corporate databases, as well as integrating the workflow of cross-border processes, CRM is supporting MNCs to integrate, coordinate, and disseminate knowledge. Finally, the segmentation and personalization capabilities provided by CRM

Case 8. IBM standardizes its relationship processes (Sources: Adapted from www.ibm.com and ICFAI, 2004)

> With a revenue of $91.1 billion in 2005 and more than 329,000 employees in 75 countries, IBM is the world's largest information technology company. Worldwide, 45,000 business partners and 33,000 suppliers are connected to IBM through the Web. In January 2000, IBM undertook the largest CRM project known at that time. Termed "CRM 2000," the project aimed at ensuring that any point of interface between the company and its customers, through any of its channels of interaction, in any country, was dealt with uniformly, providing the same service level, applying the same tools and information. Ultimately, IBM wanted to show a unified interface to its customers across the world. Four years after the project, the company was well on its way towards achieving its objective, reporting significant improvements in customer satisfaction levels. At that time, IBM's vice president of worldwide CRM deployment said, "*By getting to know our customers better and enabling more effective collaboration around the customer and among multiple IBM organizations involving sales, marketing, and support, we can significantly enhance the value we bring to our customers, while generating additional revenues and cost efficiencies for our company. The concept of 'one IBM' is a cornerstone for the way we serve customers.*"

solutions, plus marketing campaign management resources and functionalities to adopt standardized relationship processes, strongly support MNCs in the process of retrieving and applying knowledge.

CONCLUSION

In this chapter we commented on concepts and characteristics of CRM, covering aspects from its origins to supporting roles to KM. The presented theory has shown that the confluence of changing customer demands, emerging marketing theories, and available information technologies have been imposing a shift on the way organizations relate to customers. In contrast to the old economy firm, which was more absorbed in achieving operational excellence through production and service delivery processes, the new economy firm reportedly has the customer at the center of its universe.

On one hand, the evolution of marketing business strategies over time delineated the current characteristics of CRM strategies; on the other hand, the evolution of information and communication technologies enabled the adoption of different and more evolved marketing approaches over time, giving birth to the current CRM systems. These two dimensions of CRM are extremely intertwined and, as a matter of fact, the emergence of CRM strategies, concepts, and practices would not be possible without the appearance of new and evolved ICT resources.

CRM systems provide the functionality that allows an organization to make its customers the focal point of all departments within the firm. This way, the organization will be able to respond to its customers on a continual basis. More specifically, customer information databases and integrated interactivity enable an organization to develop a learning relationship with its customers, creating organizational capability to differentiate its customers through lifetime value segmentation, to develop personalized interactions with customers, and to offer tailored products or services to customers.

A fundamental issue about CRM is that CRM is more than a mere product. If one sees CRM as a system that can be bought and installed in an off-the-shelf manner, then it becomes difficult to harvest the benefits promoted by such an expensive solution. CRM should be seen as a broad business strategy that implies the redevelopment of organizational structures so that there are new service units and new product offerings arranged around a refreshed understanding of customer needs. The real concept of CRM goes beyond the product, implying deep strategic and cultural concerns.

It is possible to identify CRM strategies, practices, and solutions that strengthen and support knowledge management approaches, especially in a more complex and diversified environment such as the one where multinational organizations are inserted. Regarding knowledge about customers, the adoption of customer-focused strategies supported by CRM systems can significantly strengthen the learning capabilities of MNCs' subsidiaries. These capabilities reflect on MNC headquarters in the form of increased corporate capacity to identify local and global trends concerning customers' preferences, cultural aspects, needs, and consumer behavior. This knowledge subsidizes the elaboration of more effective global strategies by multinational organizations.

Of course, CRM does not address the whole myriad of organizational aspects and issues that are of KM concern. Its focus is on developing organizational learning capabilities that can significantly enhance an organizational ability to acquire, process, and apply knowledge about customers. The objective of this chapter was to broadly present CRM characteristics, strategies, concepts, practices, solutions, resources, and concerns that can be explored by multinational organizations with the purpose of supporting the adoption of knowledge management strategies and practices.

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ENDNOTE

1. A respected, not-for-profit, non-partisan organization that brings leaders—who repre-

sent a variety of major industries—together to find solutions to common problems and objectively examine major issues having an impact on business and society (*www.conference-board.org*); in *Journal of Business Strategy (2001), 22*(6).

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Chapter 3.22

Capacity for Engineering Systems Thinking (CEST):

Literature Review, Principles for Assessing and the Reliability and Validity of an Assessing Tool

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ABSTRACT

To successfully perform systems engineering and/or designing IT architecture roles, the systems engineers and IT architects need a systems view or a high capacity for engineering system thinking (CEST). This paper discusses the essence of this capacity, presents principles for developing a tool for assessing the CEST and presents a tool developed for use in selecting engineers for jobs that require CEST. A tool for CEST assessment may be useful for several purposes, one of which is the effective selection of candidates for engineering positions that require high CEST. The tool was tested and implemented in a pilot study aimed at examining its reliability and validity. Two types of reliability and four types of validity were checked. Then, a second study aimed at strengthening the results of the pilot study was conducted. The findings of the two studies indicate that the tool may prove to be a validated instrument.

INTRODUCTION: SYSTEMS ENGINEERING, IT ARCHITECTURE AND ENGINEERING SYSTEMS THINKING

Systems thinking, according to Senge (1994), is a discipline for seeing wholes. *Engineering Systems Thinking* is a major high-order thinking skill that enables individuals to successfully perform systems engineering tasks (Frank, 2002). To successfully perform systems engineering and/or designing IT architecture roles, both systems engineers and IT architects need a systems view or a high capacity for engineering systems thinking (CEST). Despite its importance, no high-quality tool exists as yet for CEST assessment, which may be useful, for example, in enabling a more effective selection of candidates for engineering positions that require high CEST. The current paper discusses the essence of this capacity, presents principles for developing a CEST assessment tool, and presents a tool developed for assessing the interest for job positions requiring high CEST and in selecting engineers for jobs that require CEST. The paper presents the results of two studies aimed at validating the tool.

As modern technological projects have increasingly become larger, more complex and interdisciplinary, systems engineering and designing Information Technology (IT) architecture have come to play an ever-increasing a major role in projects. In the IT sector, IT architects play the same role that system engineers play in engineering organizations, which is being responsible of seeing the whole picture of the system.

The main functions of systems engineering in technology-based and projects are: requirements analysis, functional analysis, architecture synthesis, systems analyses, verification and validation and optimally integrating individual components into a whole system that meets specific systems-level requirements (INCOSE, 2004). According to Sheard (1996), the twelve systems engineering roles are requirements owner, system designer, system analyst, validation and verification, logistics and operations, “glue”, customer interface, technical manager, information manager, process engineer, coordinator and “others”.

According to Frank and Waks (2001), *Engineering systems thinking* is the ability to:

1. **See the big picture:** the ability to: grasp and understand the whole system and the big picture, conceptually and functionally, without understanding all its minutiae and all of the system’s details; understand the interconnections and the mutual influences and interrelations among system elements/sub-systems/assemblies/components/parts; describe a system from all relevant perspectives (a well-known approach for categorizing the required views distinguishes between operational views, system views, and technological views); derive the synergy of a system from the very integration of the subsystems; identify the synergy and emergent properties of combined systems; understand the system as a whole and anticipate all the implications (including side effects) of changes in the system, engineering and non-engineering alike; understand and describe the operation, purposes, applications, advantages, and limitations of a new system/sub-system/idea/concept immediately after receiving an initial explanation, and remedy system failures and problems.
2. **Implement managerial considerations:** the ability to grasp and implement managerial, organizational and broad-perspective considerations.
3. **Acquire and use interdisciplinary knowledge:** the ability to: deal with multi-tasking and interdisciplinary knowledge; use this knowledge for developing the concepts of operation, logical solutions (functional analysis), and physical solutions (architecture synthesis); make analogies and parallelisms between systems; implement systems design considerations; conduct –ilities analyses (availability, maintainability, etc.), and run simulations and optimization analyses (Frank, 2002).
4. **Analyze the needs/requirements:** the ability to capture, understand and analyze the customer/market requirements/needs and future technological developments.
5. **Be a systems thinker:** the ability to be curious and innovative, to be an initiator and independent learner, and to have the ability to develop and ask good questions**.** CEST is also required in designing and managing information systems.

Similar results were found in a study conducted in Australia (Frampton et al., 2005) aimed at identifying the capabilities of successful IT architects. A comparison between the two studies is presented in Table 1.

Systems engineers with high CEST are more capable of (1) analyzing customers' need and requirements, (2) developing the concept of operation, (3) conceptualizing the solution, (4) generating a logical solution (functional analysis) and a physical solution (architecture synthesis), (5) using simulations and optimization and (6) implementing systems design considerations and conducting trade studies wherein it is necessary to generate several alternative solutions (Frank, 2002; Davidz, 2005). More meaningful attributes of those reputed to be systems engineers (vs. those who are not), and evidence that those reputed to be systems engineers were associated with successful systems, are reported in other studies (Frank, 2006; Frank, Frampton, Di-Carlo, 2007).

Some authors refer to CEST as an innate ability. For instance, Hitchins (2003) states that the human brain has the ability to see similarities of patterns between disparate sets of information, which presumably emanate from its drive to reduce perceived entropy. He also implies that some people are gifted in this respect. However, Frank (2002) and Davidz (2005) concluded that this ability is most likely a combination of innate talent and acquired experience and offered a course outline directed at developing CEST.

According to Warfield (2006), all sciences, including systems science, have three foundations in common – the human being, thought and language. A human being exhibits both creativity and fallibility (both are attributes of human beings). Starkermann (2003) focuses on the effects of interpersonal relationships and people's competencies, styles and attitudes - both conscious and unconscious - regarding any entity behavior. Indeed, in a prior study (Frank, 2006),

Table 1. Capabilities of successful systems engineers and IT architects

Category	Systems Engineers (Frank, 2002)	IT Architects (Frampton et al., 2005)
Background	Interdisciplinary knowledge. Understanding the whole system and seeing the big picture	Generalist
	Broad experience - job rotation, systems work roles	Broad experience
Personality traits	Think creatively	Creative
	Curious, innovator, initiator, promoter, originator	Open-minded
	Willing to deal with systems	Passionate
	See failures and screw-ups as challenges for development, not as "the end of the road."	Resilient
Capabilities	Requirements, needs and concept of operation analysis, Understanding interconnections.	Analysis
	Taking into consideration non-engineering factors such as economic/business considerations	Business related
	Good communication and interpersonal skills.	Communication skills
	Team leader, team player,	Middle-ground
	Conceptualizing the solution	Conceptualization
	Generating the logical and physical solutions	Problem solving
	Taking into consideration political issues	Situational politics
	Seeing the future	visionary

both creativity and strong interpersonal relationships were found, to be essential qualities of successful systems engineers. However, the issue of creativity deserves a special focus and will not be discussed in the current paper. Many tools and tests for assessing creativity have already been suggested (e.g. Lees-Haley, 1978). Therefore, the tool presented in this paper does not pretend to assess creativity.

The Tool for Assessing Interest Towards Jobs Requiring CEST

Despite its importance, no high-quality tool exists as yet for CEST assessment, which may be useful, for example, in effective selection of candidates for engineering positions that require high CEST. The principles for developing a tool developed for such purpose were first presented by Frank & Elata (2004) and further discussed by Frank, Zwikael and Boasson (2006). This paper extends the discussion and presents the results of a follow-on study. Actually, the proposed tool is an interest inventory. Interest inventory is a very common tool used for helping people choose a profession and as a selection tool in the recruiting process (Anastasi, 1988).

An earlier study was carried out before developing the propose tool. This study included three stages. The first involved a pilot study in which 11 in-depth, open, non-structured interviews were conducted with key figures in hi-tech industry. The second involved 17 semi-structured interviews in the role of 'the-observer-as-participant,' conducting on-site observations at the workplaces of two hi-tech companies. The third stage of the early study consisted of a survey based on a pilot questionnaire (N=31) and a final questionnaire (N=276).

The proposed tool was then developed and the content validity was achieved by basing the items of the interest inventory discussed here on the findings of a previous study whose primary aim was to identify the characteristics of engineers who have a high capacity for engineering systems thinking (Frank, 2002), experts' judgment, and literature review including the INCOSE SE Handbook version 2a (INCOSE, 2004), laws of the fifth discipline and systems archetypes (Senge, 1994), systems thinking principles (Kim, 1994; Waring, 1996; O'Connor and McDermott, 1997; Sage, 1994), some principles of systems dynamics (Sweeney and Sterman, 2000; Ossimitz, 2002) and the seven 'thinking skills' of systems thinking (Richmond, 2000).

The tool does not consider the knowledge and skills required from systems engineers. Much work in this field has already been done by the International Council on Systems Engineering (INCOSE) work group - the INCOSE Certification of Systems Engineers Exam (Muehlbauer, 2005), which is based on the INCOSE SE Handbook version 3 (INCOSE, 2006).

Usually, the items in interest inventories deal with preferences, specifically likes and dislikes regarding a diverse group of activities, jobs, professions or personality types. Likewise, the items included in the tool discussed in this paper refer to ranges of likes and dislikes regarding systems engineering activities (i.e. leading integration teams, conducting systems analyses, etc.), various disciplines and knowledge required from systems engineers (interdisciplinary knowledge, deep and detailed knowledge, etc.), systems engineering activities (i.e. leading and participating in design reviews, dealing with the whole system, etc.), and types of people involved in projects (i.e. customers, stakeholders, etc.).

The tool is comprised of 40 pairs of statements. For each pair, the examinee has to choose between the two statements according to his/her preference. The examinee checks answer "A" if he/she prefers the first statement or answer "B" if he/she prefers the second statement or answer "C" if he/she prefers either none of them or both of them. Several sample items will be presented in the presentation at the conference. In order to improve the questionnaire's reliability, questionnaire items were reorganized, so in some cases "A" represented the systems thinking answer and in other cases "B" represented the systems thinking answer. Each "A" answer received two points, while each "B" answer received one point. Thus, the range of the mean score of each participant was between 1 and 2.

Here are two example items based on the characteristic 'seeing the whole':

Item No. 2

A. When I take care of a product, it is important for me to see how it functions as a part of the system.
B. When I take care of a product, it is important for me to concentrate on this product, assuming that other engineers will take care of the other parts of the system.

Item No. 6

A. I don't like to be involved with details; I prefer to deal with the system's aspects.
B. In areas in which I'm involved, I like to understand all the details.

Please see several more sample items in the appendix.

The Need. A CEST assessment or selection tool can serve several needs. The first use is to better select candidates for engineering positions that require a high level of CEST. In the selection process, the tool can be used to help make decisions about whether to recruit or reject a potential candidate. When assessing new (recruitment) or current (promotion) of employees, the tool can augment other evaluation tools. The second use of the tool might be to improve the placement process by identifying the right candidate for systems engineering positions that require high CEST (the right person for the right job). Finally, once this tool is validated, it could be used for evaluating the effectiveness of CEST development programs and systems engineering courses.

The Pilot Study

The tool was tested and implemented in a pilot study (Frank, Zwikael & Boasson, 2006), aimed at examining its reliability and validity. The pilot study included 54 participants from a large hi-tech organization who completed the questionnaire. Twenty-nine of the participants are systems engineers, while the other 25 participants work as professional engineers (not in systems engineering positions). Two types of reliability – inter-judges reliability and Alpha reliability coefficient, and four types of validity – content validity, concurrent validity, contrasted group validity and construct validity – were examined.

A measurement's reliability is represented by the extent to which it is accurate (Anastasi, 1988) and can be checked by using several techniques. The first one is *inter-judges reliability*. The questionnaire was first sent to five senior systems engineers, who were asked to complete it and evaluate each item's suitability to the subject tested. Wide agreement among all referees was demonstrated. The second method used to check the reliability was calculating the Alpha reliability coefficient (Cronbach's alpha). The result - 0.836 – is higher than the minimum value required by the statistical literature. Cronbach's alpha measures how well a set of items (or variables) measures a single unidimensional latent construct. When data have a multidimensional structure, Cronbach's alpha will usually be low.

The validity of a measurement is the extent to which it represents the measured quantity (Anastasi, 1988). *Contrasted Groups Validity* is determined by comparing the grades of two contrasted groups. In the pilot study, the two groups were systems engineers and other types of engineers. It was found that systems engineers achieved significantly higher scores, as compared to professional engineers. A one-way ANOVA test was conducted using SPSS to analyze the differences between the groups (0.12), which were found to be significant (p-value=0.004). A summary of the analysis is presented in Table 2.

Concurrent Validity is the correlation between the scores obtained by two assessment tools. In the pilot study, the concurrent validity was checked by calculating the correlation between the participants' scores using the proposed tool and the appraisal of their supervisor. It was found that the Pearson Correlation Coefficient was close to 0.4 (p=0.05). This result is very similar to the predictive validity of other selection tools. The Pearson Correlation Coefficient measures the correlation of two variables (measures the tendency of the variables to increase or decrease together.

Construct Validity indicates the extent to which the tool measures a theoretical construct or characteristic (Anastasi, 1988). The construct validity was checked by factor analysis. Actually, this was a Confirmatory Factor Analysis (CFA). Indeed, the analysis revealed five factors that may be labeled as follows: seeing the big picture, implementing managerial considerations, using interdisciplinary knowledge for conceptualizing the solution, analyzing the needs/requirements, and being a systems thinker. These results are compatible with the factors found in a previous study (Frank, 2002)—see the definition of *engineering systems thinking* above. For example, Table 3 presents the rotated component matrix and the loadings for factor number 1 - "seeing the big picture." The table is a correlation matrix presenting the loading of each factor on each item.

The Second Study

The second study, aimed at strengthening the results of the pilot study, included 78 students – 37 senior Electrical Engineering students and 41 senior Technology/Engineering Management students – and 54 engineers, thirty of which are systems engineers, while the other 24 work as professional engineers. The objectives of this second phase were to test the: (1) *concurrent validity* by calculating the correlation between the results from the questionnaire for part of the engineers with the assessment of the employees' senior supervisor who has been familiar with their systems thinking capabilities for many years, (2) *contrasted groups validity* by comparing the CEST scores of senior EE students, senior Technology/

Table 2. One-way ANOVA test results

	Systems Engineers (SE) (*n*=29)	**Non SE Engineers (*n*=25)**	**Difference between Means**	***p*-value**
Mean	1.75	1.63	0.12	0.004

Table 3. Factor 1: Rotated component matrix

Item No.	Component				
	1	2	3	4	5
27	0.681	0.106	0.037	-0.112	-0.050
14	0.635	0.044	0.036	0.334	0.077
25	0.612	0.035	-0.057	-0.063	0.195
3	0.545	0.302	0.250	-0.180	0.291
1	0.462	0.059	0.195	0.110	0.296
39	0.426	-0.293	0.031	0.120	0.265

Engineering Management students, systems engineers and professional engineers.

The method used in this second phase to check the reliability was calculating the Alpha coefficient. The result - 0.855 – is a little bit higher than the result obtained in the pilot study – 0.836. Both results are higher than the minimum value required by the statistical literature.

In this second phase of the study, the *concurrent validity* was checked by calculating the correlation between the twenty-four systems engineers' scores using the tool and the appraisal of their supervisor. The supervisor had been familiar with the participants' systems thinking capabilities for many years. The subjective assessments were all made by the same senior supervisor to increase bias. The supervisor was asked to assess the Capacity for Engineering Systems Thinking of each engineer on a scale of 1 = very low to 7 = very high. It was found that the Pearson Correlation Coefficient between the participants' scores and the supervisor assessments was 0.496 (p=0.014). This result is higher than the result obtained in the pilot study – 0.4 (p=0.05). Both results are very similar to the predictive validity of other selection tools.

The *contrasted groups validity* was checked in the second phase by comparing the tool's CEST scores of four groups – senior Electrical Engineering students, senior Technology Management students, systems engineers and professional engineers. One-way ANOVA test was conducted to analyze the differences between the four groups' mean scores. A significant difference was found (p-value=0.00) – see Table 4. Analysis Of Variance (ANOVA) compares means by splitting the overall observed variance into different parts. One-way ANOVA is used to test for differences among three or more independent groups. Here we had four groups (senior Electrical Engineering students, senior Technology Management students, systems engineers and professional engineers).

A Post-Hoc test (Scheffe test – see Table 5) revealed that: (1) the systems engineers achieved significantly higher scores than the professional engineers, (2) the systems engineers achieved significantly higher scores than the Technology Management students and the Electrical Engineering students, and (3) the forty-one senior Technology/Engineering Management students achieved significantly higher scores, as compared

Table 4. One-way ANOVA test results: Descriptives

					95% Confidence Interval for Mean	
	N	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**
SE Engineers	30	1.7686	.23510	.04292	1.6808	1.8564
Non SE Engineers	24	1.5689	.21469	.04382	1.4783	1.6596
EE Students	37	1.3886	.27478	.04517	1.2970	1.4802
Management Students	41	1.5636	.22588	.03528	1.4923	1.6348
Total	132	1.5621	.27373	.02383	1.5150	1.6092

ANOVA

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	2.394	3	.798	13.762	0.000
Within Groups	7.422	128	.058		
Total	9.816	131			

to the thirty-seven senior Electrical Engineering students. The latter result supports the pre-assumption that the curriculum of Engineering Management deals with some systems issues while the curriculum of Electrical Engineering focused mostly on details. This result is not surprising because EM/TM students are trained to look at problems holistically.

It was also found that EM/TM students dealt poorly with issues related to pure technology/engineering. Based on this result and the result presented above, it is suggested that issues related to systems thinking, system dynamics, and systems engineering will be added to the traditional electrical engineering curriculum, while several topics related to electrical and mechanical engineering will be added to the technology management curriculum.

It was also found that there was no significant difference between the senior Technology Management students and the professional engineers. At first, this result was surprising. The pre-assumption was that, in general, the CEST of engineers is higher than the CEST of students, since undergraduate students are mostly educated to know and understand details. One explanation for this surprising result may be that the engineers who participated in this part of the study dealt with the development of cards, modules and components (i.e. dealing more with details rather than with large-scale systems).

Construct Validity indicates the extent to which the tool measures a theoretical construct or characteristic (Anastasi, 1988). The construct validity was checked by factor analysis. Table 6 presents the rotated component matrix - the loading of each factor on each item:

Extraction Method: Principal Component Analysis

Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 6 iterations.

Note: Items 5, 18, 20, 34, 40, 45, 46 and 47 were omitted in the first phase of the study.

Indeed, the analysis revealed six factors that may be labeled as follows:

Table 5. Scheffe test

					95% Confidence Interval	
(i) group	**(j) group**	**Mean Difference (i-j)**	**Std. Error**	**Sig.**	**Lower Bound**	**Upper Bound**
SE Engineers	Non Se Engineers	.1997*	.06595	.031	.0128	.3865
	EE Students	.3800*	.05916	.000	.2124	.5476
	Mang. Students	.2050*	0.5785	.007	.0411	.3689
Non SE Engineers	SE Engineers	-.1997*	.06595	.031	-.3865	-.0128
	EE Students	.1803*	.06311	.047	.0015	.3591
	Mang. Students	.0054	.06189	1.000	-.1700	.1807
EE Students	SE Engineers	-.3800*	.05916	.000	-.5476	-.2124
	Non SE Engineers	-.1803*	.06311	.047	-.3591	-.0015
	Mang. Students	-.1749*	.05460	.019	-.3296	-.0202
Mang. Students	SE Engineers	-.2050*	0.5785	.007	-.3689	-.0411
	Non SE Engineers	-.0054	.06189	1.000	-.1807	.1700
	EE Students	.1749*	.05460	0.019	.0202	.3296

Table 6. Rotated component matrix

Component						
6	5	4	3	2	1	
.002	.059	-.015	-.017	.081	.958	Q1
-.002	.054	.116	-.021	.108	.788	Q2
-.007	.049	.083	-.018	.117	.848	Q3
.094	.082	.009	-.021	.199	.684	Q4
.021	.351	-.221	.422	.109	.479	Q6
.054	.050	-.043	.059	.820	.140	Q7
.121	.121	.018	.075	.798	-.006	Q8
.016	.038	.086	.182	.731	.059	Q9
.129	.007	.048	-.005	-.047	.747	Q10
.066	.198	.012	-.027	-.017	.738	Q11
.061	.022	.052	-.038	.032	.793	Q12
.869	.084	-.030	.093	.107	.057	Q13
-.061	-.035	.097	.000	.099	.860	Q14
.066	.026	-.048	-.066	.111	.745	Q15
.036	.105	.034	.017	.895	.097	Q16
.114	.154	.066	.148	.927	.108	Q17
.049	.136	.036	.081	.870	.085	Q19
.143	.042	.116	.882	.142	-.040	Q21
.034	.166	.061	.833	.158	-.101	Q22
.142	.105	-.051	.011	.093	.743	Q23
-.062	.680	.316	.409	.084	-.025	Q24
-.027	.004	.076	-.026	.086	.819	Q25
-.040	.151	-.045	-.006	.064	.850	Q26
.025	.123	-.041	-.024	.069	.867	Q27
.105	.023	.097	.037	.787	.076	Q28
.041	.168	.329	.624	.337	.089	Q29
.685	.206	-.191	.445	.033	.041	Q30
.031	.023	.001	.041	.022	.850	Q31
-.039	-.087	.036	.131	.074	.754	Q32
.170	.114	.047	.883	.189	-.022	Q33

* The mean difference is significant at the .05 level

Factor 1 – Seeing the big picture: Items 1, 2, 3, 4, 6, 10, 11, 12, 14, 15, 23, 25, 26, 27, 31, 32, 39.

Factor 2 – Using interdisciplinary knowledge for conceptualizing the solution: Items 7, 8, 9, 16, 17, 19, 48.

Factor 3 – Analyzing the needs/requirements: Items 21, 22, 33.

Factor 4 – Being a systems thinker: Items 35, 43, 44.

Factors 5 and 6 – Implementing managerial considerations: Items 13, 30, 36, 41, 42.

These results are compatible with the factors found in a previous study (Frank, 2002)—see the definition of *engineering systems thinking* above (except 5 items – 24, 28, 29, 37 and 38 – which were not loaded according to the "right" factor).

CONCLUSION

The current paper introduces principles for developing a tool for assessing engineers' interest regarding systems engineering job positions and the results of two studies aimed at examining its reliability and validity. In the first study, two types of reliability were calculated - inter-judges reliability and Alpha coefficient reliability. One of the objectives of the second study was to re-check the Alpha coefficient reliability. Both results – 0.855 and 0.836 were higher than the minimum value required by the statistical literature. In the first study four types of validity were presented – content validity, concurrent validity, contrasted group validity and construct validity. One of the objectives of the second study was to re-check the concurrent validity and the contrasted groups validity. The Pearson correlation between the participants' scores and the assessment of their supervisor was found to be 0.496 (p=0.014) in the second study and 0.4 (p=0.5) in the first study. Both results indicate that the tool's concurrent validity is similar to the concurrent validity of other selection tools.

In the first study, the contrasted groups validity was checked by calculating the difference between the scores of systems engineers and professional engineers. In the second study, it was checked by calculating the difference between the scores of (1) senior Engineering Management and Electrical Engineering students, (2) senior students and systems engineers, and (3) systems engineers and professional engineers. In both studies, the difference between the groups was found to be significant.

The findings of the two studies indicated that the tool might prove to be a powerful instrument, to be used by industry organizations as well as systems engineering researchers and educators alike. Such a tool can be used to distinguish between individual engineers according to their systems thinking capabilities and engineering interests and abilities. However, there is still quite a long way to go before officially releasing the tool for use in SE organizations. Hence, a series of additional and more extensive tests must be conducted using the proposed tool in other cultures, sectors and organizations with a larger number of participants. The results of the reliability and validity checks presented in the current paper are quite satisfactory; however, they still await verification and validation by others.

The next step is to test the following hypothesis: A positive correlation exists between the scores achieved by systems engineers using the CEST tool and the extent to which the systems projects meet their objectives. This will be further examined in a follow-up study.

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APPENDIX

CEST INVENTORY: SAMPLE ITEMS

Note: the full instrument is copyrighted.

Factor 1: Seeing the big picture

Item No. 2

A. When I take care of a product, it is important for me to see how it functions as a part of the system.

B. When I take care of a product, it is important for me to concentrate on this product, assuming that other engineers will take care of the other parts of the system.

Item No. 3

A. It is important for me to identify the benefits derived from embedding several products/sub-systems/systems.

B. I prefer not to deal with combinations of products/sub-systems/systems but rather to concentrate on the product for which I am responsible.

Item No. 4

A. It is important for me to know what other employees in my department/project do.

B. It is important for me to do my best and not interfere to the work of other employees in my department/project.

Item No. 6

A. I don't like to be involved with details; I prefer to deal with the system's aspects.

B. In areas in which I'm involved, I like to understand all the details.

Item No. 11

A. When I deal with a product, I always look at the interconnections and mutual influences between the main product and the peripheral products.

B. I prefer to thoroughly take care of the part for which I am responsible and leave the issue of interconnections between a system's parts to the integration engineers.

Factor 2: Using interdisciplinary knowledge for conceptualizing the solution

Item No. 17

I think that every employee should gain interdisciplinary knowledge and general knowledge in several fields.

B. I think that every employee should become an expert in his/her field. Learning more fields may lead to sciolism (to know a little about many subjects).

Factor 3: Analyzing the needs/requirements
Item No. 22
A. I like to discuss the needs with the customer.
B. I prefer to leave the contact with the customer to marketing experts.

Factor 4: Being a systems thinker
Items No. 43
A. It is important for me to continuously think what else can be improved.
B. It is important for me to determine finish line and to finish my jobs in time.

Factors 5 and 6: Implementing managerial considerations
Item No. 30
A. I like to integrate and to lead interdisciplinary teams.
B. I'm a professional; I prefer not to be involved with managerial issues.

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Section IV
Utilization and Application

This section introduces and discusses the utilization and application of strategic information systems. These particular selections highlight, among other topics, optimizing the relationship between business and information technology, applications of decision making and support systems, and the ways in which strategic intelligence has been applied in society. Contributions included in this section provide excellent coverage of today's strategic environment and insight into how strategic information systems impact the fabric of our present-day global village.

Chapter 4.1

I-Fit:

Optimizing the Fit between Business and IT

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ABSTRACT

This document summarizes the initial findings of the I-Fit research project that started in August 2006 as a joint activity of a regional ICT consultancy and a university research center. The main goal of the project is to help the consultants to improve alignment between business and IT in the client organizations. The I-Fit project takes the perspective of the business manager: how a business manager can influence and increase the value of the IT services that he receives. Based on the literature on strategic alignment and Information quality, we develop the I-Fit model. The model assumes causal relationships between IT governance, Strategic Alignment, Information Quality, and Business Performance in an organization.

INTRODUCTION TO I-FIT PROJECT AND ITS OBJECTIVES

The I-Fit research project is a joint effort between KZA and Tilburg University and aims to further develop the alignment model.

The objectives of the I-Fit project are: To predict the impact of the business environment on the IT function in an organization, and to identify and manage the factors that influence the Information services in an organization.

The starting point of both the I-Fit project (and this chapter) is the well-known Strategic Alignment Model (Parker, Benson, & Trainer, 1989; Henderson & Venkatraman, 1991). Strategic alignment, or "business-IT alignment," intends to support the integration of IT into business strategy. The classic "Strategic Alignment Model" distinguishes between the business domain (business strategy and business processes) and the technology domain (information strategy and IT processes, including systems development and maintenance) in an organization.

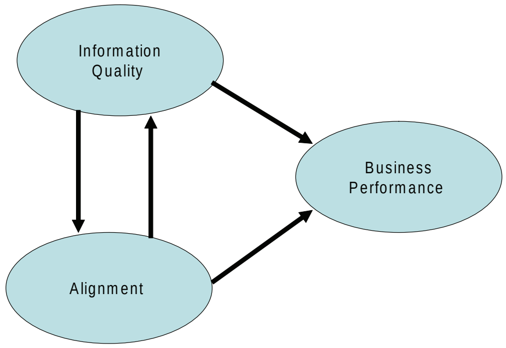
The I-Fit project focuses on three issues: identifying the key alignment processes, identifying performance indicators for alignment processes, and developing methods to improve alignment.

The deliverables of the I-Fit project include instruments or tools:

1. To provide insight for business managers in the IT consequences of decisions on Information services,
2. To support business managers to control Information services , based on alignment processes, and
3. To design strategies for the IT domain in order to maximize IT value added for the business, and (possibly) for benefits management.

This chapter summarizes the first three building blocks (Information Quality[1], alignment, and Business Performance (Figure 1)) for the creation of these tools. We briefly discuss two case studies within the project, and conclude with a generic framework addressing the relations between IT governance, Alignment Processes, Information Quality, and Business Performance. We also discuss the next steps of this I-Fit project for interested readers.

Figure 1. Building blocks for the I-Fit project



Note: The arrows indicate some possible relations between alignment, information quality and business performance

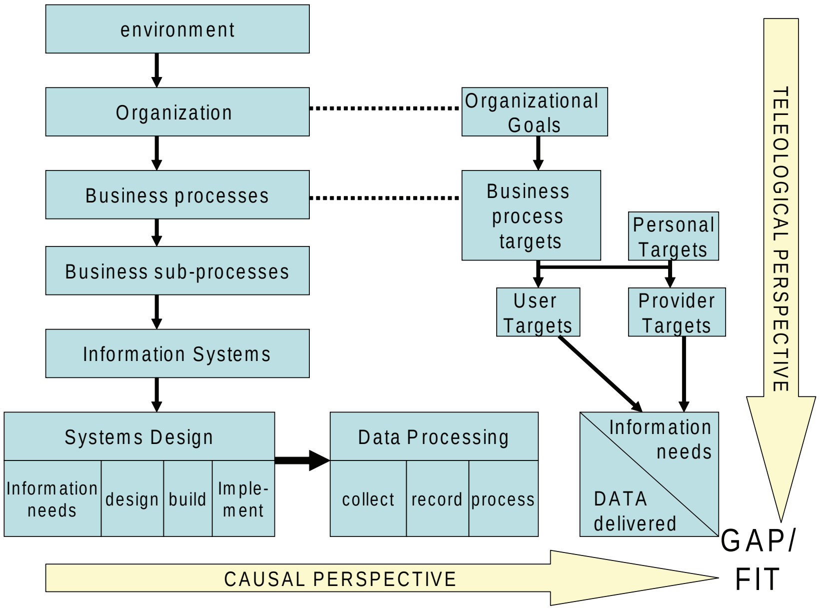
LITERATURE REVIEW

Information Quality

Our work is based on Roest (1988), Van der Pijl (1994a, 1994b), and Vermeer (1999) and denotes a typical Dutch or European perspective on information management. In this perspective, the quality of information (coming from information systems) is the key issue to explain business success. The USA approach differs since it aims to explain business success not by focusing on information, but on information technology and information systems.

The well-accepted definition of information quality is "the degree to which information is fit for use" or "fitness for purpose" (Klobas, 1995). Therefore, information quality on the highest level can simply be determined by asking for user satisfaction. However, this does not provide insight into the origins of quality failures. To analyze the origins, information Quality can be determined in two distinct ways, also known as the teleological and the causal perspective (Van der Pijl, 1994a) (Figure 2 shows these two perspectives). In the I-Fit project we use these two perspectives to determine the quality of information.

Figure 2. Causal and teleological perspectives on quality of information



Teleological Perspective

In the teleological perspective, information quality is the degree to which the information (data) that is delivered to the business fulfils the business needs. In the teleological model the quality of information is determined by the objective for which the information is intended to be used. Van der Pijl (1994a) argues that information depends on personal objectives that in their turn (partly) depend on organizational objectives. The importance of the teleological model is that it introduces organizational and business process objectives next to personal (e.g., user) objectives in the concept of information quality. From the teleological point of view the quality of information is seen as the degree to which it satisfies "stated or implicit needs," derived from the situation in which it is used.

Typical indicators for Information quality in the teleological perspective (Van der Pijl, 1994a) are: timeliness, accurateness, relevance, availability, and completeness[2]. Also, the flexibility of information (services) is important: how fast can Information services be changed in case of changes in the business needs? Note that, for instance, faster management reporting can relate to administrative requirements ("boekhoudkundige tijdigheid") and improved logistics of information processing.

Causal Perspective

Another perspective on Information quality is found in the causal model. In this perspective, Information quality is the degree to which the information that is delivered to the business is the result of a clear and correct chain of activities. These activities can be grouped in two phases: the information system development phase and the information system operation phase. The importance of the causal model of Information quality is that it is not possible to measure all aspects of the quality of information only from the information itself. The reliability of information also depends on the measures that are taken in the IS development and operational phase.

From the *causal perspective*, the quality of information is seen as the result of the quality of the processes in which it is produced. The first step in these processes is information analysis. During this stage the link between the organization's needs and the information systems is established. First the information policy is formulated and then the more detailed information needs are derived. The essence of the causal point of view in ex-post quality assessments is that not all aspects of the quality of information can be measured from that information itself. For some features it is necessary to look at one or more of the steps of the production process.

Typical indicators for Information quality from the causal perspective (Van der Pijl, 1994a) are "the information is provided according to the existing service level arrangements," "the information creation process is accountable for and transparent," and "it is SOX compliant."

Interestingly, the variety of Information quality indicators from the two perspectives create the need for business managers to balance between timeliness, completeness, accurateness, and the flexibility of information services . Aiming for the maximum performance on all quality indicators leads to high costs for information services.

Strategic Alignment

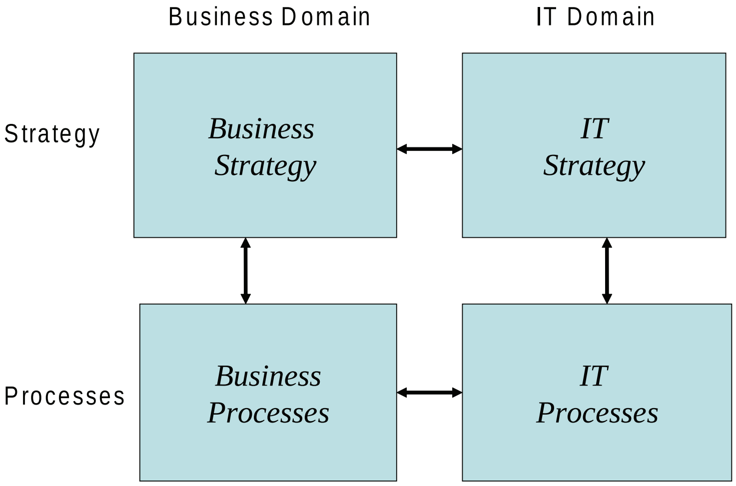
Three concepts are important to determine the impact of IT on information quality (previous section) and Business Performance (final section). In this section we define alignment, fit, and IT governance.

Henderson and Venkatraman (1993) introduced "business-IT alignment," in short "alignment," intended to support the integration of IT into business strategy. They distinguish in their classic "Strategic Alignment Model" (Figure 3) between the business domain (consisting of "business strategy" and "business processes") and the technology domain (consisting of "IT strategy" and "IT processes," including systems development and maintenance) in an organization.

Since 1990, various changes have been proposed to the Strategic Alignment Model, refocusing IT strategy into Information Systems Strategy (Strategic Information Systems Planning) and Information Strategy, showing more focus on business relations.

Information strategy is a complex phenomenon. In many organizations and in much of the information systems (IS) literature different terminologies are used. We define information

Figure 3. The Strategic Alignment Model (based on Henderson and Venkatraman (1993) and Parker, Benson & Trainor (1988))



strategy as: "a complex of implicit or explicit goals, visions, guidelines and plans with respect to the supply and demand of formal information in an organization, sanctioned by management, intended in the long run to support the objectives of the organization and adjusted to the environment."

Operationally expressed, information strategy is an instrument to manage Information services and technology in an organization. A frequently used term, related to information strategy, is strategic information systems planning (SISP) (Earl, 1993; Galliers, 1991; King, 1988; Lederer & Sethi, 1988; Ward, Griffiths & Whitmore, 1990). SISP is defined as "the process of deciding the objectives for organizational computing and identifying potential computer applications which the organization should implement" (Lederer & Sethi, 1988). The two definitions look very similar, but a strict comparison shows that the SISP definition tends to focus on explicit objectives and on applications and technology. Our definition concentrates on the use and the importance of information in an organization, starting with the planning of information (in the end influencing IT, as well as influenced by IT). We preferred this definition as a starting point to investigate how contemporary organizations deal with their needs for information and the planning of IT.

Strategic alignment is pursued along two dimensions in Figure 3: strategic fit: the (vertical) fit between strategies (business and IT) and internal infrastructures and processes, and *functional integration*: the (horizontal) fit between the business and the technology domain) (Henderson & Venkatraman, 1993).

Alignment is an elusive concept (Chan, 2002). Definitions of alignment range from high level, broadly encompassing definitions such as:

The fit between an organization and its strategy, structure, processes, technology, and environment.

A more focussed definition is:

The convergent intention, shared understanding and coordinated procedures.

Well-received views are that IS alignment is:

the degree to which the IT mission, objectives, and plans support and are supported by the business mission, objectives and plans (Chan, 2002), and *alignment is not a state, but a journey – one that is not always predictable, rational, or tightly planned* (Ciborra, 1991; Sauer & Yetton, 1997).

Chan (2002) defines IS alignment as:

- **IS alignment:** The "bringing in line" of the IS function's strategy, structure, technology, and processes with those of the business unit, so that IS personnel and their business partners are working toward the same goals while using their respective competencies.
- **IS strategic alignment:** The subset of IS alignment that concerns IS strategy and Business Unit Strategy. This component includes both strategy and processes.
- **IS structural alignment:** The subset of IS alignment that concerns the formal structure of the IS function and the business unit structure.

In the remaining discussion on this topic in this chapter, we focus on two aspects of alignment: (1) alignment as a process consisting of driver, levers, and impact, aiming to improve fit and (2) alignment as the degree of strategic fit and functional integration. Additionally, IT governance is introduced as the control structure in an organization to realize effective alignment processes.

IT Governance Defined

IT governance is defined as the way in which IT in an organization is controlled and coordinated (Brown 1997; Sambamurthy & Zmud 1999). More precisely, IT governance is about the focus of IT decision-making authority (centralized vs. decentralized control) and the processes that are in place to communicate IT decisions (Peterson, 2002).

Effective IT Governance Leads to Successful Alignment Processes

Governance comes from "kybernan" (Greek) and is related to "cybernetics" (Wiener, 1948), meaning "to steer" and "keeping a ship on its course in the midst of unexpected changing circumstances" (Peterson, 2002). Governance can be regarded as "control" in a broad perspective, meaning that governance includes the total set of controlling activities that keep the system (ship, organization) on the right (chosen) course (Malone & Crowston, 1994). Governance is a purposeful intervention in order to achieve a desired output, and describes a subsystem of decision-making units for directing and coordinating operational subsystems. The governance paradigm is based on a general systems approach of organizations (Ashby, 1956). Control is governance in a limited perspective, related to directing one subsystem.

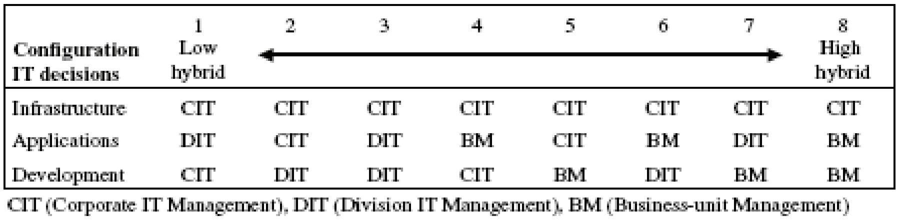
Traditionally, three configurations have been distinguished for IT governance (Sambamurthy & Zmud, 1999). In each configuration, stakeholder constituencies take different lead roles and responsibilities for IT decision making:

- **Centralized:** In this configuration, corporate IT management has IT decision-making authority concerning infrastructure, applications, and development.
- **Decentralized:** In this configuration, division IT management and business-unit management have authority for infrastructure, applications, and development.
- **Federal:** In this configuration (a hybrid configuration of centralization and decentralization), corporate IT has authority over infrastructure, and division IT and business-units have authority over applications and development.

In general, it is argued that centralization provides greater efficiency and standardization, while decentralization improves business ownership and responsiveness (Brown 1997). Table 1 shows eight types of IT governance, varying from centralized to decentralized decision making.

Peterson (2001) indicated that as companies experience increased uncertainty and complexity, and adopt multifocused strategies, IT governance designs are more hybrid with increased coordination needs. Figure 4 shows how the strategic (business) context influences the type of governance design and the integration mechanisms for IT governance, ultimately influencing IT perfor-

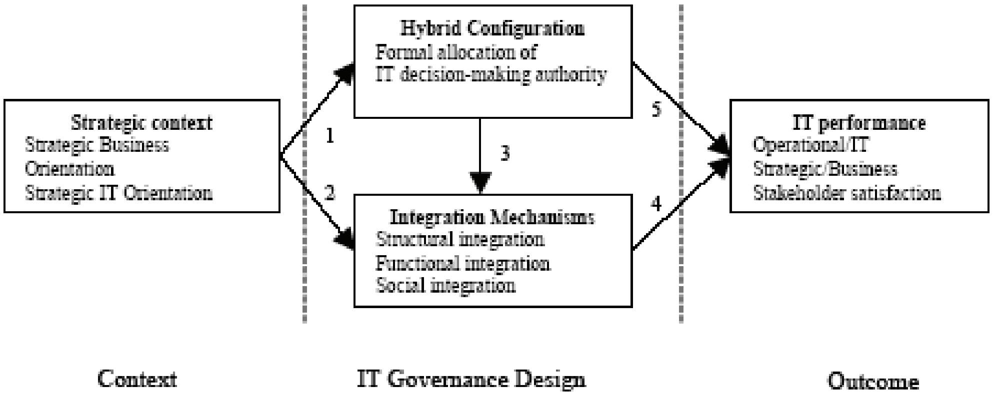
Table 1. Hybrid configurations for IT governance



Configuration IT decisions	1 Low hybrid	2	3	4	5	6	7	8 High hybrid
Infrastructure	CIT	CIT	CIT	CIT	CIT	CIT	CIT	CIT
Applications	DIT	CIT	DIT	BM	CIT	BM	DIT	BM
Development	CIT	DIT	DIT	CIT	BM	DIT	BM	BM

CIT (Corporate IT Management), DIT (Division IT Management), BM (Business-unit Management)

Figure 4. IT governance design (Peterson, 2001)



mance. Peterson showed that for organizations in a dynamic strategic context, the best IT governance structure is decentralized decision making, combined with rich integration mechanisms.

For I-Fit, it is shown later in this chapter that we have added two types of governance (information system (IS) and information (I)) to the classic IT governance definitions (e.g. the ISACA definition: "IT governance is the responsibility of executives and the board of directors, and consists of the leadership, organizational structures and processes that ensure that the enterprise's IT sustains and extends the organisation's strategies and objectives" (COBIT 4.0, www.itgi.org)).

Business Performance

Melville, Kraemer, and Gurbaxani (2004) reviewed the literature on IT and Organizational Performance and developed an integrative model of IT Business value (Figure 5). The term IT business value is commonly used to refer to the organizational performance impacts of IT, including productivity enhancement, profitability improvement, cost reduction, competitive advantage, inventory reduction, and other measures of performance.

The core of the model shows the impact of IT and complementary organizational resources on business processes and business process performance. Mediating variables are trading partner resources, industry characteristics, and country characteristics. The term performance is used to denote both intermediate business process level measures (also indicated as first order effects) as well as organizational measures (indicated as higher level variables, such as market share).

The IT business value literature does not provide a convention regarding the incorporation of costs of system development and implementation.

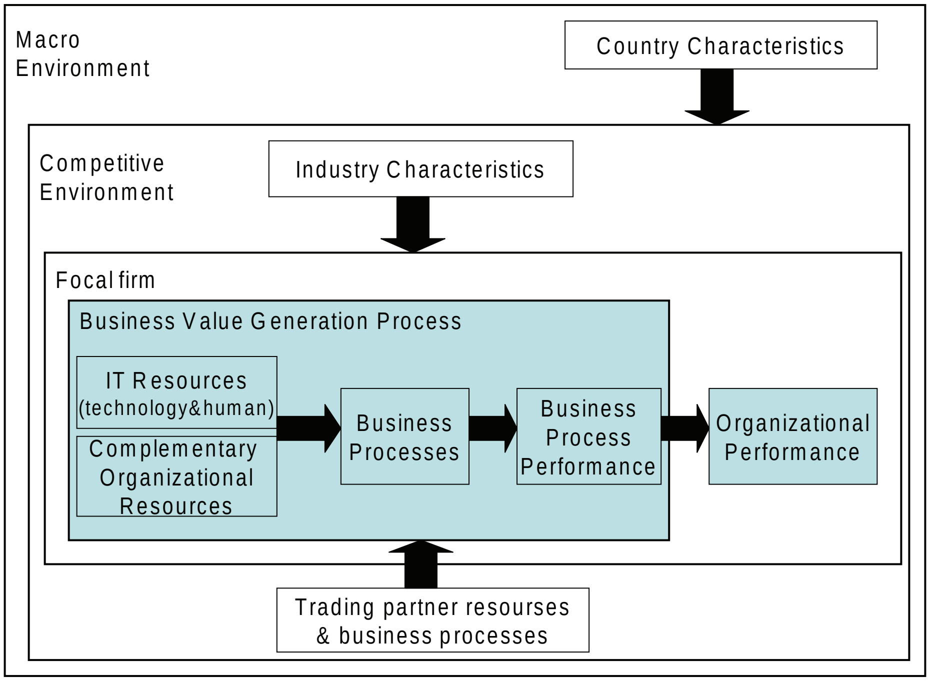
ISSUES AND SOLUTIONS FOR I-FIT PROJECT

Addressing Information Quality

Issue: Linking Information Quality to Business Objectives

In both perspectives, the quality of information relates to the degree to which information supports the goals (strategies, objectives) of the organization in which it is used. We outline these goal categories below (Van der Pijl, 1994b):

Figure 5. The IT business value model indicating the effect of IT resources on business processes, business process performance and organizational performance (Melville et al., 2004)



- **The organizational goals**. Almost every organization is characterized by the fact that its members come together to realize some kind of common goal. This common or organizational goal reflects the expectations, ambitions and aspirations of those who depend on the organization. At the level of the organization as a whole, organizational goals have to be translated into strategies that describe how these goals can be reached. Strategies arise in an interaction between structure, culture and goals of the organization. Traditionally we suppose that information has to support the organization's strategies. Recently we see, however, that information systems can also be used to shape, instead of support, organizational strategies and that they make it possible to aim for new goals.
- **The business process goals**. The existing division of labour in the organization is the basis for translating organizational goals and strategies into targets for each business process, department and individual within the organization. The degree of detail to which these targets have to be described when studying the quality of information depends on the organizational level that is chosen as a starting point for the analysis. Some organizations have explicit mechanisms for adjusting organizational goals and business process targets for different processes and hierarchical levels, while others do not. In some organizations there even is no strictly hierarchical relationship between goals and targets at all levels (operations, managerial, and strategic).
- **The personal interests**. Each individual in the organization also has its own individual interests. Status, power, responsibility, prestige and money are well known examples of personal aims, which can be influenced by background, experience and knowledge. Since the information needs of a person in

a certain function in the organization are influenced by both business process targets and personal interests, a judgement of the quality of information available to the individual has to take both elements into account.

- **The user's targets and the provider's targets**. Goals and targets can not only be subdivided according to levels in the organization but also into targets of those who are using information and targets of those who are providing others with information. A difference in position may lead to differences of opinion on the quality features and characteristics of the information received or provided.

Judging the *teleological aspects* of the quality of information in an organization means assessing the degree to which the information systems in the organization contribute to each of the goals and targets listed previously.

It is also possible to take only a subset of goals and targets into consideration. If we look at individual systems at the level of user's or provider's targets, we can study in detail which quality features and characteristics determine the contribution of systems to reaching the targets and how well the systems do so for each of these. If we look at the configuration of systems available to the organization as a whole, we take a much more global view. In that case we ask ourselves which functional contribution the systems make to the goals and targets of the organization without specifying detailed quality characteristics. Thus the detailed view of quality is replaced by a more global view in which quality of information in the organization is understood as the degree of fit between the goals and targets of the organization and the information systems that support the organization.

The causal and the teleological point of view are combined in Figure 2. At the bottom of the figure we see the steps of the process that has to be studied in the causal approach. On the upper right-hand side of the figure the set of goals and targets are shown, to be considered in the teleological approach. The vertical lines indicate the correspondence between the different levels of goals and targets and the hierarchical levels of the organization depicted on the left-hand side.

Solution: Measuring Information Quality

We see two opportunities or tools to measure the quality of information.

The first tool is the INK Information Mirror (in Dutch "informatiespiegel"), published in "Perfect Information Services (in Dutch: Excellente Informatievoorziening. Luiten, www.ink.nl). The Information Mirror consists of 25 questions from both the causal and the teleological perspectives. Answering the questions on a four-point Likert scale leads to a total score indicating the quality of Information services . *Note that this tool aims to determine the quality of Information services and not –only- the quality of information that is the result of the services.*

The second tool is the method by Van der Pijl (1994b, pp. 119-124), adapted from Bedell (1985), and focusing on the teleological perspective. The method consists of 12 steps, starting with (1) describing the objectives of the organization, the process, and the individuals involved, and (2) describing the information systems in the organization. In the next step the information systems are related to the business processes and process objectives per process. Then the relative impact of each information system to each objective and process is estimated. By adding the scores for all information systems and business processes, the total value of all IS for the organization is calculated. *Note that this tool aims to determine the quality of (the functionality of) information systems, and not the quality of information!*

Addressing Strategic Alignment

Issue: Alignment as a Process: Driver, Lever, and Impact

Henderson and Venkatraman described four types of alignment. Two alignment types are driven by business needs: (1) *Strategic execution:* business strategy drives organizational infrastructure and processes, ultimately influencing IS infrastructure and processes, and (2) *Technology transformation*: business strategy drives IT strategy, ultimately influencing IT processes.

Two other alignment types are driven by IT opportunities: (3) *Competitive potential*: information strategy influences business strategy, ultimately influencing organizational infrastructure and processes, and (4) *Service level*: information strategy influences IT infrastructure and processes, ultimately influencing organizational infrastructure and processes.

Luftman (1996) found empirical evidence that alignment can be seen as a process with a typical sequence of activities. Each alignment process has three major components that form a complete pattern of strategic change: a driver, a lever, and an impact (see also Hsiao & Ormerod, 1998). In the first perspective the business strategy is the driver for business processes or information strategy (called "levers"), ultimately affecting the IT processes ("impact"). Analysis of driver-lever-impact sequences can be found in Smits and Huisman (2007) and Alt and Smits (2007).

Similar refinements of the original alignment model can be found in Hsiao and Ormerod (1998) and Sauer and Yetton (1994), who also analyzed the relationships and different patterns of influence (different sequences of drivers, levers, and impacts) between strategy, structure, technology, and management.

Chan (2002) and Sauer and Yetton (1994, 1997) acknowledge that alignment is not a state (a situation of equilibrium between the domains that an organization can reach), but a journey ('a continuous managerial effort, not always predictable, rational, or tightly planned').

This journey and process perspective on alignment is fully in accordance with our definitions of information quality and the gap between information services and information needs:

- Alignment is a process in an organization that aims to reduce the gaps between the business domain and the technology domain, and between strategies and processes, and, ultimately the gap between information needs and information services.

Solution: Alignment and Organizational Effectiveness

The IS literature has repeatedly outlined the fundamental importance of alignment for organizational effectiveness and several attempts have been made to define the alignment concept more precisely and to develop the strategic alignment model into more concrete managerial guidelines and tools (Chan, 2002). Based on a review of literature and practice, alignment is defined by Chan as a multidimensional phenomenon, and as "a superset of multiple, simultaneous component alignments that bring together an organization's structure, strategy, and culture at multiple levels (IT, business unit, and corporate) with all their inherent demands"

Cragg et al. (2002) aimed to focus on the relationship between alignment and organisational performance, based on the argument that strategic fit has performance implications. Generally spoken: the better the fit, the better the performance (Fry & Killing, 1989). More specifically, the study wished to focus on one aspect of IT alignment, that is, the alignment between business strategy and IT strategy (Henderson & Venkatraman, 1989). In the Cragg et al. (2000) study, IT alignment was viewed as the fit between business strategy and IT strategy, similar to Chan et al. (1997). Two approaches were modelled—fit as "matching" and fit as "moderation"[3] which both rely on the close correspondence between the nine IT strategy items and the nine business strategy items. Fit as matching was based on the difference between each of two pairs of related items. Fit as moderation was modelled as the interaction between each business strategy and the related IT strategy. Thus, a gap analysis is created as to the closeness of fit to purpose.

This concept of "alignment" or "fit" expresses an idea that the object of design, e.g. an organisation's structure or its information systems, must match its context in order to be effective (Iivari, 1992). Parsons (1983) was one of the first to argue that IT can affect a firm's ability to execute their business strategy. Since then, many others have emphasised the need to develop a fit between information technology strategies and business strategies (Chan et al., 1997; Galliers, 1991; Henderson & Venkatraman, 1993; Venkatraman, 1989).

Addressing Business Performance

Issue: Frameworks for Organizational, Process, and Network Performance

The Operations Research and Management Science disciplines have provided guidelines to measure Business Performance of individual companies as well as the performance of business networks and supply chains (SC). A well-known example is the Balanced Scorecard (Kaplan & Norton, 1992), distinguishing between performance in four domains: financial, customer, process, and innovation.

The Supply Chain Operations Reference model (SCOR) for supply chain process benchmarking and performance measurement within as well as across firms, is based on five distinct management processes: plan, source, make, deliver, and the return process (Supply Chain Council, 2005). The SCOR model shows that performance can be evaluated in many ways, for example, higher flexibility, customer orientation, customization, flexibility and better cost-effectiveness. Gunasekaran et al. (2004) use the SCOR perspective and conclude that supply chain performance refers to meeting the end customer requirements, including product availability, on-time delivery, and all the necessary inventory and capacity in the supply chain to deliver that performance in a responsive matter. So, performance can be regarded "good" when the performance objectives are achieved on all levels and as set by all managers and organizations involved. Obviously, matching all these objectives is not an easy task (Hausman, 2002).

Kleijnen and Smits (2003) investigated the metrics used by organizations to evaluate Business Performance in a SC. Starting point is the set of five classic SC performance metrics reported in SC literature and practice from a single company perspective: (1) Fill rate (the percentage of orders delivered "on time"; that is, no later than the delivery day requested by the customer); (2) Confirmed fill rate (the percentage of orders delivered no later than the day agreed between the customer and the supplier); (3) Response delay (the difference between the requested delivery day and the negotiated day); (4) Delay (actual delivery day minus confirmed delivery day); (5) Stock (total Work in Process (WIP)). Kleijnen and Smits (2003) conclude that organizations now often use multiple metrics (balanced scorecard) because a single measure does not suffice.

Recently, SCOR related frameworks have become available to evaluate multiple metrics across organizations in a supply chain to support supply chain integration:

- Lambert and Pohlen (2001) present a framework in which Customer Relationship Management and Supplier Relationship Management are the two processes that capture the overall performance of a SC. The two processes must be analyzed in every supplier-customer link in a multi-tiered network to provide the supply chain metrics.

- Gunasekaran et al. (2004) developed a framework for SC performance measurement distinguishing between twelve metric types based on three management levels or responsibilities (strategic, tactical, and operational) and –per level- the four major SC activities (Plan, Source, Make, Deliver). Gunasekaran lists 44 examples of different metrics, for instance, "supplier delivery performance" is a metric for "sourcing" at the "tactical level."

Fairchild, Ribbers, and Nooteboom (2004) distinguish seven success indicators for business networks. Four indicators relate to market context and three to market processes. Market context success indicators can be summarized as (1) a high number, high volume, high variability, and high frequency of the transactions, (2) low complexity, low specificity, and high value of the product, (3) convergence of stakeholder motives, and (4) the presence of government regulations. Market process success indicators can be summarized as (1) low learning costs and low entry barriers, (2) availability of multiple transaction mechanisms, (3) trust, based on neutrality of the market, partnership with domain experts, high quality of product- and trading partner information, security of information, and a local focus.

Solution: From Alignment to Performance

Chan et al. (1997) use a well-accepted model to link Business Strategic Orientation and IS Strategic Orientation to IS Strategic Alignment, Business Performance and IS Effectiveness.

Chan et al (1997) define IS Strategic Alignment as "the alignment between Business Unit Strategic Orientation and IS Strategic Orientation" and calculate IS Strategic Alignment as the degree to which a company employs the systems that supported the strategic orientation. Note that this is only part of the total alignment processes represented in the strategic alignment model.

Chan et al. (1997) examined whether the impact of IT on performance may not be a direct one, but intermediated by other factors, such as the alignment between Business Strategy and IT Strategy. They modified the well-known STROBE model (STRategic Orientation of Business Enterprises) of Venkatraman to include performance at the IS level as well as at the business unit level. The constructs are defined in Table 2.

I-FIT MODEL: COMBINED BUILDING BLOCKS

This document has summarized the three building blocks Information quality, Alignment, and Business Performance for the creation of tools:

- To provide insight for business managers in the IT consequences of decisions on information services,
- To support business managers to control I services, based on alignment processes, and
- To design strategies for the IT domain in order to maximize IT value added for the business, and (possibly) for benefits management.

Information Quality can be determined in two perspectives: the quality of the information that is provided to the business (the causal perspective) and the quality of the information that is needed by the business (the teleological perspective). The difference between the two quality indicators illustrates the "gap" showing a certain degree of (miss-) fit. We aim to qualify the gap by distinguishing between four types of information, following the balanced score card perspectives: financial, process, customer, and innovation related information.

Strategic Alignment[5] in an organization can be determined by analyzing the alignment processes that occur in an organization (from driver, to lever, and impact) and to assess the IT governance structure and integration mechanisms in

Table 2. Dimensions to assess IS strategic alignment and business performance

Key Construct	Indicators	Key informants
STROBE (Strategic Orientation of Business Enterprises)(= Realized Business Strategy)	Company analysis, Company internal defensiveness, Company external defensiveness, Company futurity, Company proactiveness, Company Risk Aversion, Company Innovativeness	Chief Executive Officers
Business Performance[4]	Market Growth, Financial Performance, Product-Service Innovation, Company Reputation	Chief Financial Officers
IS Effectiveness (i.e., Current Value and Business Contribution of IS)	Satisfaction with IS staff and services; Satisfaction with the Information product; satisfaction with End User Knowledge and Involvement IS Contributions to Operational Efficiency, Managerial Effectiveness, Establishment of Market Linkages, Creation and Enhancement of Products and Services.	Vice Presidents of end-user, mission critical departments
STROEPS (Strategic Orientation of the Existing Portfolio of IS applications)(= Realized IS Strategy)	IS Supports for Aggressiveness, Analysis, Internal Defensiveness, External Defensiveness, Futurity, Proactiveness, Risk Aversion, Innovativeness	Executives familiar with the information systems used in the business unit (Chief Information Officers)
IS Strategic Alignment	This construct is calculated from the scores on STROBE and STROEPS	

an organization aiming to manage alignment and to reduce the gap between information needs and Information services.

Business Process Performance in an organization can be determined by assessing performance at the business process level using balanced scorecard like performance indicators.

For the I-Fit project, based on the literature review in the previous sections, we propose the I-Fit model (Figure 6), to analyze alignment (the current situation IST) in an organization. Key hypothesis in Figure 6 is that "good alignment (effective driver-lever-impact processes and good IT governance) leads to good information quality (good fit between causal and teleological quality indicators), ultimately improving Business Performance."

Key questions for analysis of the current situation (IST) in an organization are:

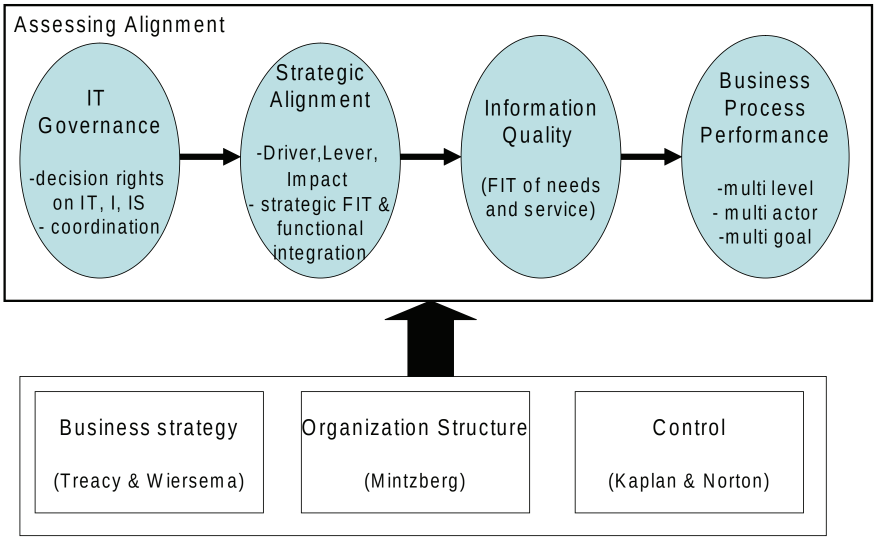
- How is IT governance implemented in the organization?
- How do alignment processes exist in the organization?
- Are existing information systems aligned with the business strategy in the organization
- Do the Information services fit with the information needs in the organization?
- How mature is the IT and business organization? (similar to the concept of CMMi?)

Answering these questions means that there is a "FIT" between the four circles in Figure 6. If there is no "fit," a new situation should be designed (SOLL), by changing one or more circles. This design process would be a joint effort of consultants and the client organization: the effort can be considered successful if insight in the IST situation has increased, and if a shared basis for implementation of improvements has been accomplished.

Cases to be Assessed in the I-Fit Project

The primary vertical focus of our initial cases is the financial industry in continental Europe. Both

Figure 6. The I-FIT model: A framework for tools to analyze alignment in an organization



banks discussed here have their names withheld for privacy reasons.

Bank "A": Within Bank A"s IT and change organization, there are a significant number of improvement initiatives, which currently driven by business process improvement (BPI) metrics. These include not only process improvement, but also compliance. Both budget allocation and required cost cutting measures currently take place based on business process improvement (BPI) metrics. This is not a very transparent process for the client internally.

This bank's business model is transforming from a traditional insurance company towards an "issuance factory". The factory model is a shared service center for insurance companies. BPI is responsible for the transition. This means, in practice, that the regular business gets little attention from BPI.

In this context, we are introducing I-Fit to make things transparent and give insight in the consequences of the current state of alignment.

Bank "B": Bank "B" is a cooperation that has recently centralized the IT function ("Group ICT") and is now outsourcing portions of this organization. Within Bank "B", its international organization has its own IT function (IS&D). Nevertheless it also uses of "Group ICT" in some areas. Sometimes the international business contacts Group ICT directly; sometimes an internal intermediary handles the responsibility. Therefore, the consequences are:

- Miscommunication;
- No clear picture of who is responsible for what;
- Internal politics, along with;
- Internal bureaucracy.

We believe that the introduction of I-Fit will play a role in making the problem transparent, as well as give insight in the impact of certain problems.

CONCLUSION: FUTURE RESEARCH DIRECTION

The tools for I-Fit are in development between the two organizations. We propose to continue this research with:

- Further defining the tools for assessing fit, information quality, alignment, and business performance.
- Validating the tools by applying them in some business situations (case analysis).
- Assessment of the validity of the hypothesis in qualitative and quantitative research.

The next step for each of the building blocks is outlined below.

Next Steps to Determine Information Quality

The two tools that are available from theory do not completely match our needs. Therefore we aim to define a tool that helps us to define and determine the quality of the information that is provided (causal perspective) and confront this with the quality of the information that is needed (teleological perspective).

A possible approach to assess the quality of information as the gap between (or the fit of) information needs and Information services in an organization. Information needs are determined by surveying a set of business managers and grouping their information needs on the four dimensions of the balanced scorecard (financial information, information on business processes, information on customers, and information on business dynamics and innovation). Information services are determined by analyzing the information output in the (main) management reports. Comparison of the needs (in four balanced scorecard perspectives) and services (in the same perspectives) shows the gaps in financial, customer, process, and innovation perspectives.

We expect always to find a discrepancy (gap) between the information provided and the information needed, showing a certain degree of (miss-) fit. Key questions are:

- How much fit is there now?
- Is the gap acceptable?
- How dynamic are the business needs?
- Can fit remain when the business needs are changing?

One approach to determining the gap between information services and information needs in the current situation and the future situation is based on making an inventory of information needs and information services. We aim to distinguish between four types of information, following the balanced score card perspectives: financial, process, customer, and innovation related information.

Next Steps to Determine Alignment and Governance

In order to analyze alignment in an organization, we aim to select tools

- To assess the alignment processes that occur in an organization: describe examples of alignment (from driver, to lever and impact), and
- To assess the IT governance design and integration mechanisms (Peterson, 2001) in an organization, aiming to manage alignment processes and to reduce the gap between information needs and information services.

Instead of focusing on IT governance, we might prefer to develop tools for assessing IS governance, or maybe even better information governance because this might fit best our focus on Information quality.

In the previous sections we have addressed “IT governance,” “alignment processes,” and “information quality.” In the next section we address “business performance.”

Next Steps to Determine Business Performance

Summarizing, Business Performance should be measured by using multiple metrics per organization, and by using the same metrics on the supply chain level to avoid suboptimization. In practice, performance metrics vary across supply chains, across organizations in a supply chain, and depend on the strategic drivers for the actors involved. This implies that supply chain performance can be successful according to one actor and a failure when evaluated by others.

To be included in the tools to assess Business Performance are topics such as:

- Six Sigma
- How we address stakeholder perspective and types of metrics depends on the types of firms assessed and the industries they participate in.

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ENDNOTES

[1] Note that we focus on (ex post) information for organizational or management control, that is, not for strategic control or operational control.

[2] See Chan et al. (1997) for balancing between information that is correct and 10% too late or 10% incomplete. See also the work of Davenport and Prusak (1997) on excess of information (information overload).

[3] For six perspectives of fit: see Venkatraman (1989): The concept of fit in strategy research: toward verbal and statistical correspondence. Academy of Management Review, 14(3), 423-444.

[4] Note that this construct differs from Business Process Performance, as defined by Davenport etal in the 1990s, and Hammer and Champy (see also Figure 4).

[5] Note that we might decide to focus on IS strategic alignment, thereby focusing on the left sections of the strategic alignment model.

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Chapter 4.2

Stability and Creativity as Contradicting Values in Information Management

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EXECUTIVE SUMMARY

This case represents the situation at a North European business school in 1996 and the development process since then. At this school, the IT environment was quite heterogeneous and unstable, causing low user satisfaction. We describe the strategic actions taken and the successful consequences of those actions. Finally, we reflect on the lessons learned in our case for the current situation, where modern organizations are planning to implement Windows Vista and Office 2007, and the school in case is facing a new organizational challenge.

ORGANIZATION BACKGROUND

Turku School of Economics (TSE) is a Finnish business school that provides research and higher education in the field of business science. The school is very active in research, and offers graduate, postgraduate and continuing education. Expert consulting services form an increasing part of the School's activities. There are approximately 2,000 undergraduate students and about 300 doctoral students at the School. The teaching and research staff numbers more than 200 and other staff about 100.

The school is organized in departments. There are five departments for teaching and research: management, accounting and finance, marketing, economics, and languages. Two departments are dedicated to consulting, research and management education services: Business Research and Development center and Finland Futures Research center. Beyond these departments, information services units (the library, IT center and communication office) and the Office for Administrative Services are taking care of supporting activities.

More detailed information of TSE can be found on www.tse.fi. Naturally, the situation is not exactly as it was in 1996 anymore, but no major changes have taken place.

The top management of TSE consists of the rector and the vice rector, the administrative director, and the board. The rectors and the administrative director are permanent board members whilst the other members are elected every third year. Students have four of the 13 seats in the board. The management model may be regarded as quite democratic, in the usual manner of Finnish universities.

In 1996, the budget of TSE was around 90 million FIM (approximately 18 million U.S. dollars). As a state-owned university, TSE got 60–70 percent of the budget from the Ministry of Education; the rest came from outside financial sources such as scientific foundations, or companies buying e-MBA courses or research projects. The main part of the budget was spent on personnel costs. In the field of economics and business administration, no major investments (e.g., equipment or laboratories) are needed to produce high quality scientific research, education or services.

In 1996, an intensive strategic planning process was undertaken in TSE. As a business school, TSE had strategic planning as one of the principal topics in teaching and research. The process, therefore, was "by the book." The newly elected Rector wanted the School to define a new vision and strategy, and he launched a planning process where almost every member of the staff was contributing in some way. The new strategy was approved by the board in September, 1996. The main message of the strategy was growing from a local teaching school to an international research organization.

Ten years later, a strong national trend for bigger university units and more international operations is evolving in Finland. The Ministry of Education is driving for cooperation or even fusions between universities. As a part of this evolution, TSE and University of Turku are enforced to rethink their positions in the Finnish academia. That led to a decision to form a consortium of these two universities with a common board. The decision was made in a very positive and constructive atmosphere in 2006. The future shared organization will get its concrete form in the years to come, and the actual deepness of unification remains to be seen. Cooperation in teaching and research is to increase, and possibly some restructuring of administration will take place.

SETTING THE STAGE

The IT architecture of TSE in 1996 was a typical mixture of the technology at that time. The LAN had been implemented some years previously, every member of the staff already had a PC on her or his desk and e-mail had been taken into use throughout the organization, though utilizing the Web was still quite novel. No mainframes were in use: a type of client/server architecture was implemented based on file servers, e-mail and Web servers. Most administrative systems such as the student information system or payroll system were installed in the computers at Åbo Akademi University, an institution with Swedish as its language of instruction also located in Turku. The network connections outside the school were developed and maintained in cooperation with Åbo Akademi University and the University of Turku. Each of these three universities boasted their own IT centers and IT resources, but cooperation was quite active and the relationships between IT professionals were excellent.

The most widely used applications in TSE were word processing, e-mail, spreadsheet, library databases, statistical analysis software and the Web. Both Windows and Macintosh were in use, the ratio of Macs at about 15 percent. The blend of applications was quite diverse:

- For e-mail, Windows users had only one option (MS-Mail); Mac users had several

programs, Eudora being the most popular.
- For word processing, Windows users had MS-Word (ver 2) or WordPerfect (DOS version); Mac users had several options, MS-Word being the most popular.
- MS-Excel was used for spreadsheet creation by all users except for a few devoted Lotus 1-2-3 users.
- For statistical analysis, both SPSS and SAS were used; SPSS was installed in a mainframe of Åbo Akademi University.
- For other purposes, users could choose their personal favorite software within budget limits.

TSE's centralized IT center consisted of the IT manager and seven full-time professionals. Besides this, part-time students were employed to assist personnel in utilizing the new technology in the IT center as well as in some other departments. The IT manager was responsible for the IT center. He had his own budget for covering the general IT expenses of the school. Those costs included the network (LAN and Internet connection), servers and the internal expenses of the IT center. Other departments paid for their hardware and software themselves. The heads of the departments made the purchasing decisions with regard to PCs and software whilst the IT center took care, in most cases, of the purchasing operations.

The IT manager reported to the administrative director. Additionally, there was an IT board consisting of the IT manager and representatives of users, students and IT professionals. However, the IT board had no real power—one professor said that it was a body in which the IT manager managed himself while coffee was being enjoyed.

CASE DESCRIPTION

In this article, we first discuss the management of end user computing (MEUC) in general. Then we reveal the information management strategy (IMS) planning task at TSE from MEUC's point of view, taking the point of time into account. The situation in TSE in 1996 was a typical consequence of loose management and therefore has more general value. We discuss the creation and implementation of an IMS in TSE. The rector nominated a working group to plan the strategy in October, 1996. The group found out that users were dissatisfied with the current state of IT, but quite keen to take advantage of the new technology. At the end of the chapter we will reveal the results of personnel user satisfaction studies that show a highly interesting connection between standardization and satisfaction.

Management of EUC

In the IS literature, users have been divided into two groups: end users and IT professionals. This line of thinking goes back to McLean (1979), who used the terms data processing professionals and data processing users. Rockart and Flannery (1983) found six categories on a continuum: nonprogrammers, command level users, end user programmers, functional support personnel, end user support personnel and data processing programmers. The basic distinction between end users and IT professionals is the relationship to IT. Professionals create applications for others; end users deploy the applications (Cotterman & Kumar, 1989).

Classification into two groups is sensible, because in a real-life organizational setting, the end user group creates a demand of services to be supplied by the IT/IS department (Leonard, 2001). Although this kind of demand/supply approach has been criticized and the alignment approach has been emphasized (Duchesi & Chengalur-Smith, 1998; Henderson & Venkatraman, 1992; Zee & Jong, 1999), the two groups and the interaction between them remain. Unfortunately, mistrust often characterizes this interaction, preventing a sound alignment.

The relationship between the IT/IS department and end users may be disturbed because of the power unbalance caused by the nature of the relationship. The supply side can perform its tasks adequately at best. In many cases, the system failures or users' low participation in IT projects cause dissatisfaction with the IT/IS department (Kettinger & Lee, 2002). Smith and McKeen (1992) interviewed line and IT managers, and both groups seemed to have suspicious attitudes: "IS people are techies and don't understand business...[they] don't have interpersonal skills"; and "The users don't know what they want." Clearly, the stereotypes of these two groups are somewhat different to each other. Couger and Zawacki noted already in 1980 that IT professionals want to have more challenges and fewer human contacts than other people—and that is probably still a valid notion.

IT/end user's alignment culminates in the standardization policy of the organization. The discussion on standardization started already during the 1980s, when the EUC was a new phenomenon. By 'EUC' we mean the voluntary use of computers in the broad sense of the term. An essential feature in EUC is the user's free choice of tools and their use (Igbaria, 1990). Additionally, there is a more narrow approach to the EUC concept in the literature, defining EUC as systems developed by end users to support their decision-making (e.g., Aggarwal, 1994). Gerrity and Rockart (1986) introduced the idea of monopolistic (standardization) versus laissez-faire strategy. Munro and Huff (1988) stated that most organizations evolve from laissez-faire strategy to controlled growth strategy, either through control or acceleration. Henderson and Treacy (1986) explained the evolution using a state model, according to which the growth of a new technology and controlling its use always follow each others in cycles.

The essential issue in standardization is the power balance between the IT/IS department and the user organization. Trust and respect for each other is the key to healthy communication (Leonard, 2000). Halloran (1993) stresses the clear domains of responsibilities as a key to the success of information systems. It is fairly easy to bring forward arguments for a strict control strategy. Having such a strategy, the organization may achieve advantages in purchasing IT, organizing user support or training and maintaining user work stations and the infrastructure.

The users' or departments' power to locally plan and control IT resources is the counter-argument. From the point of view of a middle manager it may be hard to understand the IT/IS department's argumentation for a "one for all" policy. Thus, coordinated development and greediness for power compete with each other. The former is based on synergy and rationality; with the latter, the motivation is merely emotional. The weighting of these two options varies case by case—the determining factor in most cases rests in opinions of the most powerful persons in the organization. These kinds of decisions are usually more politically than rationally based.

The Starting State

Strategic IS planning (SISP) had been one of the areas of priority in TSE's teaching and research for several years, and the Rector himself had been the leading researcher in this field (see for example, Reponen, 1994). With this background, setting up an IMS planning project was an eloquent decision. The aim was to create an IMS that well supports the strategy of the school.

Lecturer T was appointed to the project champion. He had experience in IMS planning processes in companies and had taught SISP and information management for several years. Other 10 members of the project group represented different departments. The team's work took four months, including the following actions:

- A survey for the personnel. A questionnaire based on the UIS model (Bailey & Pearson, 1983) and EUCS model (Doll & Torkzadeh,

1988) was constructed in order to determine personnel satisfaction on services and tools, and opinions on the importance of possible focusing areas. Such areas as the development of infrastructure and systems, the improvement of user skills or user support services were presented. The questionnaire comprised close to 70 questions, with a Likert-like scale from 1 to 5 covering the following areas: the success of SISP, the IT/IS policies, the service level of IT center, the IT/IS in users' disposal, user skills and the focus of IT deployment. The satisfaction with regard to specific administrative systems was not studied. The questionnaire was delivered to the personnel as a whole, the response rate being over 70 percent. The results provided extremely useful guidance for focusing on development actions.

- 22 interviews in which the viewpoints of various stakeholders were examined more deeply. A prominent set of problems and suggestions emerged.
- Several meetings of the project group. In most cases, lecturer T wrote drafts that were discussed and elaborated by the group. Lecturer T had a strong position in the entire process. Besides being the chairman and the writer, he carried out both the survey and all the interviews. One could criticize the methods being too much on the "planning school" side and that a more "learning school" kind of approach (Minzberg, 1987) would have been more fruitful. However, the plan was finalized in January 1997 and approved by the board in March 1997, after which the implementation started with a kickoff seminar having a very enthusiastic atmosphere in May, 1997.

According to the survey and the interviews in 1996, the situation at the school was more or less chaotic and user satisfaction was low. Several problems were identified:

- Incompatibility problems when users changed data between each others or with outsiders.
- The service level of IT center was found to be very low. The professionals were hard to reach and their attitude towards users was not adequate.
- Internal communication was not on a satisfactory level. The main method of informing the personnel was a leaflet delivered to everyone every 2–3 weeks.
- Some administrative processes were inefficient, this based partly on deficient information systems, partly on deficient working procedures, and partly on problems in human relationships.

The discussion concerning Macintosh versus Windows was quite lively. In the IT center, Mr. V was dedicated to serving all Mac users. As a matter of fact, Mr. V refused all assignments that were not Mac-related. He was a Mac enthusiast and promoted that option heavily. The choice between Mac and Windows was done by every user freely and seemed to be somewhat random. A kind of competition or even 'war' was going on. The students had both options: one of the four computer labs was supplied with Macs, and both systems were used in teaching, which was also based on the personal preferences of the IS teachers. For instance, lecturer T taught DSSs by using Excel in the Windows environment, but also PageMaker by using Macs.

Incompatibility was an everyday source of displeasure. Usually, problems came up when a Windows user received a file from a Mac user. The file could not be opened or the layout was damaged. The IT center was not very willing to help in these cases because of each person's antipathy against one of the two systems. Most users, however, were rather neutral and used the system they had incidentally received on their desks. Only a small—but loud—group of users participated in the "war." During the IMS planning process, Lecturer T's mailbox was the target of heavy 'bombing', with comments in favor of Macintosh. Lecturer T himself was quite indifferent on the matter: he liked Mac as a personal tool but understood very well the arguments towards organizational control.

The Challenge of the IMS Planning Group

During TSE's planning process, many interviewees presented promising new ideas of using IT in research, teaching or administrative activities. Lecturer T realized that the full potential of resources—both human and technical—had not been exploited. As a university, TSE can be categorized as a "professional" organization, in Minzberg's (1991) typology. In this kind of setting, EUC should be the main focus of IT development, because usage typically takes the form of personal computing, for example, word processing.

The IMS planning group had to decide on future actions. Clearly, some dramatic change was required. Most users were annoyed with the current state of affairs, this being a result of a long history of "driftwood management." Users understood that problems were resolvable if the IT services were organized in a new way. The IMS planning group faced a heavy stress on change and, on the other hand, a strong hopefulness and optimism concerning the future. The general technological development at that time (Internet usage growth, EUC growth, emerging e-learning technology, etc.) was changing the way universities operated. In terms of the strategic grid by MacFarlan (1984), the academic world was in a "turnaround mode"; IT was evolving from support to a more strategic role.

The selection of operating systems and basic software (i.e., applications that are used by every user) seemed to be the most crucial issue. Should the planning group suggest a monopolistic strategy or a laissez-faire strategy? So far, there had been no well-defined strategy, EUC had grown rapidly without management policies. This was the case in most organizations in the early stages of end user computing (Munro & Huff, 1988).

A monopolistic strategy had its supporters. Professor S, a strong person inside the school, promoted stability, because researchers and teachers are loaded every day with deadlines, and the tolerance against interruptions is quite low. Students as well as many researchers and teachers wanted the school to be a modern pioneer in deploying new technology. They were afraid that too much control would limit creativity.

The IMS planning group had to make a choice. Should stability be the objective, or creativity? These are justifiable but conflicting demands. Other issues where the planning group needed to take up a stand were at least the following:

- The organizing of user support. The current situation was unsatisfactory.
- The centralization versus de-centralization of IT services. Some departments were quite satisfied with the students they had hired for assistance. Some heads of departments even claimed that user support could be arranged in a more effective way by themselves instead of the IT center.
- The cooperation level with the IT centers of the University of Turku and Åbo Akademi University. TSE was clearly the smallest of the three universities in town and had the lowest number of users and IT professionals. On the other hand, IT investments per employee were higher in TSE than in the neighboring universities.
- The development of user skills. Most users were not satisfied with their ability to utilize the tools in their possession.
- The development of the infrastructure. Users were annoyed with e-mail interruptions as well as with their Internet connections or even the applications in their workstations. A more stable environment was required.

IMS Approval and Implementation

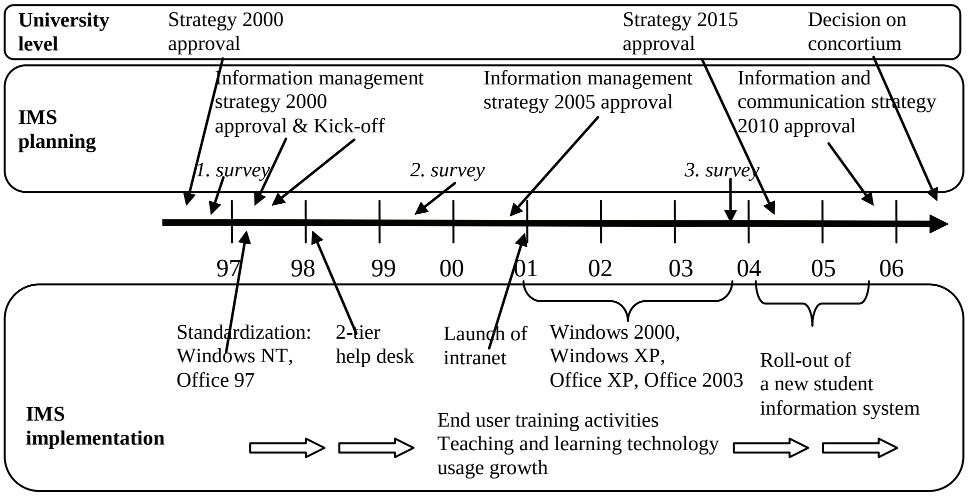
After a planning process lasting four months, the working group formulated a suggestion for an IMS. The strategy, called IMS2000, was approved by the board in March, 1997. After that, a strong and enthusiastic implementation project was started, focusing on development ideas presented in the strategy. The three most effective actions taking place were the following:

- The standardization of operating systems and office software. Windows NT and Office 97 were defined as the only options in use. Macintosh users were given one year to shift to a Windows environment.
- A two-tier help desk was established inside the IT center. A team consisting of part-time students was set up to take care of the front-end service, supported by the IT professionals as a back-end team. End users (both personnel and students) were provided with one contact point they could reach by phone, e-mail or visiting the office.
- An end user training program was launched. The IS teachers responsible for students' EUC courses agreed to teach personnel as well. The content of the training sessions was planned for each group (e.g., researchers) task-specific. Goals of the training should be linked to goals of the organization (Mahapatra & Lai, 2005), and the use of tools should fit the users' tasks (Goodhue & Thompson, 1995).

Figure 1 depicts the strategic development of IT in TSE since 1996. The process of planning the IMS2000 was described in detail. The resulting plan and its implementation covered the years 1997–2000. When coming to the end of this period, the Rector nominated a new working group to update the IMS, which was done quite smoothly and a new strategy, called IMS2005, was approved by the board of the school in December, 2000. In that point there were no major development efforts.

The recent history is as follows. In 2004, a new strategy for the school (Strategy 2015) was approved by the board. Consequently, a new IMS was to be written. The strategy called "Information and Communication Strategy 2010" was approved by the board at the end of 2005. This time the strategy includes all the "information services", i.e., IT services, communication services and library services. These services are offered by three separate administrative units now integrated

Figure 1. The strategic development of IT in TSE since 1996



tighter than before. At this point, the useless IT board was discontinued.

The Development in User Satisfaction

When planning the IMS first time in TSE, we carried out an UIS survey. The survey was then repeated in 1999 and again in 2003, and the results showed that the IMS process was quite successful. UIS represents the only measurements that were done: no economical input/output analysis is available. However, the IT budget has increased quite moderately since 1996.

The most interesting results from the surveys are presented in the following. They are scientifically interesting and exceptional because of the longitudinal nature of our study. We studied the user satisfaction before and after certain activities, so that we can draw conclusions of those activities' influence on user satisfaction. The response rates were so high that we may well regard the averages as the general opinion of the personnel as a whole (over 70 percent in 1996 and in 1999, about 40 percent in 2003). Satisfaction measures do not vary significantly between subgroups (Doll et al., 2004), and therefore no further subgroup analysis is required. Table 1 shows the averages of answers to selected questions. The average of all answers with the same kind of scale was 3.57. This figure represents a "general mental average" against which the average of a specific question may be contrasted.

Our study provides exceptional insight into the influence of standardization in the long run. The argumentation for strict control strategy is usually based, from the organizational development point of view, on rational thinking. The counter-arguments are usually based on user satisfaction, which is threatened by the power loss. Our case shows that, as a matter of fact, the control strategy increases the end user satisfaction in the long run. Such a strategy makes the user environment more homogenous and stabile. The stability is what users most desire, because it enables them to perform their tasks more efficiently and effectively. Our results, which strongly support this line of thinking, are presented in Figure 2. Also, the averages in Table 1 show the high and increasing importance of stability.

The main information management activities in TSE since 1996 have been standardization, the

Figure 2. The standardization policy: free choice of operating system (i.e. Windows versus Macintosh or Linux)

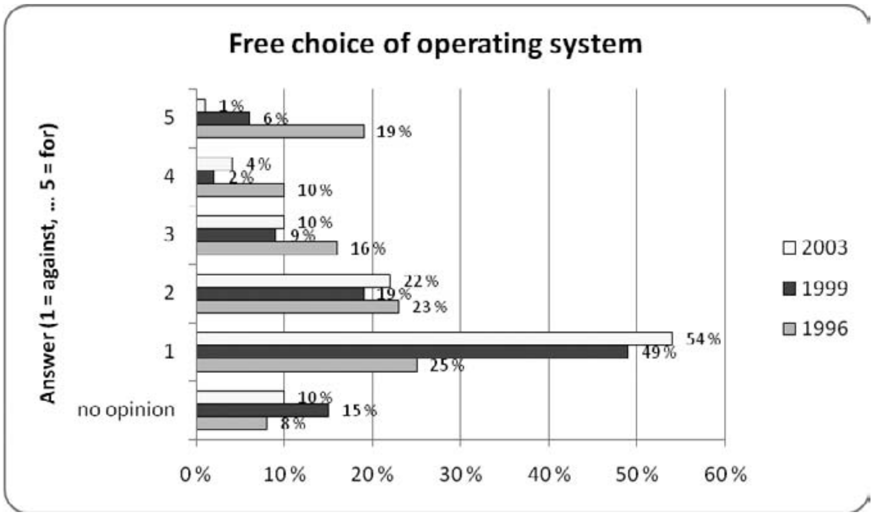


Table 1. Averages of answers in 1996, 1999 and 2003

Question	***Average of answers 1996 (N=176)***	***Average of answers 1999 (N=169)***	***Average of answers 2003 (N=105)***
Selection of operating system:			
Everyone should have the right to choose between Macintosh and Windows (1=Absolutely not, 5=Absolutely yes)	2.71	1.79	1.62
Focus of development:			
Importance of the stability of the workstation and its software (2 questions)	4.71	4.74	4.74
Importance of the stability of the network (2 questions)	4.09	4.15	4.44
Importance of workstation processing power	3.84	3.97	3.98
Importance of the novelty of software and hardware (3 questions)	2.88	2.80	2.46
Importance of user skills	4.17	4.27	4.35
Importance of www as a communication media (2 questions)	3.72	4.11	4.32
Importance of e-mail as a communications media (3 questions)	4.16	4.36	4.26
Importance of teaching technology (computer labs, audiovisual systems, etc. 4 questions)	3.88	4.05	4.07
Satisfaction with IT services and management:			
Satisfaction with the services offered by the IT center (12 questions)	3.35	3.52	3.52
Satisfaction with purchasing policies (5 questions)	3.96	4.18	3.79
Satisfaction with the desktop computer in use	4.21	4.49	4.19
Satisfaction with printers and other peripheral devices in use (3 questions)	3.63	3.88	3.51
Satisfaction with own computing skills:			
Satisfaction with personal skills in using e-mail (4 questions)	4.13	4.46	4.54
Satisfaction with personal skills in using the Internet (5 questions)	2.94	3.26	3.40
Satisfaction with personal skills in using operating system and computer in general (5 questions)	3.61	3.57	3.53
Satisfaction with personal skills in using general-purpose software such as Office (7 questions)	2.94	3.42	3.60
Satisfaction with personal skills in using library databases	2.89	n/a	3.74

Key: 1=Not at all important/Very dissatisfied, 5=Very important/Very satisfied (if no other explanation given) establishment of a help desk, end user training and the intranet launch (see Figure 1). User satisfaction measures show that these efforts have been worth taking. Figure 3 shows the clearly increased satisfaction to user support and Figure 4 to the training; averages in Table 1 show the same effect. The increase of computing skills (see Figure 5) based on self-assessment may be a consequence of training, but there may be other influencing factors as well.

CURRENT CHALLENGES FACING THE ORGANIZATION

In this chapter, we shall shift the focus from past to present. Although the situation in the mid-00s is quite different than in 1996, there are certain similarities in the state of technological development and in the decision-making challenges of strategic IS planning. We will reveal the latest development in the literature of IT management, discuss Windows Vista as the most important issue of the current state of technology, and conclude with presenting the future challenges of IT management in TSE.

Contemporary Issues in Management of EUC

The phenomena of EUC started in the early 1980s and became "business as usual" during the late 1990s. McLean and Kappelman stated already in 1993 that EUC was not an independent phenomenon anymore but rather is integrated in organizational computing. Later on, the management of EUC has not been in the core of IT/IS research or practical IT/IS management. During the last few years, the alignment of IT and business has become a very popular issue. End users receive and use IT services, and the crucial management question is how the organization uses resources to deliver a portfolio of services to the end users (Peppard, 2003). Zee (1998) stressed the cultural change in the role of the IT function: the focus was (at the end of the 1990s) moving towards customer orientation, that is, to the delivery of measurable and negotiable service products. The IS function was not to be treated anymore as the deliverer of computer systems but merely as a service provider (Peppard, 2003).

Discussion of satisfying end users' needs and achieving a balance of supply and demand of IT services has lead to the concept of SLA—the ser-

Figure 3. Satisfaction with user support

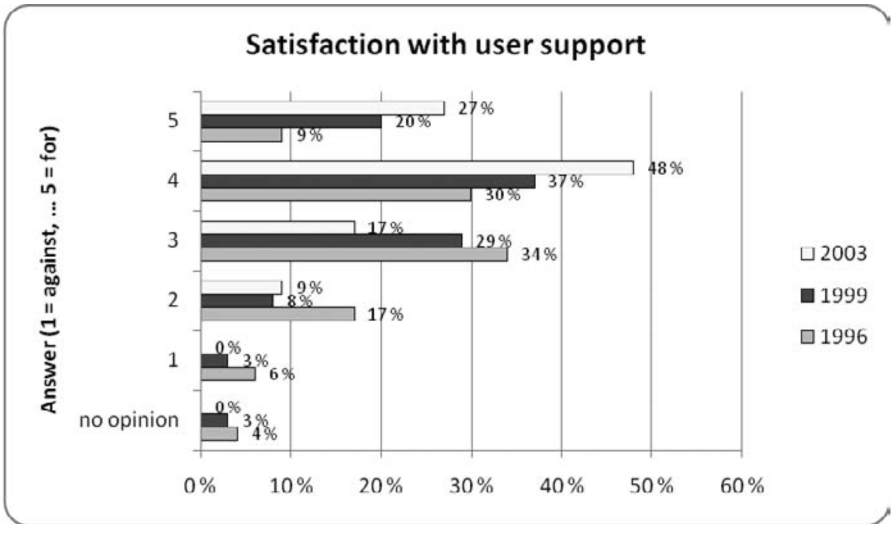


Figure 4. Users' satisfaction with training

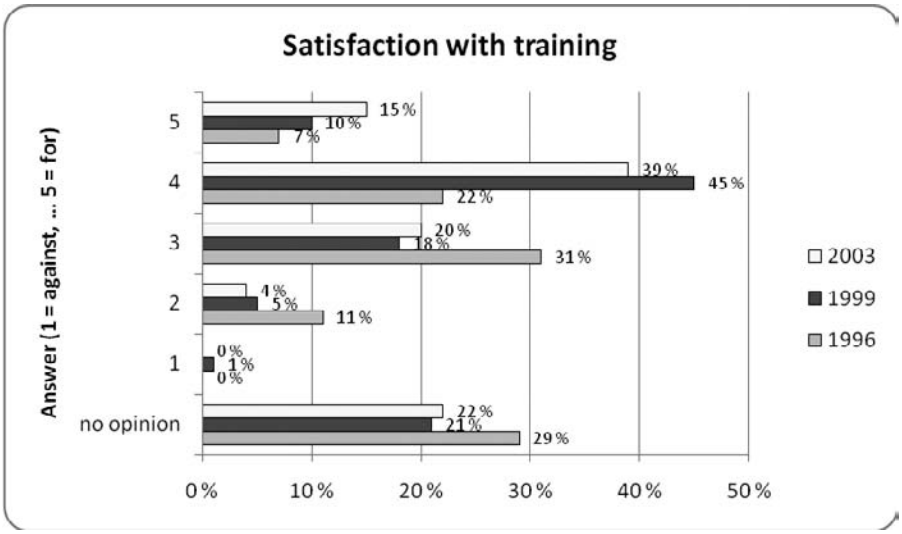
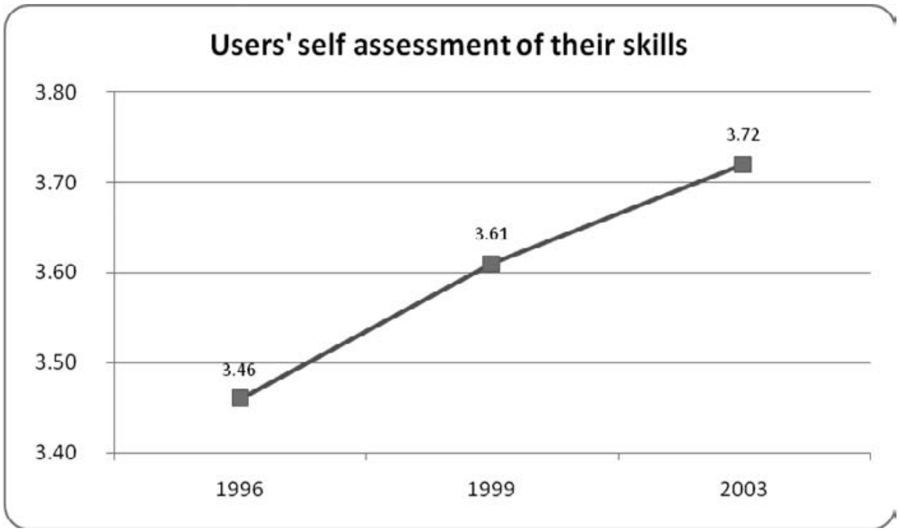


Figure 5. Users' self assessment of their skills (average of 21 questions)



vice level agreement. It is an agreement between the supplier of an electronic service and the users of the service that defines and quantifies the minimum quality of service which meets business needs (Hiles, 1994). The service provider may be an internal IT/IS department, or the provision may be outsourced from an outside operator. Outsourcing continues to grow as a business practice when ASP, Web hosting or other such services become more popular (Fitsilis, 2006).

The growth of users' needs is endless. They need more sophisticated support when skills improve (Guimaraes et al., 1999). At the same time, the improving cost-awareness of line management puts stress on leaning IT operations. These conflicting trends combined with the recent discussion on the "commodity character" of IT (Carr, 2003) have increased the requirements for IT/IS management. The use of "best practices" is becoming a common solution to respond to the growing requirements. IT service management methodologies and standards such as ITIL, COBIT, eSCM, BS 15000 or ISO 17799 are well-recognized in the business world.

These methodologies like ITIL certainly help IT management to organize services. ITIL is obtaining the role of a de facto standard, especially in Europe. It organizes IT service activities round two key process areas: service support and service delivery. The processes are well-defined in the ITIL literature and fairly easy to apply in any organization. However, there are some challenges in applying them. Forte (2007) notes that ITIL as such is insufficient and its overly blind utilization may mechanize processes and prevent the sound development of services. Feldman (2006) recommends analyzing the organization's own weaknesses and apply "best practices" such as ITIL only selectively where needed.

Although there is much evidence with regard to the advantages of SLAs in IT service management, research has identified major problems in applying them (Antonio, Arienzo, Esposito et al., 2004; Hiles, 1994; Trienekens, Bouman, & Van Der Zwan, 2004). Fitsilis (2006) categorizes these problems in two areas: problems related with traditional service level management, such as developing SLA semantic models; cost models; better understanding of SLA terms, and so forth; and problems that arise from technology and marketplace evolution such as SLAs for federated environments, for aggregated services and for on-demand services, and so forth. Trienekens et al. (2004) explain that the problems arise from SLA specifications: specification of effort versus specification of results, or unclear service specifications. Another mistake on the customer side is to make "dead-end" agreements that are not dynamic and prevent further development (Trienekens et al., 2004).

Problems with SLAs are apparently related to the lack of management skills in defining the needs of various services and dealing with vendors. The speed of technological development and emergence of new operation models such as ITIL have simply been too demanding for IT management—there is currently a lack of formalism in the specification and metrification approach (Trienekens et al., 2004). In that sense, the current circumstances are reminiscent of the situation during the early stages of EUC when companies failed to incorporate its management into strategic IS planning (Hackney, Kawalek, & Dhillon, 1999).

Windows Vista as the Next Challenge

The technological mainstream during the last fifteen years has supported the implementation of various versions of Microsoft's Windows. In the mid-2000s, most organizations are using either Windows XP or Windows 2000 as the primary operating system: use of Macintoshes or Linux is rather marginal. After the launch of Windows NT (1996) and Office 1997, organizations faced a rather heavy transformation to the new environment, including infrastructure upgrade and user training. Since that time, the upgrades have been effortless. The next step, Windows Vista and Office 2007, is once again causing more pain.

There are widely reported advantages in the new operating system (Garcia, 2007; Malik & Perry, 2007; Potter, 2007; Stokely, 2007):

- A more reliable computing system.
- Increased manageability and better controlling tools for the administrators through dramatically improved Group Policy implementation.
- New ammunition to keep malware off the workstations.
- New technologies focused on keeping stored data safe.
- Glitzy 3-D windows are enjoyable for the end users.

However, companies are indecisive in implementing Windows Vista and Office 2007. The first sales figures after Vista's market launch were disappointing (Sliwa, 2007). The transformation will be troublesome for both IT departments and end users. Many companies are waiting for service packs and implementing new systems only one-by-one as new computers are purchased (Lewis, 2007). There are several good reasons for hesitation on the part of management (Malik & Perry, 2007):

- The new graphical interface does not really improve effectiveness, though is nice to have.
- The current stable environment will be disturbed during the transformation process.
- Compatibility updates by third party software and hardware vendors will take some time.
- End users are put to a new learning curve.

On the other hand, there is pressure to start the roll-out process, because Microsoft has announced that support for older operating systems will stop in 2009 (Malik & Perry, 2007). The promises of better security and other new features make the upgrade quite compelling. Many users and IT professionals are eager to benefit from the system. Decision-making will be based on opinions and emotions; no particular wisdom on when to start is available. Waters (2007) expects companies to first implement Office 2007 and then Vista. He predicts that Vista will be the last workstation-based operating system and the end of the PC era. An Internet-based, ASP type of software delivery may take over after Vista.

The Future IT Services in TSE

In previous chapters, we have described a 10-year process of strategic IT development at a business school. Various development patterns could have taken place in, for instance, the use of Macintoshes or in organizing IT services. According to the satisfaction measures, the decisions made and actual actions taken may be considered rather successful. However, the standardization and training approach taken ten years ago may not be sufficient in the future situation. The modern method of standardization observes an SLA type of setting. Although it evidently has advantages, applying SLA in an organization may freeze the service to stay on the minimum acceptable level, where routine operations are well-supported but innovativeness does not flourish. The end users' own application development is increasing, and they deploy IT in more sophisticated ways, for example, by participating in wiki and blog-like environments (Ferneley, 2007). These new trends are contradictory to the standardization approach and may impair the balance of using and supporting services: that is, the relationships between the IT department and the user organization. End users want to be involved in IT development and decision-making: otherwise, authorities are resisted (Rondeau, Ragu-Nathan & Vonderembse 2006).

The main future challenge of information management in TSE is to respond to the organizational changes that the school quite probably will face during the next few years. A strong national development towards bigger university units is in progress in Finland. There are three universities in Turku, and thus a discussion of new structural options is natural. Due to language reasons[1], the Swedish-speaking Åbo Akademi University will remain independent, though there will be an increase in cooperation with the neighbours. TSE and the University of Turku are nevertheless forming a consortium with a common board. The new structure will apply in August, 2008. The actual form of the future organization is still under working development, but the main objective is to enhance cooperation in teaching and research.

Some restructuring of the administration may also be anticipated. Considering IT services, there are apparently several options that have to be investigated and evaluated in the near future. Examples of such options are:

- Continuing as before without any major changes,
- Merging the IT/IS departments of TSE and the University of Turku,
- A new kind of division of responsibilities between the IT/IS departments of these two universities, or
- Selective outsourcing of IT services (e.g., infrastructure maintenance).

In a situation where the future structure of the organization is blurred, the strategic planning of IT is extremely difficult. On the other hand, the general development of technology is requiring rather urgent charting of the roadmap in infrastructure development. The (possible) transition to Windows Vista and Office 2007 is a heavy process that requires all the resources the school can allocate. In TSE's case, external pressures, technological pressures and end users' increasing requirements are now challenging the strategic information systems planning.

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ENDNOTE

[1] Both Finnish and Swedish are official languages in Finland. Approximately five percent of the population speaks Swedish as their mother tongue, and they have relatively substantial political power.

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Chapter 4.3

Strategic Management of International Subcontracting:

A Transaction Cost Perspective

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ABSTRACT

Research on international subcontracting has been policy-oriented and industry-focused. There is a lack of understanding of the phenomenon from strategic management and international business perspectives. This article conceptualizes international subcontracting as a type of relational contract formed by buyers and suppliers from different countries, aiming to facilitate the sourcing of products or components with buyer-specific requirements. It builds a transaction cost model for studying the strategic choice of international subcontracting as an intermediate governance structure, sitting between arm's length outsourcing arrangement and vertically integrated multinational enterprises (MNEs). A set of propositions are developed to aid future empirical research and to provide managers with some guidelines for organizing supply chain across borders. The model also allows managers to examine the complex nature of a range of subcontracting relationships and identify the specific mechanisms that can be used to preserve and manage the dyadic principal-subcontractor exchanges.

INTRODUCTION

International subcontracting is an important phenomenon in international business (IB) studies (Casson, 1990) and has been an effective means of accelerating industrial development since 1960s, fostering the specialization among countries that reflects comparative advantages (Germidis, 1980). Through such measures as the establishment of free trade zones, developing countries encourage local firms to undertake subcontracting jobs for foreign firms to earn hard currency and to accumulate technological know-how (Hamada, 1974). Firms from developed countries are frequently attracted into subcontracting arrangements to exploit low labour and production costs in developing countries. The studies of international subcontracting are mainly policy-oriented (Cohen, 1975; Riedel, 1975; Sengenberger & Pyke, 1991) and geography or industry-focused (Kashyap, 1992; Lawson, 1992; Rogerson, 1995). Few have examined why firms from developed countries choose to use subcontracting arrangements in the first place. Moreover, despite some classifications of international subcontracting activities according to functional or market criteria (Gereffi, 1993; Holmes, 1986), the nature of subcontracting relationships remains unexplored due to the lack of theoretical underpinning of international subcontracting as a form of international business organization. Grounded on transaction cost theory (Buckley & Casson, 1976; Hennart, 1982; Rugman, 1981; Williamson, 1975, 1979, 1985), this article aims to provide a firm-level analytical framework for analysing the subcontracting choice and the nature of subcontracting relationships, complementing the existing literature's emphasis on studying international subcontracting as a macro-economic phenomenon. The framework will also aid managers in choosing strategically between outsourcing, subcontracting, and vertical integration when organizing their supply chain.

Although "transaction costs differ depending on both the nature of the transaction and on the way that it is organized" (Coase, 1937, p. 386), transaction cost economics (TCE) as formally developed by Williamson (1975, 1979) is not mainly concerned with the transaction itself, but with the contractual arrangements (the ways) through which transactions are organized (Cheung, 1983). Contractual or institutional arrangements, normally referred to as governance structures, are "the institutional matrix within which transactions are negotiated and executed" (Williamson, 1979, p. 239). Drawing upon the legal concept of generic contracting forms (Macneil, 1974, 1978) and relating them to the nature of transactions, Williamson (1979) matched the transactions to the contracts. By so doing, he provided a framework 'to assess the efficacy of alternative means of contracting' (Williamson, 1990, p. 8) and illustrated which governance structure (including the firm, the mark and intermediate contracts) has the lowest cost under given circumstances.

Despite the criticisms (some are highly theoretical and sometimes obscure or even mistaken on what they are criticising) (e.g., Conner & Prahalad, 1996; Ghoshal & Moran, 1996), empirical studies show Williamson-type of transaction cost-comparative contracting approach has more predictive power than other major IB theories such as resource-based view (RBV) in informing the choice between different forms of governance structures for organising firm interdependence (e.g., Hennart, 1991; Reddy, Osborn, & Hennart, 2002). Much of the RBV (Barney, 1991; Peteraf, 1993; Wernerfelt, 1984) and its closely-related competence perspective (Foss, 1996; Knudsen, 1995) entail ex post rationalizations for success and has been remiss in predictive respects (Williamson, 1999). This article therefore employs TCE as an analytical framework for examining the choice of international subcontracting.

THE CONCEPT OF INTERNATIONAL SUBCONTRACTING

There is a great deal of ambiguity on the definition of subcontracting in the existing literature (Hovi, 1994). However, there are some essential features about the international subcontracting as a form of investment. First, international subcontracting involves two independent units located in different countries, reflecting a type of cross-border inter-firm relationship. But the fact that a firm is legally independent does not necessarily mean that it will be economically independent. The relationship between subcontracting parties is defined as "quasi-integration," in which subcontractors from less developed countries are often dependent on principals from developed countries, where the demand of subcontracting is derived (Germidis, 1980). Second, in a subcontracting arrangement, the subcontractor provides the principal with products or services on agreed terms and conditions set by the principal, where certain business activities such as marketing or product design may not be carried out by the subcontractor (Halbach, 1989). The goods produced are required to conform to specifications intended for a definite principal, making it impossible or very difficult to sell them to other customers (Germidis, 1980). Third, the principal usually provides specialised physical equipment and/or ongoing technical assistance to the subcontractor to assure product specifications and quality (Sharpston, 1977). The enforcement mechanisms are usually between principals and subcontractors themselves and no third party oversees the execution of the contract. The bond linking them together is thus out of market (Germidis, 1980). Consequently, a significant level of transaction-specific investment has to be undertaken both by subcontractors to meet the specifications set by principals and by principals to ensure the performance of subcontractors. These basic characteristics reveal that the nature of international subcontracting conforms to Williamson's (1979, 1985) notion of a relational contract with a bilateral governance structure. Casson (1987) identified subcontracting as a distinctive type of intermediate contractual arrangement, an alternative to the vertically integrated multinational enterprises (MNEs).

The lack of a clear definition of subcontracting in the existing literature is due to the lack of theoretical underpinning. Based on the essential features identified above and in line with Williamson-type of transaction costs-comparative institutional framework, this paper defines international subcontracting as a type of long-term relational contract between buyers and suppliers in different countries that aims to facilitate the sourcing of products or components with buyer-specific requirements. This definition distinguishes international subcontracting from common arm's length industrial outsourcing and in-house supply within an MNE's network, providing the basis for conducting an analysis of the choice of international subcontracting over its alternatives and for developing some testable propositions regarding such a choice.

THE CHOICE OF INTERNATIONAL SUBCONTRACTING

The previous conceptualization allows us to examine the choice of international subcontracting as an intermediate relational contract, lying between arm's length outsourcing arrangement and internalised MNEs, and to develop some testable propositions based on the comparison between international subcontracting and its market and hierarchy alternatives.

The Choice of Subcontracting over Outsourcing

In transaction cost framework, the choice of a relational contracting form is made when transactions between buyers and suppliers are characterised by mixed asset specificity, recurrent exchange and a low degree of uncertainty (Williamson, 1979, 1985). Central to the framework is the concept of asset specificity (Williamson, 1975). Also labelled transaction/relationship-specific assets or dedicated assets (e.g., Dyer, 1997; Dyer & Singh, 1998; Dyer & Nobeoka, 2000), asset-specificity refers to durable human and physical investments undertaken to support particular transactions (Williamson, 1985) and cannot be redeployed to another transaction without some loss in the productivity of the asset or some increase in the costs in adapting the asset in the new transaction (Besanko, Dranove, & Shanley, 2004). In a buyer-supplier exchange relationship, relationship-specific investments are nonfungible signals of commitment that create economic losses if the relationship is prematurely terminated (Jap & Anderson, 2003). The requirement for transaction or relationship-specific investments creates potential costs in the market execution of transactions. When the asset specificity feature involved in transactions is low, buyers and suppliers keep their relationship at arm's length.

A common industrial outsourcing activity refers to such market-based transaction of standard products or components which involve little transaction-specific investment. In outsourcing, both buyers and suppliers capitalise on their comparative advantages of trading and realising economies of specialization (Sharpston, 1977). While outsourcing may involve a long-term relationship between buyers and suppliers, it does not require the support of long-term contract. The products and components in common outsourcing activities are non-specific and there are many buyers and sellers. Some buyers and suppliers may be engaged in the trading of standard goods for a long time. But they are not bonded by contracts requirement and each side can switch to other trading parties easily due to the low asset specificity in their trading relationship.

When products or components contain some degree of product specifications and are not "off the shelf," they can no longer be bought on the spot market. Buyers look for long-term contractual arrangements to assure the supply of the specialised inputs and products. As previously defined, subcontracting is a kind of long-term contract that aims to facilitate the sourcing of products or components with buyer-specific requirements. This clarification is important because the term "subcontracting" is often misunderstood as an exclusive portrait of buyer-supplier relationship and therefore the distinction between common outsourcing and subcontracting is blurred (Wang, 2007). As such, asset specificity is an important reason for making long-term contracts (Kay, 1995), explaining the choice of subcontracting over outsourcing. To protect themselves from exposure to transaction costs arising from making asset-specific investments, both parties involved in subcontracting relations have incentives to form a long-term relational contract. Thus, we suggest:

Proposition 1: *International subcontracting is chosen over outsourcing when there is a high level of asset-specificity in the purchasing/supplying transaction.*

The Choice of Subcontracting over Vertical Integration

The economic rationale of international subcontracting is to realise economies of specialization through externalising non-core production activities to achieve cost advantage (Sharpston, 1977). But firms can acquire existing low-cost suppliers in developing countries as their subsidiaries or set up plants in low-cost regions and relocate non-core activities to the new ventures. On the other hand, if the aim is to access technology expertise or other proprietary know-how held by suppliers, the buyer firm could still acquire them through equity integration with suppliers. Therefore, other than achieving production cost economies and acquiring complementary assets, there must be additional reasons for firms to choose subcontracting rather than vertical integration through acquisitions or greenfield.

Engaging vertical integration through acquisition to exploit low production costs or to access complementary assets overseas would entail significant transaction and information costs, which justify the choice of subcontracting. First, the desired assets of the acquied firm are hard to disentangle from the non-desired ones, which impose a high cost on acquiring suppliers (Hennart, 1988). Under this circumstance, purchasing the target overseas firm would force the buyer to enter unrelated fields or to expand suddenly in size, with the attendant management problems

(Hennart, 1991). This cost is particularly high for firms that rely mostly on cost rather than differentation to survive. Thus, we suggest:

Proposition 2: *International subcontracting is chosen over acquisition of overseas suppliers when the desired assets of the acquied firm are hard to disentangle from the non-desired ones.*

Second, management costs after the acquistion make subcontracting preferrable. Acquisition of a foreign supplier means the buyer also takes over an existing labor force and a well-established administrative structure. Considerable difficulties might be expected by the buyer in managing the foreign supplier firm that has cultivated its own organizational routines and corporate culture, in addition to the nationial culture distance (Hennart & Park, 1993). Hence, a subcontracting arrangement may be desirable as it avoids the post-acquisition management costs by leaving the management of supplier firm to the overseas subcontractor itself. Thus:

Proposition 3: *International subcontracting is chosen over acquisition of overseas suppliers when the post-acquisition management costs are expected to be high.*

Third, information costs in assessing the value of the target firm inhibit the acquisition (Hennart & Park., 1993). Buyers may not acquire overseas suppliers for the purpose of establishing low-cost supply bases but for the potential gain from complementary assets held by suppliers. But it may be difficult to assess the true value of these complementary assets due to the intrinsic bounded rationality constraint and the expectation that overseas suppliers may opportunistically exaggerate the value of their assets. A subcontracting arrangement retains the possibility for principals to gather information on the value of overseas subcontractors' complementary assets without financial exposure in an equity relationship, and may be used as a transitional arrangement for future acquisition of the overseas supplier. Hence, we propose:

Proposition 4: *International subcontracting is chosen over acquisition of overseas suppliers when the pre-acquisition costs in assessing the value of the target firm are high.*

Fourth, high exit barriers in an equity relationship may jepodize the flexibility valued by the firms. In contrast, a subcontracting arrangement allows the buyers to rescind the contractual relationship with suppliers at a relatively low exit cost. In addition, impediments to acquistions arising from governmental and institutional barriers are not uncommon. Many developing countries discourage and restrict the foreign equity control of local companies while the pervasive anti-trust legislation in developed countries also acts against acquisitions (Wang, 2007). We therefore suggest:

Proposition 5: *International subcontracting is chosen over acquisition of overseas suppliers when there are institutional barriers to acquisition*

When making the choice between subcontracting and building new plants (greenfield) in low-cost countries, the following factors need to be considered. First, relocating low value-added operations to newly established greenfield plants may achieve a similar level of cost reduction in labor and other production factors. But relocation to another country through greenfields requires additional knowledge in managing labor and production in an unfamilar environment, and becoming acquainted with the specific local cultures and environment is a time-consuming process (Bell, 1996). Greenfield investments may be necessary for companies that aim to develop foreign markets for their products, but not for firms that simply seek a low cost supply base overseas. When the cost of learning cannot be recovered quickly, a subcontracting arrangement rather than a greenfied will be sufficient to achieve the objective of cost reduction.

Second, even when the buyer firm plans to develop the foreign market in the future, subcontracting may still be a preferred entry mode as it allows the firm to acquire knowledge of local market before the subcontracting arrangement is replaced by a wholly-owned subsidiary (Kogut, 1988). In this case, the choice of subcontracting economises on the cost of acquiring local knowledge, allowing the prospective entrant to test the potential of the local market while exploiting the foreign country as a low cost supply base in the mean time. Hence:

Proposition 6: *International subcontracting is chosen over greenfield when there are sigificant costs involved in learning how to operate greenfield plants overseas*

THE RANGE OF SUBCONTRACTING RELATIONSHIP

Transaction-specific investments bond principals and subcontractors in a relational long term supply arrangement, but it also leaves room for parties to bargain, shirk, or break the relationship for short-term gains (Williamson, 1985). The so-called hold-up problem often arises when one party in an exchange relationship commits transaction-specific or relationship-specific investments (Wathne & Heide, 2000). The asymmetric investments in specific assets allow a firm to behave opportunistically to increase its short-term, unilateral gains in a dyadic channel relationship (Brown, Dev, & Lee, 2000). In a subcontracting relationship, whether and how to preserve the contractual arrangement is primarily a matter of the nature of the relationship between the principal and the subcontractor concerned.

There is a whole range of international subcontracting relationships in terms of the degree of interdependence and bargaining power between principals and subcontractors. The perceived dependence and bargaining power are the function of the combination of many factors, including the degree of asset-specific investments, frequency of transactions and uncertainty (Williamson, 1979, 1985). Variations along those transactional dimensions determine the degree of interdependence and bargaining power between subcontracting parties, which in turn constitute a variety of subcontracting relationships. This section not only examines a range of subcontracting relationships but also their corresponding governance mechanisms. In studying how firms mitigate opportunism in marketing channels, Brown et al. (2000) identified three specific mechanisms: (1) ownership, (2) investment in transaction-specific assets, and (3) development of relational exchange norms such as role integrity, flexibility, and long-term orientation. As ownership does not apply to the governance of subcontracting relationship, which is essentially a commercial exchange, we focus on the efficacy of the other two mechanisms in preserving and managing subcontracting relationships.

First, a loose subcontracting relationship denotes a low interdependence degree between principals and subcontractors, the switching cost for both parties is low as neither side makes significant asset-specific investments. The principal does not rely on a particular subcontractor or subcontractors for supply and the subcontractor also has a broad customer base. The principal only need to provide minimal technical assistance to the subcontractor and the subcontractor does not need sophisticated machinery and skills to perform subcontracting jobs. The frequency of orders has little impact on the relationship since both sides are loosely tied to each other and the exit costs are low for both sides when facing market demand fluctuations. Examples abound in commercial subcontracting (Gereffi, 1993). In this case, neither the principal nor the subcontractor has strong incentive to maintain a long-term association with each other. Consequently, neither investment in transaction-specific assets nor development of relational exchange norms will be necessary.

Second, a subcontractor is more dependent when the principal has stronger bargaining power. This occurs when asset-specific investments made by the parties are asymmetric. The buyer commitments are usually confined to specific physical capital, including specific dies, moulds and tooling for the manufacture of a contracted product (Nishiguchi, 1994). The subcontractor, on the other hand, has to invest in special-purpose equipment, employ skilled workers and engineers who are devoted to customer-specific operation; expand production capacity to meet the principal's requirement. The industry structure is such that many suppliers from developing countries are competing for relatively few buyers from developed countries. It is difficult for a subcontractor to diversify its customer-base and its sales revenue. To secure long-term orders from the principal, the subcontractor has to invest a greater degree of specific assets, which in turn leave them vulnerable to the potential hold-up by the principal. However, such an unbalanced subcontracting relationship may not be unstable. Although buyers from developed countries have much leverage among many suppliers in developing countries, stable long-term relationships with their suppliers can enhance performance certainty by reducing the costs in seeking suitable overseas suppliers, in drawing up multiple contracts, and in monitoring multiple suppliers in different countries. All of these benefits would be lost in a frequent shift of suppliers. Opportunism by one party can erode the long-term gains potentially accruing to both parties in a dyadic buyer-supplier relationship (Brown et al., 2000). These are also the reasons why arm's length outsourcing may involve a long-term relationship. But the higher degree of asset specificity points to a more inter-locked pattern of relationship in subcontracting than in outsourcing. Both the principal and the subcontractor have incentives to maintain the long-term relationships. Consequently, both sides may invest in transaction-specific assets and develop relational exchange norms in order to consolidate the relationship.

Third, situations where a principal is more dependent on a subcontractor are less common. They happen when the overseas subcontractor holds know-how crucial to the principal's production cycle. Some once-off and occasional large purchasing orders that involve sophisticated work such as in aerospace (Esposito & Storto, 1994) and shipbuilding industries (Smitka, 1991) might qualify as examples, since they require highly specialized expertise and more importantly there are more buyers than suppliers in the global market. Subcontractors enjoy stronger bargaining power when they are not merely producing certain products or components, but serve as intermediates for transferring knowledge of the local market to foreign buyer firms. In this case, a local subcontractor's bargaining power stem not from the transaction characteristics, but from the foreign buyer's strategic purpose in developing the local market with the help of the local supplier (Wang, 2007). Nevertheless, the subcontractor may be unaware of the principal's strategic motive and fail to materialise its power advantage in dealing with the foreign principal firm.

Fourth, when the principal and the subcontractor are mutually and heavily dependent on each other, the demand for equal collaboration is high. Subcontracting of this type requires highly specialized investments from both sides and the relationship is balanced (Wang, 2007). In such a subcontracting relationship, the principal typically contracts out the assembly of a final product. The principal commitments contain a high degree of asset specificity since complete assembly requires the highest integration of contract-specific physical facilities, including dedicated assembly lines, tooling and testing equipment (Nishiguchi, 1994). Moreover, the principal will incur human asset-specific investments in the form of managerial training and technical assistance to the overseas subcontractor to attain the production specifications (Sharpston, 1977). For subcontractors, end-product assembly for a particular overseas buyer will require specific investments both in human capital (e.g., employ highly skilled workers or provide special training) and in physical assets (e.g., purchase specialised machinery and equipment). Therefore, principals and subcontractors commit a similar level of asset-specific investments, which support an equal collaborative relationship characterised by common interest, mutual obligations, and trust (Morris & Imrie, 1992; Smitka, 1991). Under this circumstance, the principal and the subcontractor rely on both mechanisms to govern their ongoing exchanges and mitigate opportunism: investments in transaction-specific assets that create a mutual hold-up situation and development of shared relational exchange norms such as role integrity and harmonious conflict resolution (Brown et al., 2000).

CONCLUSION

International subcontracting is often studied as an important instrument for industrial development at the policy level. Few studies have looked at the phenomenon from international business and strategic management perspectives. In line with Williamson-type of transaction cost-comparative contracting approach, the article defines international subcontracting as a type of long-term relational contract between buyers and suppliers in different countries, aiming to facilitate the sourcing of products or components with buyer-specific requirements. Building rigorously on the transaction cost theory, the paper develops an analytical framework to investigate the choice of international subcontracting over its market (arm's length outsourcing) and hierarchy alternatives (vertical integrated MNEs).

The comparison between subcontracting and its alternatives provides both prescriptive and pridictive value for international managers who face the strategic choice between outsourcing, subcontracting and vertical integration when organizing the supply chain across national borders. Table 1 summarizes the major transaction characteristics, advantages, and distantages of the different forms of supply chain organization.

Based on the framework, we developed a set of testable propositions that can be used not only for future empirical research but also to aid managers in making strategic choice between outsourcing,

Table 1. Outsourcing, subcontracting, and vertical integration

	Transaction characteristics	Advantages	Disadvantages	When to use it
Outsourcing	Arm's length contract	Better for realizing economies of specialization and comparative advantages	Unstable exchange relationship due to low switching costs	Most suitable for facilitating trading of standard goods and services
Subcontracting	Relational contract with bi-lateral governance	Stable long-term relationship between particular buyers (principals) and suppliers (subcontractors)	High switching costs to alternative trading partners due to higher degree of asset-specific investments	Most suitable for facilitating purchasing and supplying of goods and services containing some degree of asset-specific investments
Vertical integration	Relational contract with unified governance	Complete hierarchical control over the supply of goods and services within the boundary of the firm	High agency costs in incentivising and managing in-house suppliers	Most suitable for organizing purchasing and supplying of highly idiosyncratic goods and services

long term subcontracting, and vertical integration (Greenfield or acquisition) for organizing supply chain across borders. For example, we suggest that international subcontracting should be chosen over outsourcing when there is a higher level of asset-specificity in the purchasing/supplying transaction. It should be chosen over greenfield when there are sigificant costs involved in learning how to operate greenfield plants overseas. When choosing between international subcontracting and acquisition of overseas suppliers, managers should consider a range of factors, including how difficult it is to disentangle the desired assets of the acquied firm from the non-desired ones, how costly it is to assess the true market value of the acquisition targets ex ante and in managing the acquired firms ex post.

The framework also allows us to examine the specific nature of a range of subcontracting relationships. We identify four types of subcontracting relationships in terms of the degree of interdependence and bargaining power between principals and subcontractors. We demonstrate how the variations along transactional dimensions, especially asset-specific investments by the principal and the subcontractor, shape the different dyadic exchange relationship. We also argue that the two major governance mechanisms, investments in transaction-specific assets and development of relational exchange norms, have different efficacy in preserving and managing a range of subcontracting relationships. The paper thus offers a conceptually coherent foundation for researchers and managers to analyse international subcontracting as a form of international business organization at the firm level, complementing the existing literature's emphasis on studying the topic as a macro-economic phenomenon.

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Chapter 4.4

EBBSC:
A Balanced Scorecard-Based Framework for Strategic E-Business Management

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ABSTRACT

E-business is far more about strategy than technology, and the strategy of e-business is very important in today's dynamic and competitive environment. In this article, we describe a balanced scorecard-based framework in detail and discuss its potential e-business uses. This framework enables e-business managers to plan and allocate resources more effectively and align strategic objectives with performance results. It also provides a stable point of reference for e-businesses to understand and manage the fundamental changes introduced by e-business initiatives.

INTRODUCTION

The Link of Objectives to Strategies

E-business has rapidly developed from being a vision of the future world of business to being "the" way of doing business (Whelan & Maxelon, 2001). This business opened new channels for communication and selling, a new source of data on customers and competitors, and changed the face of competition tremendously (Koutsoukis, Dominguez-Ballesteros, Lucas, & Mitra, 2000; Porter, 2001). Clearly, business processes of the 21st century must be more efficient and dynamic to build and sustain value across the organization, though having a dot-com presence does not necessarily point to success. As Raisinghani and Schkade (2001) pointed out "perhaps, one of the best ways to succeed in the world of e-business is to start off with a dynamic and new e-business strategy" (p. 601).

E-business is far more about strategy than technology. An effective e-business strategy is an elaborate and systematic plan of action that incorporates different organizational levels, different parties, different elements, and growth pattern features (Bakry & Bakry, 2001). Unlike traditional business strategy, e-business strategy considers a company's business management architecture and how it can be improved, integrated and automated by instant and global Internet communication. Indeed, the Internet has spawned new e-business strategy and radically transformed existing models (Basu & Muylle, 2002; Pant & Ravichandran, 2001). These new models incorporate Internet technology, universal connectivity, and Web browser capabilities to integrate business processes within and beyond an enterprise. As a result, old business models should be adapted to the new conditions, and companies worldwide should develop an effective e-business strategy to fit the new conditions (Whelan et al., 2001).

What distinguishes many of the dot-coms from traditional organizations is not their new technical power, but their innovative and imaginative new business models (Hamel, 2000). This study proposes a balanced scorecard based e-business framework for the development and assessment of e-business strategy in this new age. Aided by this innovative and comprehensive e-business framework, managers can identify the major decision factors involved in their e-business strategies, specify the direct and indirect relationships among the factors, and generate strategies that would improve overall business performance.

BACKGROUND REVIEW

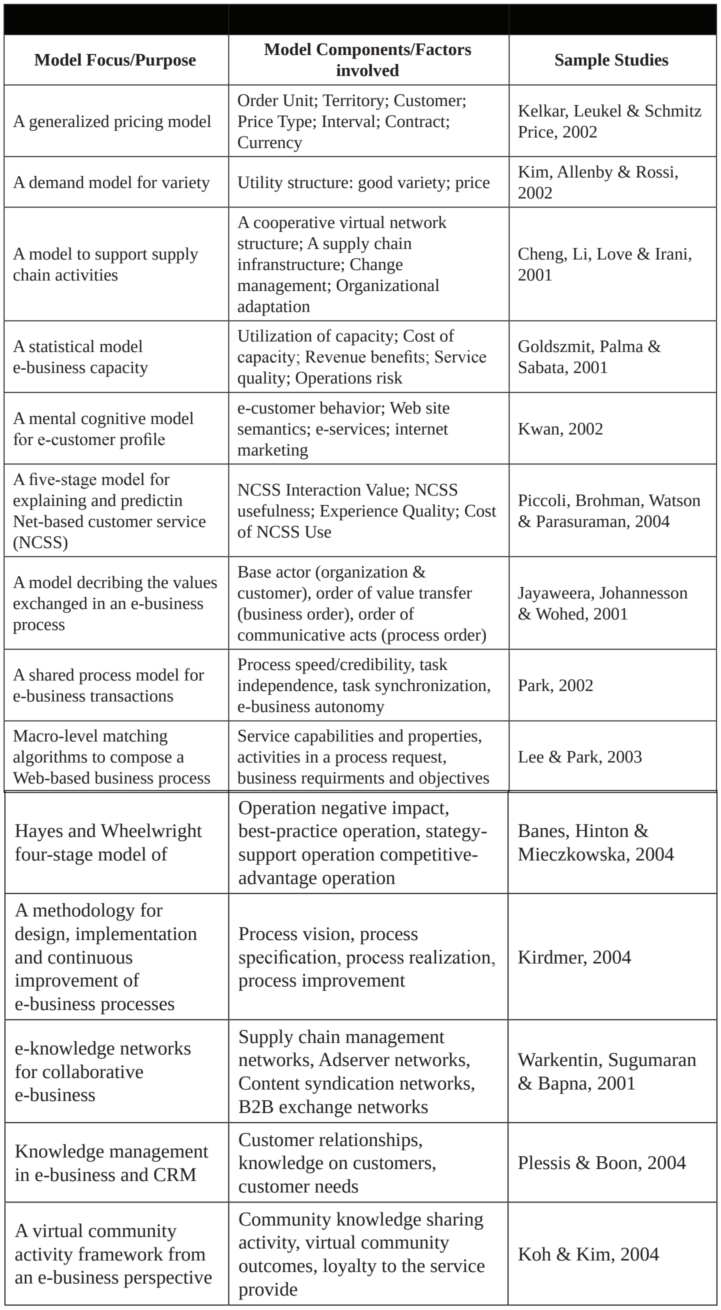
The Evolution of E-Business Models

A commonly cited reason for e-business failure has been the lack of a workable and concrete strategic business model to guide e-business efforts (Paper, Pedersen, & Mulbery, 2003). While a comprehensive framework for strategic e-business management seems desirable, there are few studies that offer complete and integrated views of e-business strategy (Dubosson-Torbay, Osterwalder, & Pigneur, 2001). In the business model literature, many academic studies have provided a theoretical basis for, and some empirical testing of, the models (Horsti, Tuunainen, & Tolonen, 2005). These studies fall into two broad categories. The first group develops subsystem models in support of a specific aspect of e-business applications, while the second group involves generic frameworks to reflect e-business reality.

Table 1 provides a brief overview of the existing subsystem model studies. As this table demonstrates, although each of the subsystem models involves operationalized views of a particular aspect of e-business, none offer a complete and integrated view of e-business strategy as a whole.

Among the generic e-business strategy models, Whelan et al. (2001) proposed a five element e-business architecture. The five elements are product, channel, customer management, resource management, and information. Afuah and Tucci (2001) presented a more detailed list of model components including scope, customer value, revenue sources, connected activities. Like Whelan et al. (2001), these researchers did not specify the interrelationships and causality between these components. Hamel (2000) offered a more complete model than the others. This researcher used a four part framework that describes links between model components (e.g., "Configuration" to connect the "Core strategy" and "Strategic resources"). Similarly, Dubosson-Torbay et al. (2001) used a framework to analyze e-business with four principal components: product innovation, customer relationship, infrastructure management, and financial aspects. Damanpour (2001) also identified four elements of e-business from a systematic perspective: business/financial models, relationships, commerce, and responsiveness. Still another e-business model is composed of a value cluster, marketing offering, resource system, and financial model (Rayport & Jaworski, 2001). Going beyond the segment frameworks, De, Mathew, and Abraham (2001) developed a pragmatic framework that offers a series of different perspectives for the analysis of e-business: transaction costs, switching costs,

Table 1. The first group sub-system e-business model studies



Model Focus/Purpose	Model Components/Factors involved	Sample Studies
A generalized pricing model	Order Unit; Territory; Customer; Price Type; Interval; Contract; Currency	Kelkar, Leukel & Schmitz Price, 2002
A demand model for variety	Utility structure: good variety; price	Kim, Allenby & Rossi, 2002
A model to support supply chain activities	A cooperative virtual network structure; A supply chain infranstructure; Change management; Organizational adaptation	Cheng, Li, Love & Irani, 2001
A statistical model e-business capacity	Utilization of capacity; Cost of capacity; Revenue benefits; Service quality; Operations risk	Goldszmit, Palma & Sabata, 2001
A mental cognitive model for e-customer profile	e-customer behavior; Web site semantics; e-services; internet marketing	Kwan, 2002
A five-stage model for explaining and predictin Net-based customer service (NCSS)	NCSS Interaction Value; NCSS usefulness; Experience Quality; Cost of NCSS Use	Piccoli, Brohman, Watson & Parasuraman, 2004
A model decribing the values exchanged in an e-business process	Base actor (organization & customer), order of value transfer (business order), order of communicative acts (process order)	Jayaweera, Johannesson & Wohed, 2001
A shared process model for e-business transactions	Process speed/credibility, task independence, task synchronization, e-business autonomy	Park, 2002
Macro-level matching algorithms to compose a Web-based business process	Service capabilities and properties, activities in a process request, business requirments and objectives	Lee & Park, 2003
Hayes and Wheelwright four-stage model of	Operation negative impact, best-practice operation, stategy-support operation competitive-advantage operation	Banes, Hinton & Mieczkowska, 2004
A methodology for design, implementation and continuous improvement of e-business processes	Process vision, process specification, process realization, process improvement	Kirdmer, 2004
e-knowledge networks for collaborative e-business	Supply chain management networks, Adserver networks, Content syndication networks, B2B exchange networks	Warkentin, Sugumaran & Bapna, 2001
Knowledge management in e-business and CRM	Customer relationships, knowledge on customers, customer needs	Plessis & Boon, 2004
A virtual community activity framework from an e-business perspective	Community knowledge sharing activity, virtual community outcomes, loyalty to the service provide	Koh & Kim, 2004

infrastructure investment, revenue models, and other elements.

Table 2 summarizes the scope and model components of the generic e-business frameworks. As this table illustrates, no operational generic models have been offered, or implemented, by the proponents. The generic frameworks, instead, provide theoretical guidance on components that could be included in a comprehensive and integrated e-business strategy model.

One exception is the high level e-business framework, with preliminary empirical evidence, proposed by Hasan and Tibbits (2000). These researchers developed a BSC-based case study for e-business management in an Australian state-government utility. The researchers, however, did not identify and formulate the goals, measures, and targets in each scorecard perspective.

As Tables 1 and 2 indicate, the literature has not offered a comprehensive and concrete model of e-business strategy. The electronic business balanced scorecard (EBBSC) model proposed in this study attempts to close that research gap by linking business strategies to a broad range of measures, examining important business issues facing e-business managers, and providing a complete and integrated view of e-business management.

EBBSC FRAMEWORK SPECIFICATION

The proposed EBBSC framework identifies four essential perspectives. These perspectives include the financial, customer, internal processes, and learning and growth views. First introduced in the early 1990s as the balanced scorecard (BSC), these views provide a balanced picture of current operating performance as well as the drivers of future performance in traditional businesses (Kaplan & Norton, 1992, 1996). The underlying motivation for this vision and strategy has been explored repeatedly (Dutta & Manzoni, 1999; Lee & Ko, 2000; Lohman, Fortuin, & Wouters, 2004; Marr & Schiuma, 2003; Soliman & Youssef, 2001; Sandstrom & Toivanen, 2002) and is therefore not repeated here.

Table 2. 2nd group generic e-business framework studies

Afuah & Tucci (2001)	**Damanpour (2001)**	**De et al. (2001)**	**Dubosson et al. (2001)**	**Hamel (2000)**	**Hasan & Tibbits (2000)**	**Rayport & Jaworski (2001)**	**Whelan & Maxelon (2001)**
price, revenue sources, sustainibility (what is difficult to initiate of the business model)	business financial models (business model and opportunities)	Revenue models (Advertising, retail, banking & information harvesting)	Product innovation (market segment, value proposition), Financial Aspects (cost & revenue structures)	Core Strategy (business mission, product/market scope, differentiation basis), Pricing structure	Finance/ Business value	Financial model	Product
Customer value (distinctive offering or low cost), Scope (customer & products/ services)	Relationships (relationships & collaboration management)	Transaction and Switching costs, User Experience, Models, Versioned products/niche marketing	Customer Relationship, Infastructure Management I (partner network)	Customer Interface (support. info & insight, relationship dynamics); Customer benefits	Customer User perspectives	Marketing offering	Customer management
connected activities (interdependency between different activities)	Responsiveness (efficiency & timing of transactions) Commerce (e-buying & selling mechanism)	Network externalities, Infastructure investment	Infastructure Management II (activities & processes)	Strategic resources (core processes); Configuration; Value network, company boundaries	Internal business/ Process	Value cluster	Channel
Implementation (resources needed); Capabilities (skills needed)	--	--	Infastructure Management III (resources/ assets)	Strategic resources (core competencies, strategic assets)	Innovation/ Learning future readiness	Resource system	Resource management; Information

Because the methodology of the BSC explicitly focuses on links among business decisions and outcomes, it is intended to guide strategy development, implementation, and communication, and to provide reliable feedback for management control and performance evaluation (Malina & Selto, 2001). Although most implementations emphasize BSC success as a commercial product, the rationale behind the BSC does appeal to managers who face new challenges in the modern business environment (Hasan et al., 2000).

As indicated by Hasan et al. (2000), the real challenge is to determine how the BSC can be successfully applied in the context of e-business. E-business functions in a constantly changing environment of interdependencies, which has been perceived as highly uncertain, stemming from increased information visibility and dynamic market structures (Golicic, Davis, McCarthy, & Mentzer, 2002; Wang, 2001). In this environment, traditional success measures may be incomplete, and possibly misleading, and the original BSC framework may require radical modification.

Using literature findings and underlying theories, we adapted the original BSC into the comprehensive e-business management framework (EBBSC) shown in Figure 1. As this figure indicates, the EBBSC consists of four perspectives, including the business core, analytic e-CRM, process structure, and e-knowledge network.

Tables 3 and 4 compare this EBBSC concept with the subsystem and generic model studies. As this comparison indicates, the EBBSC framework is based on the e-business model literature but represents a more complete, explicit, and integrated view of e-business strategy. Such a framework can be utilized to translate e-business strategies into conceptual blueprints for strategic management control and performance evaluation. The EBBSC framework also provides a stable point of reference for e-businesses to understand and explore e-business initiatives effectively.

Business Core Perspective

Although e-business models differ somewhat from traditional brick and mortar models, the fundamental needs of consumers and businesses remain the same. Consumers want desirable products and services at competitive prices, while businesses want profitable marketing and production. The focus should be on long-term and short-term decision making in the dynamic, competitive, and compressed business cycles of the global e-era. Figure 2 depicts the business core perspective in the framework. As indicated in the figure, the primary objective is profit maximization.

Within the e-business value cycle, many intangible and tangible firm and industry-specific factors may affect profit through revenue and cost influences (Spanos, Zaralis, & Lioukas, 2004).

Figure 1. Adapted four perspectives for strategic e-business management (Adapted from Wang & Forgionne, 2005)

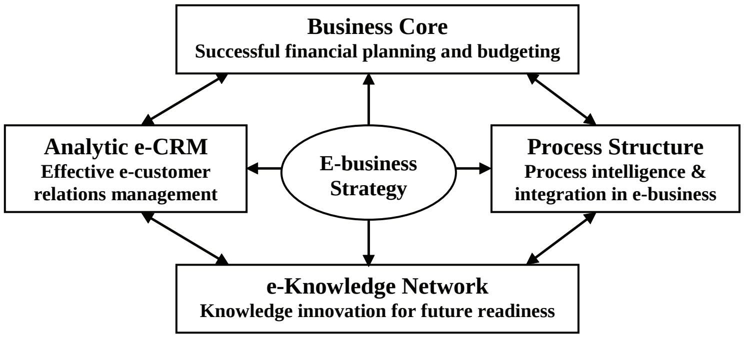


Table 3. The first group sub-system e-business model literature comparison

EBBSC Framework Perspectives	Comparative Model Components in Literature	Sample Representative Studies
Business Core Successful financial planning and budgeting	Profit maximization, Pricing mechanisms, Price structures, Revenue sources, Demand uncertainties, Budget mode, Financial performance, Market optimization, Internet marketing	Kelkar, Leuke; & SchmitzPrice, 2002: Kim, Allenby & Rossi, 2002; Valadares Tavares, Pereira & Coelho, 2002; Motiwalla & Riaz Khan, 2003; Liu, Wynter & Xia, 2003; Chen, Liu & Song, 2004
Analytic e-CRM Effective e-customer relations management	Customer value, Customer knowledge, E-customer profile, Customer efficiency, Consumer power, Customer needs, e-CRM essence, Customer perception, Mass customization model	Bielski, 2000; Rowley, 2002; Mei & Harker, 2002; Wan, 2002; Fletcher, 2003; Olsson & Karlson, 2003; Wang & Tang, 2003; Vrechopoulos, 2004; Piccoli, Brohman, Watson & Parasuraman, 2004
Process Structure Process intelligence & integration in e-business	Process patterns, E-logistics platform, Process (semi)-automation, Process independence & sychronization, Operation management, Value (e) -chain, Process networks	Jayaweera, Johannesson & Wohed, 2001; Par, 2002; Lee & Park, 2003; Oh, Hwang, & Lee, 2003, Barnes, Hinton & Mieczkowska, 2004; Kirchmer, 2004
E-Knowledge Network Knowledge innovation for future readiness	Knowledge Management, E-knowledge networks, E-knowledge decision model, Knowledge exchange, Customer knowledge, Knowledge chain model, Knowledge sharing	Malhotra, 2000; Warkentin, Sugumaran & Bapna, 2001; Raisinghani & Mead, 2002; Malhotra, 2002; Rowley, 2002; Allard & Holsapple, 2002; Plessis & Boon, 2004, Koh & Kim, 2004

Some factors involve Internet considerations, such as network performance (e.g., network security and e-capacity). Risk and uncertainty will be created by intangible organizational and environmental factors (Palmer & Wiseman, 1999). Representative decision factors in the business core perspective as a result of the Internet effect are highlighted in Figure 2.

Revenues increase from product and service expansions, new customers and markets, and higher value re-pricing. Price, capacity, supply chain management efficacy, and staff proficiency are the major determinants of the quantity supplied. Capacity is limited by the equipment and/or available personnel, but also by the limit associated with network technology (Goldszmidt et al., 2001). A stronger emphasis on supplier relationship management reduces uncertainty (Craighead et al., 2003; Golicic et al., 2002). Supply chain management efficacy can be used as an indicator of the bargaining power of suppliers (Porter, 2001).

On the demand side, there are traditional determinants, including customer retention and the marketing mix, and new e-business factors. Customer retention measures the company's customer loyalty (Smith, 2002) or stickiness (Ingsriswang et al., 2001). Since customers can now compare prices and services with a-click, it is more challenging to attract and retain customers in the virtual business world.

The marketing mix, coined by Borden (1965), consists of traditional price, product, promotion, and place (Borden, 1965; Brooksbank, 1999; Kotler & Armstrong, 1997; Smith & Saker, 1992), as well as enhancements unique to e-business. For example, pricing must be adjusted to the specific requirements of e-procurement (Kelkar et al., 2002). The original "Place" factor is decomposed into e-marketing presentation and distribution effort. Similar to the store design of a physical shopping mall, the Web presentation style and structure can attract online customers and build

Table 4. The second group generic e-business framework comparison

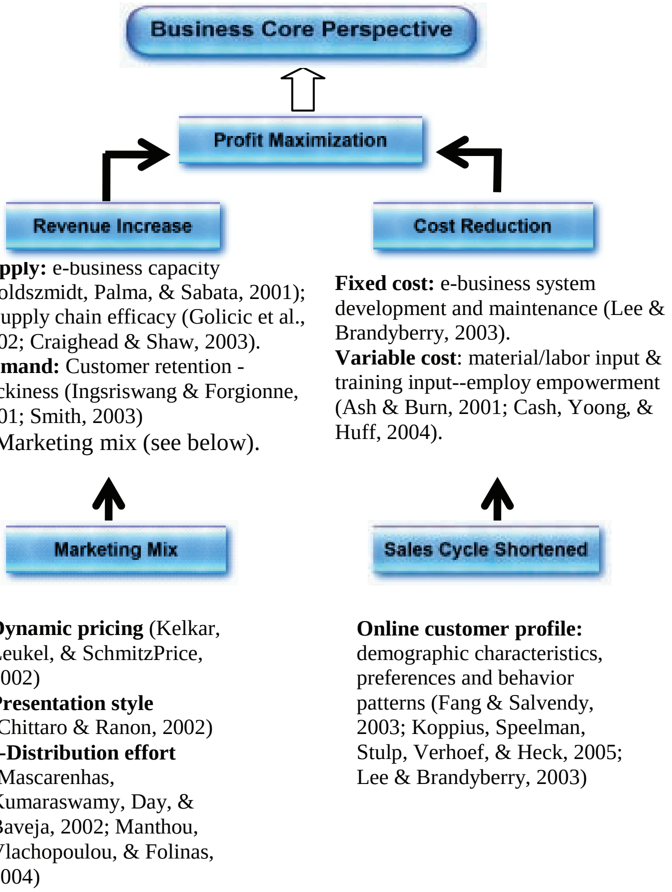
Framework commonality	**Afuah & Tucci (2001)**	**Damanpour (2001)**	**De et al. (2001)**	**Dubosson et al. (2001)**	**Hamel (2000)**	**Hasan & Tibbits (2000)**	**Rayport & Jaworski (2001)**	**Whelan & Maxelon (2001)**
Business Core Perspective	price, revenue sources, sustainibility (what is difficult to initiate of the business model)	business financial models (business model and opportunities)	Revenue models (Advertising, retail, banking & information harvesting)	Product innovation (market segment, value proposition), Financial Aspects (cost & revenue structures)	Core Strategy (business mission, product/ market scope, differentiation basis), Pricing structure	Finance/ Business value	Financial model	Product
Analytic e-CRM Perspective	Customer value (distinctive offering or low cost), Scope (customer & products/ services)	Relationships (relationships & collaboration management)	Transaction and Switching costs, User Experience, Models, Versioned products/niche marketing	Customer Relationship, Infastructure Management I (partner network)	Customer Interface (support. info & insight, relationship dynamics); Customer benefits	Customer User perspectives	Marketing offering	Customer management
Process Structure Perspective	connected activities (interdependency between different activities)	Responsiveness (efficiency & timing of transactions) Commerce (e-buying & selling mechanism)	Network externalities, Infastructure investment	Infastructure Management II (activities & processes)	Strategic resources (core processes); Configuration; Value network, company boundaries	Internal business/ Process	Value cluster	Channel
e-Knowledge Network Perspective	Implementation (resources needed); Capabilities (skills needed)	--	--	Infastructure Management III (resources/ assets)	Strategic resources (core competencies, strategic assets)	Innovation/ Learning future readiness	Resource system	Resource management; Information

customer loyalty in e-business (Chittaro & Ranon, 2002). Distribution involves traditional and Internet (as called e-channel or virtual e-chain) management and innovation (Manthou et al., 2004; Mascarenhas et al., 2002).

Another way to maximize profit, besides increasing revenue, is to reduce fixed and variable cost (Lee & Brandyberry, 2003). Traditionally, fixed cost refers to invariable selling and administrative expenses. In the context of e-business, fixed cost can include e-business system development and maintenance expenses, as well as other utility and management overhead. Variable cost measures the materials, money, and labor expenses involved in producing/importing and selling the product. In the context of e-business, labor expenses should include the effort spent on knowledge management (transmission, sharing, and innovation), building relationships, and education in e-era technology (Ash & Burn, 2001; Cash et al., 2004).

One indirect, but potentially effective, method to reduce cost is to shorten the sales cycle. In addition to product quality, price, and the e-marketing mix, the customer profile is an important determinant of the e-business sales cycle. This profile is a composite variable that reflects the customers' demographic characteristics, preferences, and behavior patterns. As noted by Lee and Brandyberry (2003), when compared with traditional customers, online customers tend to be less stable due to their "Logical," rather than "Physical," relationships.

Figure 2. Business model perspective of strategic e-business management



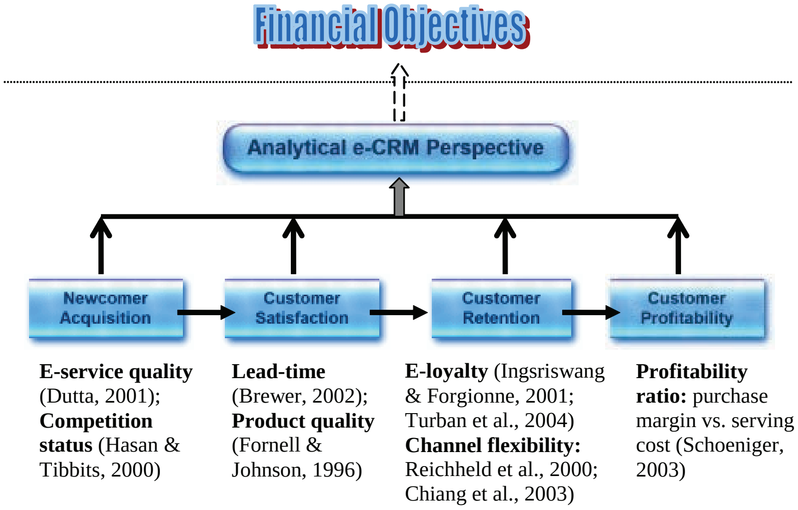
Supply: e-business capacity (Goldszmidt, Palma, & Sabata, 2001); e-supply chain efficacy (Golicic et al., 2002; Craighead & Shaw, 2003).
Demand: Customer retention - stickiness (Ingsriswang & Forgionne, 2001; Smith, 2003)
e-Marketing mix (see below).

Fixed cost: e-business system development and maintenance (Lee & Brandyberry, 2003).
Variable cost: material/labor input & training input--employ empowerment (Ash & Burn, 2001; Cash, Yoong, & Huff, 2004).

Dynamic pricing (Kelkar, Leukel, & SchmitzPrice, 2002)
Presentation style (Chittaro & Ranon, 2002)
e-Distribution effort (Mascarenhas, Kumaraswamy, Day, & Baveja, 2002; Manthou, Vlachopoulou, & Folinas, 2004)

Online customer profile: demographic characteristics, preferences and behavior patterns (Fang & Salvendy, 2003; Koppius, Speelman, Stulp, Verhoef, & Heck, 2005; Lee & Brandyberry, 2003)

Figure 3. e-CRM perspective of strategic e-business management



E-service quality (Dutta, 2001); **Competition status** (Hasan & Tibbits, 2000)

Lead-time (Brewer, 2002); **Product quality** (Fornell & Johnson, 1996)

E-loyalty (Ingsriswang & Forgionne, 2001; Turban et al., 2004) **Channel flexibility:** Reichheld et al., 2000; Chiang et al., 2003)

Profitability ratio: purchase margin vs. serving cost (Schoeniger, 2003)

Analytic e-CRM Perspective

Customers are at the core of all businesses. With the Internet, customers have realized the benefits of shopping online, including convenience, broader selection, competitive pricing, and greater access to critical business information (Chen et al., 2004). Relationships and collaborations are forged in e-business to enter new markets or enhance customer, supplier and business interactions (Damanpour, 2001). On the other hand, customers' involvement in online retailing is impeded by security and privacy concerns, download time, and other technology barriers, or unfamiliarity (Chen et al., 2004). Furthermore, customers can switch to other competitive URLs in seconds with minimal financial cost (Ingsriswang et al., 2001), which makes successful customer management especially vital in e-business (Ace, 2002).

Figure 3 depicts the e-CRM perspective. As indicated in the figure, the keys to achieve customer profitability are customer acquisition and customer retention, i.e., to continuously attract newcomers and retain loyal customers. Achieving customer satisfaction can turn newcomers into loyal customers. Representative decision factors in the e-CRM perspective, which have not been covered previously, are highlighted in Figure 4.

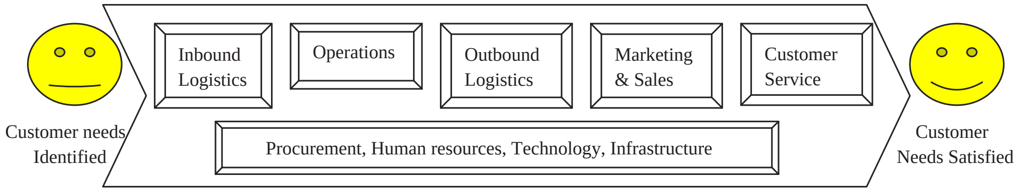
The success or failure of a customer acquisition campaign depends on precise, timely targeting that delivers valuable offers to prospects and keeps costs low. This targeting could involve finding previously untapped customers (for example, baby diapers for new parents) or competitors' customers (Berson, Smith, & Thearling, 1999). While acquisition costs vary widely among various businesses, optimized targeting with proper customer profile research and e-marketing mix strategy is consistently a top priority, as is e-service quality and competitive status. E-service quality involves network reliability and customer support (Dutta, 2001), while competition status represents the company's external relationship with the supplier, availability of other distribution channels, entry barriers, rivalry, and product substitutes (Kaplan et al., 1992; Hasan et al., 2000).

The next step is to ensure customer satisfaction with lead time, product quality, service quality, and competitive pricing (Kaplan et al., 1992). Lead time measures the time required for the company to meet its customers' needs, sometime referred to as "order-to-delivery cycle time" (Brewer, 2002). Quality measures the defect level of products as perceived and measured by the customer. A product with high quality and a high level of customization may increase the degree of customers' satisfaction (Fornell & Johnson, 1996). E-service quality and price also will greatly impact satisfaction.

However, satisfied customers are not necessarily loyal customers (Gale, 1997). Loyal customers, who repeat their purchases or visits persistently, are valuable business assets (Turban et al., 2004). According to Reichheld and Schefter (2000), e-loyalty is an economic necessity in the e-era. The idea is to develop and maintain long-term relationships with customers by creating superior customer value and satisfaction (Ingsriswang et al., 2001).

Goodwill, the favor or prestige that a business has acquired beyond the mere value of what it sells (Merriam-Webster online, 2005), reflects

Figure 4. A generic value chain (Adapted from Lewis, 2001)



the cumulative impact of marketing and customer satisfaction (Anderson & Fornell, 1994; Jennings & Robinson, 1996). Companies should determine their and use their core competencies to target the market (Smith, 2002). Channel flexibility refers to the convenience and availability of distribution channels besides the Internet. According to Reichheld et al (2000), the seamless integration of different channels can prove to be valuable. This finding has been verified by Chiang et al. (2003)'s, who determined that the e-channels could increase the e-business companies' profit indirectly through retail channels.

All customers are not created equal. If the company could properly measure the profitability of its customers, it can implement corresponding margin strategies to achieve higher customer and corporate profitability. Profitability can be measured at either the individual or segment level by identifying the customers' purchase to cost margin. Costs uniquely traceable to customers include customer transactional cost, customer service and support cost, packaging, delivery, and post sales costs. The ratios of the mix of customer purchase margin to the customer serving cost are thereby revealing when compared on an individual customers basis, as well as by segment or channel (Schoeniger, 2003).

Process Structure Perspective

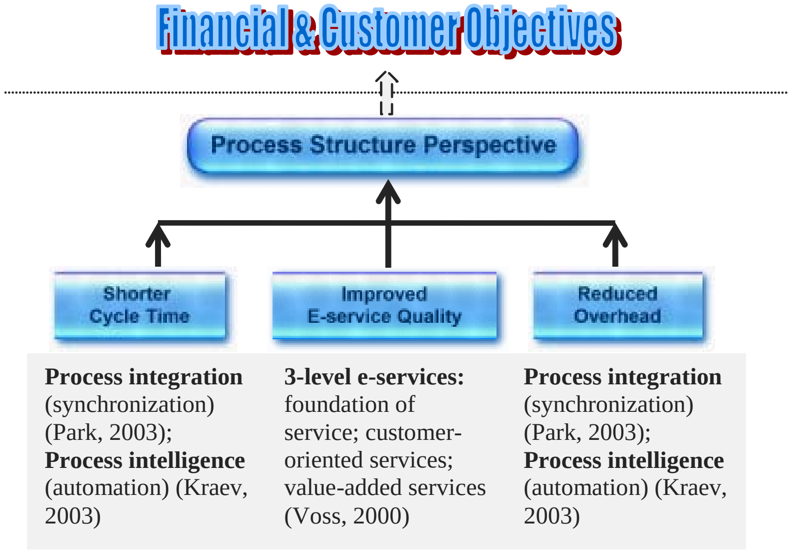
E-business should feature speed, flexibility and fluidity, sometimes described as agility (Introna, 2001; Metes, Gundry, & Bradish, 1998). Existing business processes must be seamlessly integrated with the new, electronic form of interaction with suppliers and customers. A generic value chain is illustrated in Figure 4, which offers an abstract description of the processes within any type of business (including e-business). To be feasible in e-business, the internal process view should consider the flexibility and intelligence of the process structure (Hasan et al., 2000).

For e-businesses to operate successfully there must be flexibility and scalability to accommodate continuous process changes, readiness to provide an up-to-the-minute and integrated view of the product, process and equipment, and capability to collect and store the results of historical and proactive analysis for future process innovation. Such process improvements can be achieved through intelligence and integration of business models and data with the Internet and with the systems of the company's trading partners. As summarized in Figure 5, improved effectiveness and efficiency in these core business processes will lead to faster cycle times, enhanced service quality, reduced overhead, and more competitive offerings.

Different from the customer-perspective sales cycle, the general cycle time measures the time needed by the business to plan and stock (inbound logistics), inventory and schedule (operations), lead time (order-to-delivery time), and invoice a particular product (outbound logistics). Accordingly, incremental costs are induced as the cycle lengthens. Effective process integration and intelligence can optimize this cycle, measurably reduce inventories and help offer exactly the products that the market demands at any given time. Wherever there are manual and sporadic tasks in the product cycle, there are chances for overhead costs, delays, and errors, all of which can all contribute to longer cycle times.

In the EBBSC framework, process integration is a composite variable that reflects the degree of problem critical data, information and knowledge sharing, and transmission across different departments and groups (from downstream to upstream and inbound to outbound). Process integration also incorporates the effectiveness of two or more identical (horizontal) or successive (vertical) stages in producing or distributing a particular product. Process intelligence represents the ability of the business processes to perceive and act in the surrounding environments, to respond appropriately to the prevailing circumstances in a dynamic

Figure 5. Process structure perspective for e-business strategy



business situation, to learn and to improve the process with prior experiences.

As emphasized in the e-CRM perspective, e-service is the glue that holds the e-business process together (Tschohl, 2001). According to Voss (2000), customer service generally involves three levels of service and overall e-service quality can be estimated by incorporating the quality indicators of the three levels of e-services.

- The first level, foundation of service in e-business, includes minimum necessary services, such as site responsiveness (e.g., how quickly and accurately the service is provided), site effectiveness (e.g., site interface friendliness and freshness), and order fulfillment. The e-business companies should monitor network performance and infrastructure to ensure basic customer service.
- The second level, customer-oriented services, involve: (1) informational capabilities: service and help information availability, perceived ease and actual convenience of finding the help needed, customer profile personalization, and interactive communication with service representatives, and (2) transactional capabilities: site security and privacy, order configuration, customization and tracking, complete support during the ordering process and after the purchase period.
- The last level, value-added services are extra services, such as location sensitive selling and billing or online training and education that add value to overall service quality. Some value-added services may stand alone from an operational perspective, while others add value to existing services. Overall, value-added services provide operational and administrative synergy between or among other levels of services.

Being agile and flexible, the virtual process of e-business replaces the traditional product inquiry and physical clearinghouse process and provides greater operating advantages that may lead to reduced overhead. As the cycle time is shortened through process integration and intelligence, overhead will be reduced accordingly. Process integration and intelligence is a significant advantage in achieving e-business focus and flexibility because, in many instances, these capabilities can replace the need for a well-defined organizational structure and often whole layers of staff.

E-Knowledge Network Perspective

Targets for success keep changing so that the company must make continual improvements to survive and succeed in the intensive global competition (Kaplan et al., 2001). Organizations operating in the new business environment should be adept at creation and application of new knowledge as well as ongoing renewal of existing knowledge archived in company databases (Malhotra, 2000; Soliman et al., 2001).

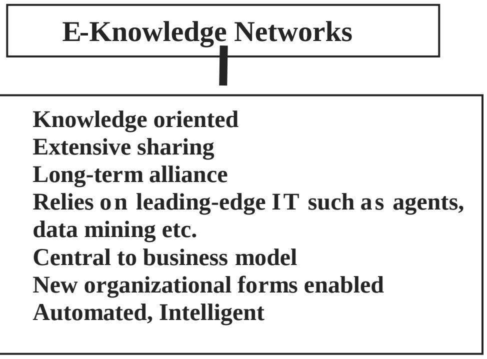
E-business knowledge (or "e-knowledge"), including knowledge about internal functions and processes, about customers and markets, and about strategic partners, can be created, shared, and managed more effectively by a combination of new organizational designs and the adoption of new technologies, such as data mining and intelligent agents. Organizations are now creating knowledge networks to facilitate improved communication of data, information, and knowledge, while improving coordination, decision making, and planning based on the Internet-driven "new economy" technologies that were unavailable until recently (Warkentin, Sugumaran, & Bapna, 2001).

Figure 6 highlights some of the characteristics of e-knowledge networks.

This enhanced e-knowledge innovation and management will lead to greater back-office efficiency, flexible adaptation to market changes, greater customer intimacy, improved strategic planning, improved decision making, rapid and flexible relationship management processes, and other organizational benefits. There are additional implications of staff proficiency, process integration, and process intelligence, as summarized in Figure 7.

Specific manager proficiency and employee skills are required to operate in the new competitive e-business environment. E-business managers are responsible for identifying the major factors involved in their business strategy, specifying the relationships between the factors, and generating long-term and short-term strategic e-business plans that will improve overall organizational performance. Similarly, employees should be provided with particular skills and proficiencies across different departments. For instance, customer service team is capable of assisting customers throughout their online purchase process in a timely and friendly manner to ensure customer satisfaction and retention. A technical support team is in charge of ensuring that the site runs properly and securely under all circumstances.

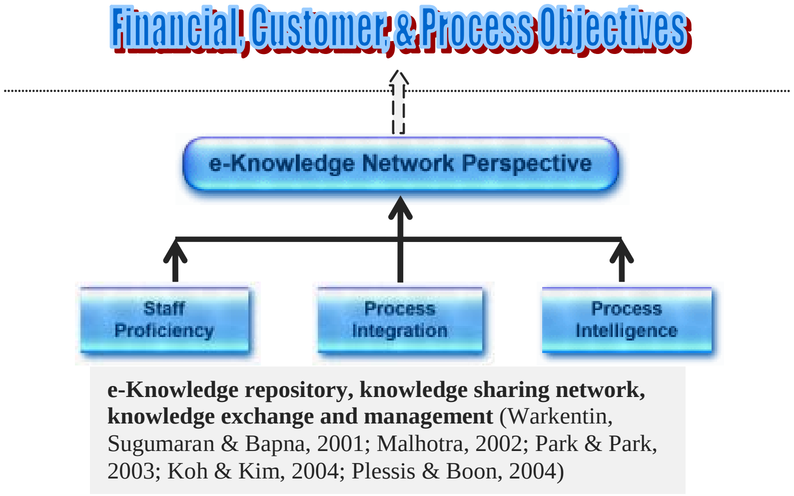
Figure 6. E-knowledge networks characteristics (Adapted from Warkentin et al. 2001)



The e-knowledge network offers a repository where new knowledge is created and collected, while existing knowledge, archived in data warehouses, is renewed and updated. Management and operational judgment, knowledge, and experiences are shared and managed to facilitate improved communication, coordination, decision making, and planning. Staff training can be utilized to improve employee skills and maintain currency with the technology shift.

Process integration enables a company to unify every aspect of its back-end infrastructure and increase responsiveness to inventory levels, customer demands, and delivery schedules by integrating disparate business processes, not only within an enterprise, but also across organizational boundaries. To achieve process integration in e-business, the communication infrastructure must be designed for a mission-critical environment,

Figure 7. E-knowledge network perspective of strategic e-business management



e-Knowledge repository, knowledge sharing network, knowledge exchange and management (Warkentin, Sugumaran & Bapna, 2001; Malhotra, 2002; Park & Park, 2003; Koh & Kim, 2004; Plessis & Boon, 2004)

scalable to increasing numbers of transactions and trading partners, and robust enough to integrate with the core business applications. E-knowledge innovation and management facilitates the integration process by creating e-knowledge networks that are characterized by automated exchange of rich knowledge by unattended computer systems, programmed to capture and evaluate knowledge with data mining algorithms, share it with strategic allies, and direct the operation of key interactive processes. Through e-knowledge networking, internal business data can be retrieved and shared across different departments and groups, and problem critical information and knowledge can be transmitted, integrated and processed from downstream to upstream as well as inbound to outbound.

The flattening of the organizational hierarchy also contributes to process integration, which leads to higher process efficiency, visibility and transparency. In contrast, traditional organization structures are hierarchical and functionally oriented (Chen & Ching, 2002). As a result, information is filtered and modified as it makes its way through different levels of management. Enabled by e-business capabilities, companies with a flattened organizational hierarchy have the built-in flexibility to move swiftly toward capturing new opportunities, react quickly to shifts in the environment, and respond promptly to the customers needs.

Process intelligence facilitates matches between the company's offering and target customers, competitors, and the current business by automating the decision and action processes and initiating real time analytics of sales and e-services as well as business notification and alerting (Park & Park, 2003). Such effort requires a wide range of process steps to be understood and represented, not only within an organization, but communicated to trading partners.

An e-knowledge network generates and stores immediate (real-time) knowledge about internal functions and processes, about customers and markets, about strategic partners, and about supply chain partners (suppliers, vendors, dealers, and distributors). Using the knowledge repository, the company can create new internal and external structures and relationships, which leads to further knowledge and continuous strategy improvements. Intelligent technology, which enables communication with trading partners across different platforms, can help represent, implement and track external business processes (contact agents of other companies, request information on merchandise/suppliers, and negotiate with them about purchase conditions) in a dynamic and flexible way (Park et al., 2003).

EBBSC SUMMARY AND ILLUSTRATION

Using the EBBSC components, we can develop the major measures and factors involved in the EBBSC framework. These measures and factors, which have been identified in each EBBSC perspective, are summarized in Table 5.

The major measures (Square) and the corresponding decision factors (Oval) and relationships (Arrow Lines) specified in the EBBSC framework are illustrated in Figure 8. This framework also forms the basis for specifying a precise and explicit functional model for strategic e-business management. At the conceptual level, it offers the e-business manager a big-picture perspective that is critical in generating effective e-business strategies. Aided by this framework, e-business companies can identify the major factors regarding the four e-business perspectives and specify the direct and indirect relationships among the various factors.

As an illustration, consider an e-business that seeks to acquire more customers in the next planning period. The manager first will locate the strategic measure of new customer acquisition in the framework and identify the relevant decision factors. As the EBBSC framework indicates, these factors include the customer profile, competition, the marketing mix, and e-service quality. Next, the manager can formulate a tentative strategy plan. In this case, the framework suggests that the company needs critical data and information regarding the prospective customer population and the competitors. Based on the collected information, management must decide on a specific marketing mix and e-service solution. Starting from the market mix or e-service quality components, the EBBSC framework suggests the steps to create the mix and quality plan. Having the priority of the strategic objective at each stage, the manager can plan and allocate the available budgets and resources more effectively to achieve these objectives.

DISCUSSION AND CONCLUSION

In this study, we have developed a balanced scorecard-based framework for strategic e-business management, which contributes to both theory and practice. From a theoretical standpoint, the balanced scorecard adaptation offers an innovative methodology to formulate and evaluate e-business strategy. The EBBSC framework also indicates that e-business strategy making will involve multiple decision criteria. Using this framework, the decision maker can establish an evaluation model for strategic e-business decision support. Figure 9, for example, shows such a multi-criteria e-business strategy evaluation model utilizing the strategic measures specified in the EBBSC framework. Based on the Analytic Hierarchy Process (AHP) concept (Forgionne, 1999), this EBBSC strategy evaluation model associates a hierarchy of evaluation measures relevant to the context of e-business strategy in an integrated fashion.

Using the hierarchy in Figure 9, the decision maker can make pairwise comparisons of decision criteria across the multiple dimensions. The AHP methodology then will convert the multiple measures into an overall scorecard value for each considered strategy. This AHP-based EBBSC evaluation model, then, will identify, in rank order, the most promising e-business strategies.

In practice, the EBBSC provides a means of identifying business opportunities and threats in both the internal and external environment, analyzing current business capabilities and resources to address the opportunities and threats, and generating effective e-business strategies that would improve the company's overall business

Table 5. Description of the measures & factors in the EBBSC framework

Factor (symbol)	Explanation	Factor (symbol)	Explanation
Profit (Profit)	The difference between the revenue and cost	Marketing-mix (M)	The company's effort on commercial processes involved in promoting/selling
Revenue (R)	Total income in a given period	Customer Acquisition (CA)	The number of new customers acquired in a given period
Cost (C)	The total expense (e.g. money, time, and labor) incurred in a given period	Customer Satisfaction (CS)	Measure of determination that a product meets a customer's expectations and needs
Price (P)	The amount of money needed to purchase the product	Customer Retention (CR)	Measure of customers revisit to the site and repeat purchases over a period of time
Purchases (PU)	The total quantity of product actually sold to customers	Customer Profitability (CP)	The ratio of the customer serving costs to the mix of customer purchase margin
Quantity Demanded (QD)	The total quantity customers are willing and able to purchase	Staff Proficiency (SP)	The efficiency of the company staff in providing the product and service
Quantity Supplied (QS)	The total quantity the company offers for a sale	E-service quality (EQ)	Measure of the company's e-service quality
Variable Cost (VC)	The portion of cost that varies in relation to the level of production activity	Process Integration (PIG)	The degree of the company's business process integration
Sales Cycle (SC)	The time between the point the product is listed and the point the product is sold	Process Intelligence (PIL)	The ability of the company's business process to respond to and improve its position in the business environment
Cycle Time (CT)	Time that elapses in conducting inbound operations, and outbound logistics	Knowledge Network Efficacy (KNE)	The company's investment in knowledge transmission, sharing, and innovation
Unit Cost (UC)	The cost per product	Capacity (CT)	The equipment, personnel, and technology capacity of the company
Fixed Cost (FC)	The portion of cost that is independent of the number of products produced/sold	Goodwill (G)	The company's accumulative prestige and perceived value in the market
Product (PD)	Measure of the product quality, positioning, and Internet branding etc.	Competition (CO)	Measure of the rivalry between the company and other businesses in the market
Presentation	The selection of product presentation and distribution formats	Channel Flexibility (CF)	The convenience and availability of distribution channels besides the Internet
Promotion (PM)	The company's expenditures on product promotion	Supply Chain Efficacy (SCE)	The effectiveness of the company in managing relationships with its suppliers
Profile (PF)	The target customers' average disposable income, needs or preferences index	Staff Qualification (SQ)	General rating of the company's staff skill level
Distribution Effort (DE)	The company's effort on distribution channel	Staff Training (ST)	The company's investment in staff training

performance and profitability. As illustrated in Figure 10, proper decision technology can deliver the EBBSC model, provide intelligent decision support to practitioners in overcoming analytical and technical barriers, and guide e-business managers towards an effective e-business strategy. The EBBSC also provides a stable point of reference for e-business companies to understand and manage e-business initiatives, enables e-business managers to plan and allocate resources (including tangible and intangible strategic assets) more effectively, and align strategic objectives with performance results.

As an innovative and exploratory framework for strategic e-business management, the EBBSC offers several opportunities for future endeavor.

Figure 8. An overview of the EBBSC framework

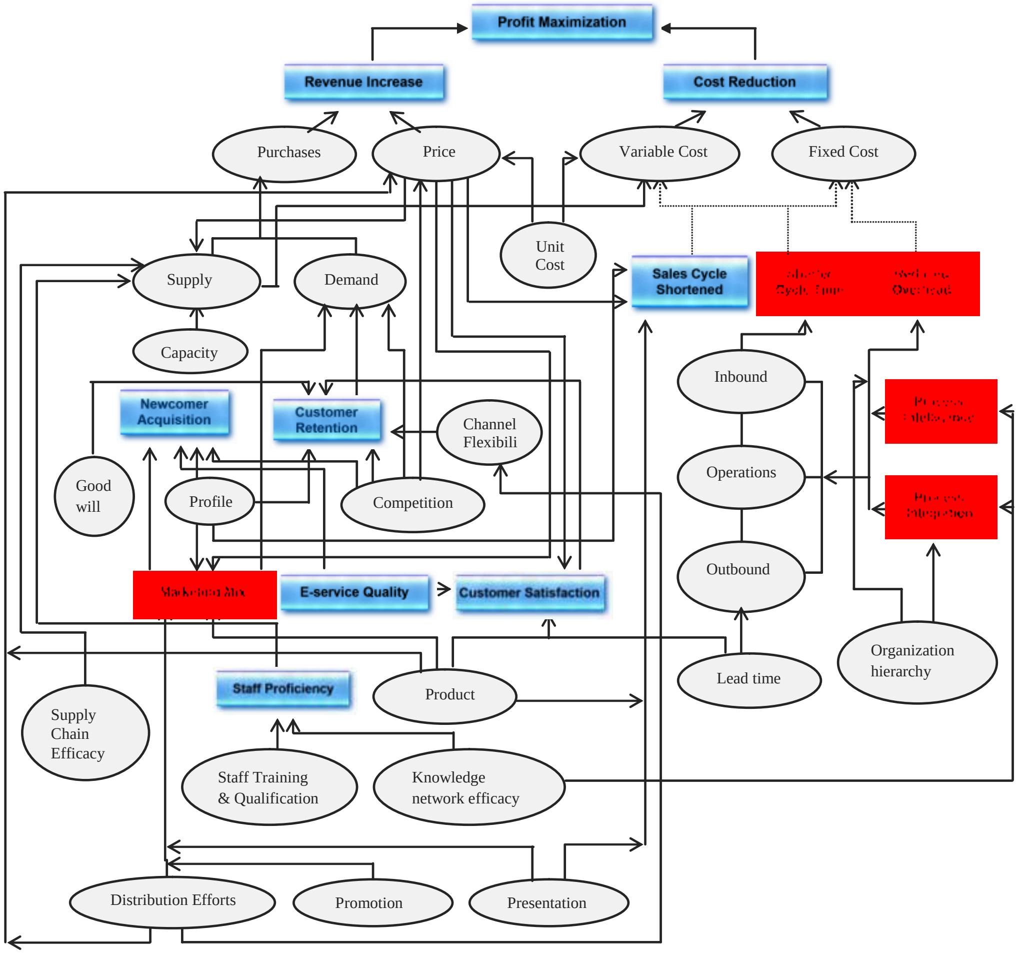


Figure 9. EBBSC strategy evaluation model

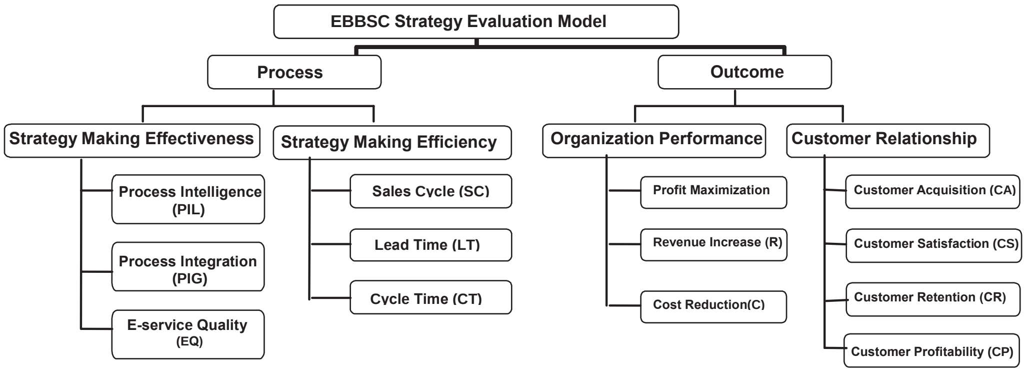
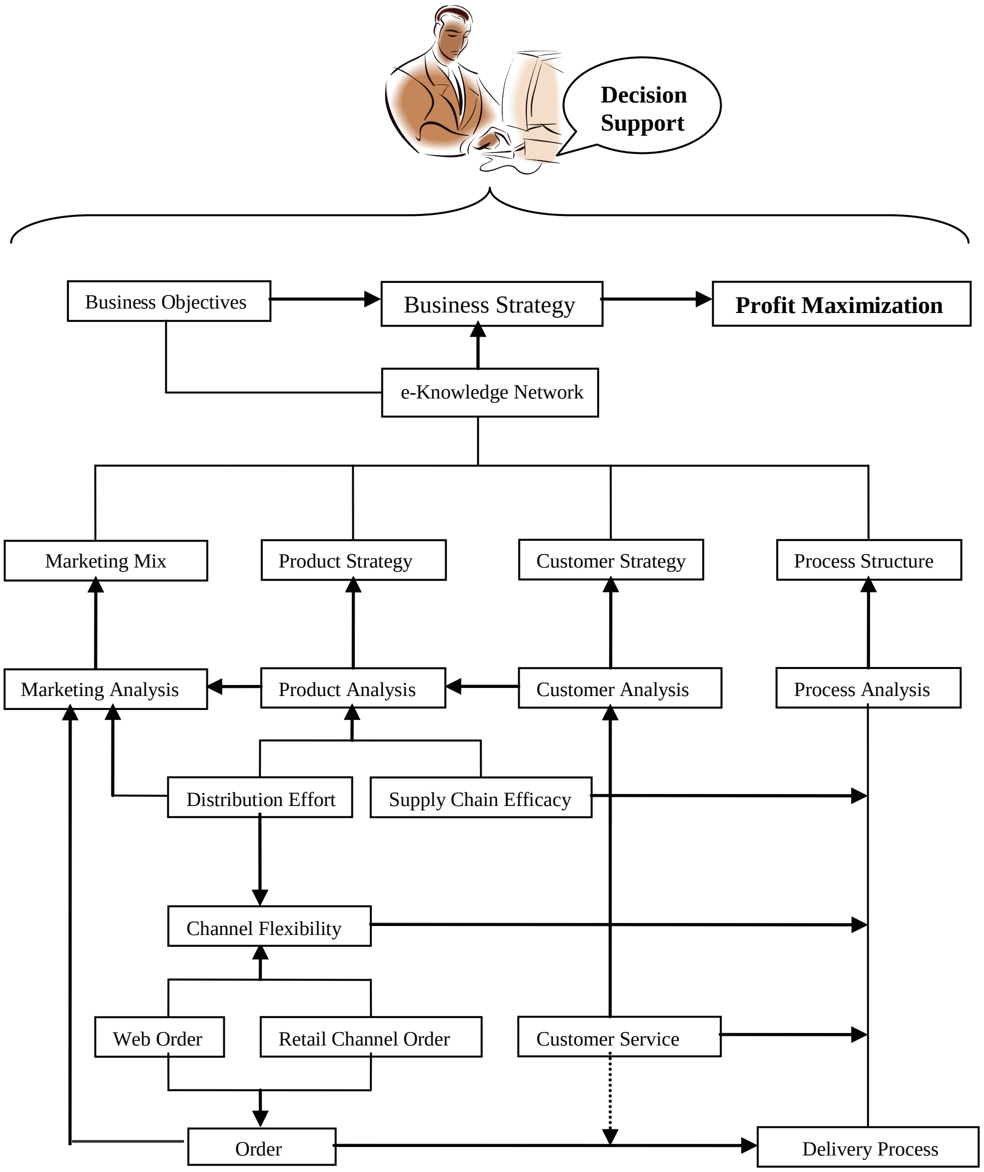


Figure 10. EBBSC mediated decision support architecture for e-business strategy



First, empirical research is needed to specify the measures, decision factors, and corresponding functional relationships in each e-business perspective. Another possible extension is to apply the EBBSC methodology to both profit driven and non-profit e-businesses.

To illustrate a potential non-profit application, consider an academic surgical organization. Under the business model perspective, instead of profit or revenue oriented indicators, specific measures would include management expenses, research grants, billings or collections, and days in receivables for outstanding invoices. Comparatively, the e-CRM perspective can be measured by patient satisfaction, number of outside referrals, invited lectures given or articles published in peer-reviewed journals. The process structure could include measures of operating room cases, consultations performed, clinic cancellations or length of stay. Finally, e-knowledge learning and growth could include measures of internal and external clinical program development or research development and faculty promotion. The specifications of the conceptual model will be determined by the specific application settings and the data sources selected to operationalize the model. Such empirical issues could possibly result in different versions of the operationalized model in practice, but the conceptual EBBSC framework remains feasible and applicable across different practice fields.

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Chapter 4.5

Strategic Management in City Government:
Integrating Information Communication Technologies and Marketing in a Causal Model to Drive Stakeholder Satisfaction and Economic Development

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ABSTRACT

Integrating information communication technologies (ICTs) and marketing in strategic management of city government is critical to achieving stakeholder satisfaction and economic development. As a result of the rapid growth in computer networks and access to online services, the use of ICTs, for example, Internet and Intranet, as a communication and marketing platform can provide a city with a global advantage. City marketing focuses on promoting the attributes of a location to prospective stakeholders so that these individuals, businesses, and investors are attracted to visit, locate, or invest in the city. A causal model is presented where ICT is used to not only to deliver services to internal stakeholders, but also to market a city to external stakeholders. To be successful, managers need to be skilled in current technologies and marketing practices. Case study applications are discussed as well as the questions to address in future research to most effectively integrate ICTs and marketing in city management.

INTRODUCTION

Organizations are increasingly faced with the global challenges of international competition and as a result, the adoption of information communication technologies (ICT**)** as a marketing competency has become a strategic imperative (Gummesson, 2002; Lapierre & Medeiros, 2006; Brady, Fellenz & Brookes, 2008). City governments are utilizing emerging technologies and especially, ICTs, as a major catalyst to market and communicate with stakeholders to ultimately attain strategic objectives such as growth and economic expansion. The purpose of this chapter is to provide a model for the use of marketing and ICTs in strategic planning to create a distinctive competency and address the challenges that result in achieving strategic performance objectives. The causal model developed in this chapter proposes that ICT initiatives and investment in the ICT infrastructure can be used to improve internal stakeholder services and satisfaction as well as with a marketing plan to promote the attractiveness of the city image to external stakeholders. Marketing and ICTs are presented as activities in a strategic map of causal linkages: by developing and recruiting employees with the skill sets required to effectively integrate ICT initiatives and marketing plans that develop customer relationships and improve service quality, a city's image to both internal and external stakeholders will be enhanced. Excellent internal processes and service levels can advance community outcomes such as health, safety and welfare as well as a city's overall reputation which ultimately impact the attainment of strategic goals such as economic development.

First, a review of the developments in performance management, balanced scorecards, and strategic management is discussed with an eye toward developing a generic causal model for city management that starts with developing the employee and the information capital of the organization which in turn improves internal processes, services and eventually, stakeholder satisfaction. The strategic group map (Kaplan & Norton, 1996) was chosen as a framework for the model because it challenges strategic planners to go beyond measuring lagging performance indicators such as economic development and growth to specify the drivers of economic development and growth. For example, if a city's image drives economic growth and marketing positively impacts a city's image, by measuring and investing in marketing initiatives, corresponding improvements in image and then economic growth will occur.

The role of ICTs in contemporary marketing practices (CMP) over the last decade is examined as an effective solution to meet the challenges brought about by a connected, global economy and expanded and empowered customer base. Given the importance of technology in developing a strategic marketing plan, a number of ICT applications are presented. Several case study applications are discussed to illustrate the application and benefits of ICTs to city marketing. Last, the future role of ICTs in city government is examined by posing the fundamental issues in the form of research questions to be answered that will illuminate how to effectively integrate specific ICT and marketing practices into strategic management of city governments. The management mindset that is required to be successful and competitive, both in determining the strategic direction and implementing the technological changes required by the new marketplace is addressed.

PERFORMANCE MANAGEMENT AND A CITY STRATEGIC GROUP MAP

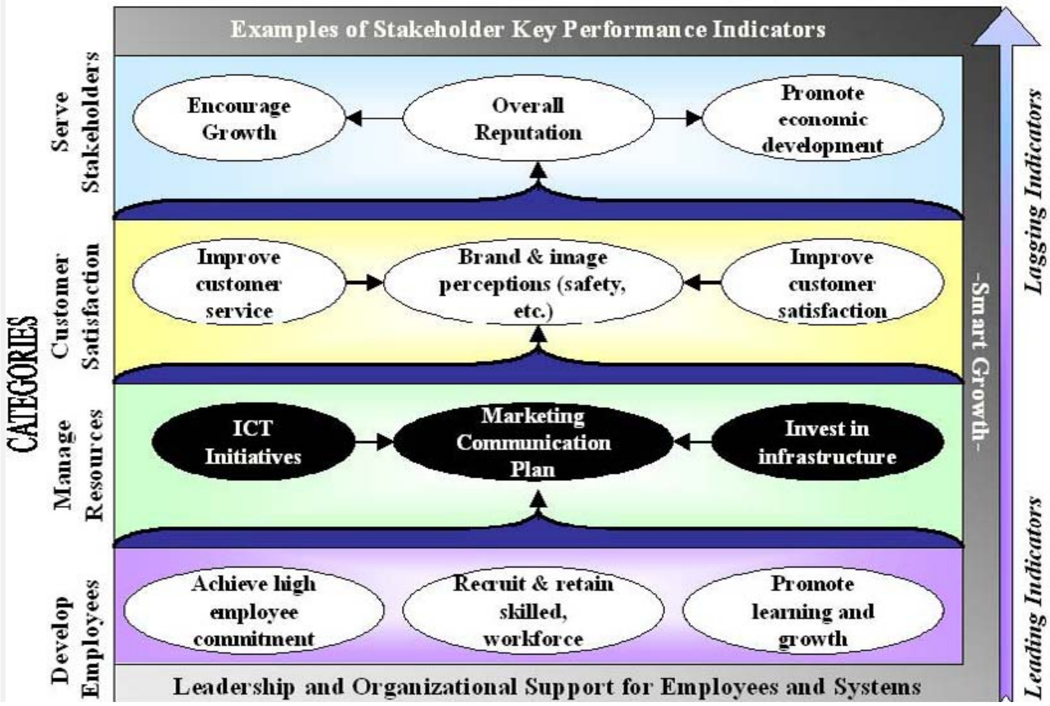
Over the last decade, developments in performance measurement have signaled the need for organizations to monitor performance dimensions that go beyond traditional financial measures to include measuring and improving those factors that ultimately impact financial performance such as stakeholder satisfaction.

In 1992, Kaplan and Norton introduced the balanced scorecard as an overall framework for establishing a performance measurement system that predicts financial results. They provided a framework for capturing metrics at the executive level based on four categories: (1) customer satisfaction, (2) financial performance, (3) internal processes and (4) employee innovation and growth. In brief, nonfinancial measures provided the balance needed to supplement financial measures and align employees with strategy. Although many of the balanced scorecard applications are in industry, the City of Charlotte, North Carolina applied the concepts to city management and developed a city scorecard (Syfert & Elliot, 1998 ; Eagle, 2004).

Kaplan and Norton (1996, p. 149) define strategy as "a set of hypotheses about cause and effect" and maintain that every measure should be identified in a chain of outcome measures and corresponding performance drivers of the outcome measures. They introduced the concept of strategy maps--there is a causal path among the four perspectives. Hence, the categories and measures within the categories are linked in a causal path of leading and lagging indicators. Essentially, improving employee innovation and growth (which includes technological and organizational capabilities) will result in continuous improvement of key internal processes. Improved internal processes that deliver value to the customer will lead to subsequent improvements in customer satisfaction, which in turn will result in improved financial performance. The value of using this approach is that managers are more likely to be successful in meeting/improving the performance of lagging indicators, such as economic growth, by identifying and verifying the factors that drive economic growth.

The four categories (and performance measures) in Kaplan and Norton's (1996; 2004) strategic group map are typically adapted or customized when applied to a particular organization. In Figure 1, an example of a strategy map

Figure 1. City strategic map



for city government is proposed that illustrates the central role that marketing and ICTs play as leading indicators to customer and stakeholder satisfaction. The model reads from the bottom up--the leading indicators at the base drive the next level of indicators until the uppermost level of stakeholder outcomes is reached. First, employee development is essential to drive effective resource management. Next, investment in ICT initiatives and infrastructure as part of a marketing communications plan helps manage resources efficiently as well as market a city. Using ICT as a marketing tool can improve branding/image perceptions, customer service and customer satisfaction. Enhancing a city's identity or image, services and customer satisfaction will ultimately impact key performance indicators such as overall reputation, economic development and growth. In the following sections, the major categories and factors within each category are discussed with an emphasis on the central role that ICT and marketing play in eventually producing positive stakeholder outcomes.

DEVELOP EMPLOYEES

The catalyst for successful resource management is a committed and skilled workforce which is supported by the organization's culture and leadership to continue to learn and grow (Matherly, 2007). Figure 1 is an example of a strategic group map for city management. The category at the bottom of the model includes three areas to address in order to develop employees; an institution needs to achieve a high level of employee commitment, recruit and retain a skilled workforce, and promote learning and growth of employees. Both Baldrige (2008) and Kaplan and Norton (1992) recognize the essential role that the people, i.e., employees and managers, play in driving process improvements and performance excellence. In a study of ICT deployment in marketing applications, Brady, Fellenz and Brookes (2008) conclude that there is a "need to study and expand the skill set of marketers into technological, managerial, and organizational areas to more fully enable the use of ICT within contemporary marketing practice" (p. 108). Not only do employees need the skills to work effectively within an organization's existing technology infrastructure, they also must be familiar with new technologies to expand ICT initiatives to create competitive advantage. Only by training and developing existing employees or recruiting and hiring employees/contractors with the required ICT skill set can a city effectively implement new applications and forms of ICT.

With the rapid changes in and complexity of ICTs, there is a corresponding increase in the information processing and analytical requirements of managers creating a challenge in integrating technology changes into strategic planning and marketing (Fisher, Raman & McClelland, 2000; Holland & Naude, 2004). Executives must choose technologies that are integrated with the needs of the organization *and* customers and manage any resistance and barriers to implementation (Leverick, Littler, Bruce & Wilson, 1998; McAfee, 2006). Without a sufficient skill set in technology, planners will be unable to take advantage of emerging opportunities and maximize the value of ICTs (Brady, 2003). The practical reality is that managers are being asked to understand, develop and implement ICT applications that efficiently and effectively market their services to stakeholders—the customer interface—as well as integrate the programs across operations. For example, an organization's ability to assimilate, store and retrieve new information and apply this learning affects successful customer relationship management (CRM). CRM systems capture and integrate customer data from across the city, consolidating the data, analyzing the data, and then distributing the results to various systems and stakeholders across the organization. Effective organizations are those that invest in both the technology infrastructure and organizational learning to support the building of their marketing intelligence (Chen & Ching, 2004). A learning organization that fosters employee commitment and growth, for example, by investing in training and development, will result in more effective and efficient resource management.

MANAGE RESOURCES

Employees who are committed to achieving a city's performance objectives and skilled in technology applications and marketing can drive the development of the appropriate technology infrastructure that can effectively market a city to stakeholders. In Figure 1, the ability of a city to manage resources effectively and positively impact customer satisfaction is determined by how effectively ICT initiatives are deployed which requires an investment in the ICT infrastructure. Further, the ICT infrastructure needs to be integrated into the marketing plan both to deliver services to internal stakeholders and to market the city to external stakeholders. ICTs provide greater access to information, dramatically increase the speed of transmitting information and allow for wide-spread broadcast and use of information. By providing services through an ICT interface, improvements in service, quality, accuracy and operations will result in a subsequent increase in customer satisfaction.

Marketing, through the effective use of ICTs, can improve a city's image, attract new businesses or help retain and expand existing businesses, as well as accentuate a city's attributes such as its workforce, talent pool and services offered. Similarly, an effective ICT marketing program can counteract negative images through the positive interaction of city employees with citizens and visitors. ICTs can enhance communication and improve relationships between the city and its citizens and help secure community support for changes in service delivery. For example, ICTs can be used to increase citizen participation in local government and through collaborative problem solving and communication help reverse an economic decline of an abandoned downtown area. Moreover, the potential for ICTs to alleviate poverty and promote economic growth in developing countries justifies greater attention and systematic analysis (Eggleston, Jensen & Zeckhauser, 2002).

Expand ICT Initiatives and Invest in the Technology Infrastructure

Expanding ICT initiatives and investing in the organization's technology infrastructure are essential to success and a growing assortment of technology tools are available for cities to employ. Technological devises and software are primarily related to obtaining and sending information at unprecedented speeds. Wireless networking affords a city with greater mobility and in many cases affords smaller cities the ability to maintain the same presence and competitive advantage that many larger cities have on the internet. The business community argues that wireless internet access is good for economic development and a handy tool for business travelers (Swope, 2007). Mobile devices and software allow remote connection to desktops and office networks for access to information. Electronic transfer of information is not only more efficient and timely but it can improve accuracy.

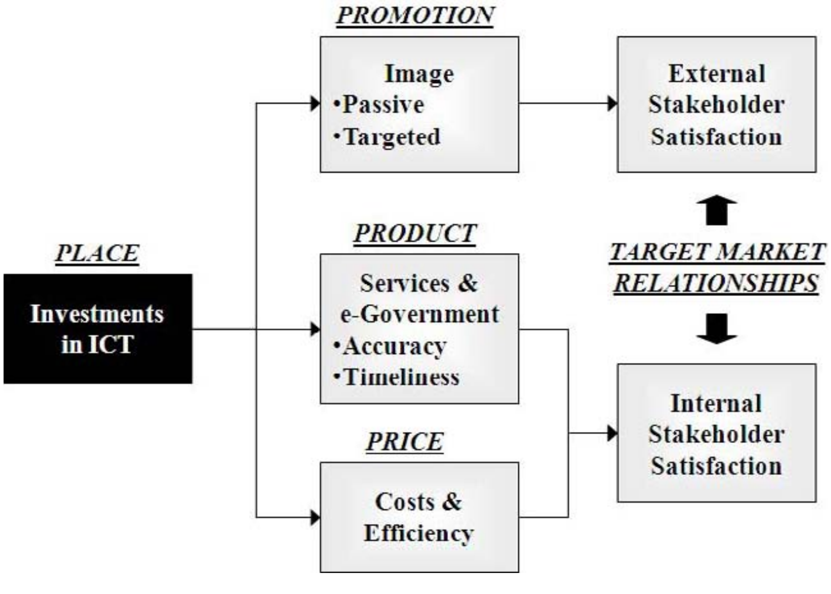
Develop and Implement City Marketing Plan

Marketing is recognized as a body of professional skills and techniques for bringing the producers of products and services together with people that need or can use them. A review of strategic group maps in peer reviewed journals as well as those reported in the public domain reveals that although hundreds of organizations have developed strategic group maps, a key factor absent in these applications is marketing as a leading indicator and driving force in developing community perceptions of the organization's image which ultimately impacts lagging indicators such as economic growth and financial performance. More and more, marketing principles are being applied to city management and city websites deliver brand information that can create value, a positive image, recognition and recall that attracts external stakeholder groups. The qualities which make a city unique create an identity or image that can be used to market a location (Erickson & Roberts, 1997). Based on a communication-based marketing model, Duncan and Moriarty (1998) point out the importance of managing consistent messages across all stakeholder groups so that communications are managed strategically to build brands and external relationships. Tschirhart (2008) demonstrates that while many city government websites deliver brand information, there are substantial inconsistencies in whether cities follow this recommended branding practice.

Marketing can play a central role in establishing a particular city as an attractive location and ICT is an effective and efficient method for communicating and facilitating a host of marketing activities. In Figure 2, the four P's (product, price, place and promotion) are integrated in a marketing and ICT model that emphasizes the importance of target market relationships. ICT is place, i.e., ICT is the mechanism/channel used to promote a favorable city image; conduct services (product); and improve operations and efficiency (price). Both internal and external stakeholders can be targeted by marketing communications efforts of cities. These stakeholders include the citizens, city council and mayor, city manager, department heads, employees, bonding agencies, investors, economic development prospects, visitors, shoppers, tourists and current businesses. Moreover, ICT can be designed to be interactive, e.g., by conducting services and communications online.

Having an excellent offering or product does not ensure that prospective buyers will know about it. ICTs are fast becoming the main medium for proactive, targeted marketing – they

Figure 2. Integrated marketing and ICT communication strategy



can be customized, personalized, shared, two-way, interactive and cost-effective. In Figure 2, targeted marketing can be used to improve the image of a city with external stakeholders. ICTs can facilitate marketing and the exchange of mutually beneficial information between a city and its stakeholders. The use of ICTs provides a viable resource to cities, facilitates competitive advantage and opens opportunities for future success. CRM systems can be used to organize, store and retrieve relevant information required for tailored, multi-channel marketing. Pinpoint marketing – getting the right message to the right people at the right time – and data mining capabilities are enhancing marketing efforts for seasonal activities so that previous users are solicited when similar activities are planned. Online community networks are natural marketing channels. Marketing packages can be quickly produced to prepare professional presentations that are available with user friendly software programs to effectively communicate a city's financial condition, for example, to bond rating agencies. Ease of access to financial information helps these agencies determine bond ratings that can lead to substantial monetary savings as investors evaluate the risk involved in purchasing city bond offerings.

Integrating ICTs with the Marketing Plan

Over the last decade, new directions for marketing and management have been identified in response to changes in factors that influence organizational success. Numerous researchers are calling for a multidisciplinary framework that integrates managing ICTs uses, forms and infrastructure with contemporary marketing practices (e.g., Achrol & Kotler, 1999; Coviello, Miller & Marcolin, 2001; Gommans, Krishnan & Scheffold, 2001; Brady, Saren & Tzokas, 2002; Brady, 2003; Brookes, Brodie, Coviello & Palmer, 2004; Chen & Ching, 2004; Barwise & Farley, 2005; Brodie, Coviello & Winklhofer, 2008). Gummesson (2002) defines the new economy as a network society that focuses on services, emerging customer roles, information technology, globalization and alliances between countries and these forces have ushered in a shift from the traditional marketing paradigm (the four P's-product, price, place and promotion) to relationship marketing and interactive marketing (Webster, 1996; Deighton, 1996; Webster, 1998; Day & Montgomery, 1999; Webster, 2005). Relationship marketing is a necessary perspective requiring a new mindset to address the networks and interactions that are embedded in organizations, markets and society. The network organization includes all stakeholders that interact with the organization—both intra and internet interactions. Similarly, in a survey of marketing research professionals, Struse (2000) identified the top influences of the 21st century as the internet, globalization of business, culture and research and one-to-one (relationship) segmented marketing. Increasingly, technological expertise and investment will be required as part of strategic planning and marketing.

Generally, ICTs can be used as a marketing communication tool to promote a city's image in either a passive or targeted mode (see Figure 2). In the passive form, they can provide: citizen access to information, government functions and services; locations and directions to parks and community centers; calendars of city-sponsored events and activities; access to property information and citizen services; job postings; phone and staff directories; meeting notices; statistics about the city; and tourist information. Stakeholders recognize that the Web is a good place to conduct a site search (Bastain, 2007). Having information readily available and accessible can provide a competitive advantage as a city can showcase strengths and opportunities to potential stakeholders. For example, having accurate, referenced data allows businesses and cities to conduct systematic and realistic evaluations of prospective locations. Increased levels of information access enable a city to differentiate incentive packages to increase competitiveness and improve success rates in attracting new residents and businesses. Stakeholders can conduct research using community and regional websites as primary information sources and avoid the high costs of external consultants (Bastain, 2007).

E-government is the application of the Internet and related technologies to digitally enable government and public sector agencies' relationships with citizens, businesses, and other arms of government. In addition to improving the delivery of government services, e-government can make government operations more efficient and also empower citizens by giving them easier access to information and the ability to network electronically with other citizens. Governments use internet technology across many operations, agencies and levels to deliver information and services to citizens, employees, and businesses with which they work (Laudon & Laudon, 2006). The Organization for Economic Co-operation and Development (OECD) recognizes e-government as a major enabler of good government practices (OECD, 2003). The OECD's charter is to promote policies designed to achieve high economic growth and expansion for over 30 member countries and recognizes that e-government helps improve efficiency and services as well as achieve policy outcomes and economic objectives. To illustrate, ICTs can be transactional providing for: license renewal and payment; remittance of parking citations and court fines; registration for programs and other functions; interactive job applications; online permits, business licenses, court documents; sales tax collection; distance learning; web casting of city/county meetings; communications with local leaders; and links to other key sites (airport, transportation, hotels). ICT and access to digital democracy can enhance the community's democratic participation in public affairs; for example, with e-voting and e-ballots, and citizens can express and exchange views with elected representatives (Bozinis, 2007).

ICTs can be used to facilitate compliance with governmental regulations. For example, in some countries, citizens are entitled to information about the affairs of government and the official acts of public officials and employees. Interactive technology expedites the delivery of information, and provides a conduit for continuous feedback that can significantly impact responsiveness to stakeholders. Timeliness of information and availability allows cities to respond quickly to community needs. However, this requires the monitoring and coordination of numerous communications from multiple media.

In summary, ICTs can be used to communicate service information to internal stakeholders, improve operations and efficiency and promote city programs that advance community well being, e.g., health, safety and welfare. The success of e-government in the provision and delivery of public goods and services as well as marketing communications is well documented (e.g., Mellor, 2006; Kim, 2007; Halaris, Magoutas, Papadomichelaki & Mentzas, 2007). In order to implement ICT changes effectively and efficiently, Gummesson (2002) stresses the importance of focusing on internal networks and interactions. ICTs allow for employee interaction and shared information that can improve communications, operations and efficiency. On a global level and especially where stakeholders are geographically dispersed, applications such as video communication technology are more cost efficient and timely than face-to-face interactions. Moreover, interactive technology provides a mechanism for supplying information and interfacing with stakeholders on a personal basis such as after hour's contact which is especially effective at facilitating transactions and dealings across international time zones. ICTs expedite the communication and exchange of information which can facilitate consensus building and support for decisions and plans, for example, to invest or locate in a given community (West & Berman, 2001).

CUSTOMER SATISFACTION

The reputation of an organization, defined as the set of attitudes and beliefs that an individual or market holds about an institution, can provide a competitive advantage that enhances an institution's long-term ability to create value (Goldman, Gates & Brewer, 2001; Suh & Amine, 2007). In Figure 1, customer satisfaction results from how well resources are managed, i.e., integrating ICTs and marketing applications will (1) improve operations and efficiency, (2) promote the city image, brand identity and relationships, and (3) improve service and quality. Since ICTs can provide immediate access to a wealth of information and allow for a tailored response to inquiries, cities can improve services and lower costs, cultivate direct relationships and further facilitate customized communication. To promote image and brand identity in order to remain competitive in a rapidly changing global environment, city managers can use ICT to communicate, market and interface with stakeholder groups. City managers and elected officials typically set specific objectives to focus their marketing, financial and operational efforts. These activities include: establishing the image a community seeks to portray; target marketing to national and international investors; providing data for global economic development opportunities; promoting city activities; and enhancing city services.

Research in marketing points to the pivotal role that image marketing targeted to identified market segments has in impacting economic development and growth (Suh & Amine, 2007). An organization's reputation is an important intangible resource, can provide a competitive advantage and is particularly important in global markets (Gardberg & Fombrun, 2002). How stakeholders develop their image of an organization is based on the information they receive (Schuler, 2004) and an effective and efficient vehicle for communicating and facilitating image marketing is the use of ICTs.

Two-way marketing and communications techniques in local government can establish stronger links between citizens and government, build community, and improve the local business climate, while boosting a municipality's image and civic pride (Kellogg & Lillquist, 1999). This can also provide cities with a competitive advantage and opportunities for an increased rate of return on marketing investments. Cities that capture and analyze the demographics of their communities can use the information to market to potential retail and economic development stakeholders, i.e., targeted promotions. For example, education, occupation and income are all measures of purchasing power, but they also reflect other attributes that are vital to economic development, such as the labor pool and intellectual capital. Since it is important to recognize that all businesses are not equally interested in all segments or demographic information, cities should design strategies that will best serve their different target markets. Providing regular demographic updates that are available to requestors in a downloadable format gives a city the opportunity to provide data, analysis and reports to prospective investors.

Providing easy access to municipal government information that can be used, for example, to estimate traffic flow and demand, can enhance the bottom line for private business. Sharing and showcasing the creative tools and innovations local governments are using results in more effective communication with citizens, businesses, visitors and other audiences. To illustrate, Geographic Information Systems (GIS) are tools for storing, retrieving and manipulating data to solve complex problems, e.g., operations such as the school districts can display a map with features associated with data. By selecting a given school, test scores, student demographics and financial expenditures are available. Similarly, police departments can profile crime statistics and characteristics by geographic areas which can help lower crime rates. Hence, using GIS results in more efficient and effective responses to community needs (Nedovic-Budic & Godschalk, 1996; Brown & Brudney, 1998).

The accumulation and circulation of community information in electronic databases can have a broad impact on city marketing and brand identity. By compiling a city's consumer characteristics, potential customers or prospects can be selectively targeted with promotional material through various media. This information is valuable to marketers and retail decision makers. Optimal selection of locations for stores and showrooms or franchises, regional shopping malls, etc., is facilitated through the use of this information. Target marketing to potential stakeholders offers an opportunity for city growth and economic development.

Websites with up-to-date and salient information will attract more traffic from location consultants and companies seeking site locations. Additionally, cities can target the distribution of information to increase marketing effectiveness and reduce media planning expense by resource allocation in areas that provide the greatest rates of return. Cities can focus their marketing efforts to the economic development segments they are interested in developing, e.g., industry, investors, etc. Software is available to track information requests and management can use this tracking technology to further enhance their web-based information offerings.

Some of the additional benefits of e-government are that it: is always open (i.e., 24-hour city hall); expedites transactions; reduces costs; improves citizen and business satisfaction; improves security application and accessibility; allows language options; and facilitates greater citizen participation (Shark, 2007). Also, the advantages of ICTs include timely compilation and dissemination of information and increased efficiency, e.g., lower transaction costs. ICTs facilitate participatory democracy/public decision making and enable wide, efficient and transparent participation between citizens and organizations to arrive at better and faster decisions through negotiation (Benyoucef & Verrons, 2008; Kim 2008). Such proactive problem solving helps cities to compete in an increasingly changing and global environment.

Presently, city administrators and leaders are leveraging resources and forming partnerships to expand and improve services, communications and infrastructures. They are striving to make their communities more attractive places to live, work or vacation – places where people want to raise children and perhaps retire (Kellogg & Lillquist, 1999). Cities must perform cost/benefit analyses to offer incentives that will contribute to the long-term success of the community. Successful implementation of ICTs can result in the acquisition and delivery of community information as well as individual consumer information. This information can then facilitate the design of new effective marketing strategies. Investing in ICT initiatives that result in better efficiency and cost savings ensures a city's ability to remain competitive. To illustrate, with rising fuel costs, there are significant cost savings in making data accessible and coordinating interactions such as telecommunications and video conferencing that do not require stakeholders to travel and be available on site.

Cities employing ICTs can create a competitive advantage when they are able to integrate information regarding factors such as building permits issued, market characteristics, constituent data and infrastructure condition, within a jurisdiction. Tracking building permits issued provides a competitive advantage for cities as they are an indicator of the economic vitality of a city, reflecting the amount of private investment being made in the local community. This is advantageous to a city given that bond agencies desire non-governmental investment in the local community. Examining trends in long-term growth helps prospective businesses/investors determine the likelihood that their investments will be profitable.

By improving operations, service and quality, community (internal customers) satisfaction will increase. In addition, by integrating ICT and marketing initiatives to proactively promote the city's image and build customer relations, improvements in external stakeholders will result. Cities that can more effectively promote the qualities of their locale to prospective stakeholders seeking information for tourism, relocation, economic development, etc., have a competitive advantage over other cities in attracting visitors, residents, and investors.

STAKEHOLDER OUTCOMES

In Figure 1, the final, top category is stakeholder outcomes and includes lagging performance indicators that are a result of improvements in customer satisfaction. In brief, if a city promotes its image and brand identity, builds relationships with customers and has high levels of customer service, its overall reputation will be enhanced which will also encourage economic growth and development as well as advance community outcomes such as health, safety and welfare.

The role of economic development is to increase the per capita income of a city's residents. For example, community information about activities, attractions and events can be communicated through ICTs resulting in increased tourism which brings in financial resources vital to community prosperity. Local government communications can encourage citizen responsibility, create citizen ownership and support and empower people to solve problems on their own, without having to rely solely on government (Kellogg & Lillquist, 1999).

More and more, stakeholders are sophisticated participants requiring substantial flows of information from a more organized but complex market; therefore, ICTs are essential for attracting and retaining business activity in an intensely competitive market (Perryman, 2006). The ultimate goal is for cities to meet their stakeholder needs, to provide information to prospects and to improve overall productivity. Cities seek to respond to an increasing demand from users for access to information that does not require the use of intermediaries. ICTs allow for service and resource comparisons with other jurisdictions which are increasingly sought after by prospective investors and economic developers on a regional, national and global basis. User-friendly interactive software can eliminate the need for users to have extensive technical knowledge in order to access information.

Further, cities can partner in a collaborative environment with other stakeholders to support common goals of economic growth and development and enhance global competitiveness. By leveraging critical expertise and financial resources, the community benefits. ICTs can facilitate the development of complementary interests between cities and private corporations to support city marketing. Government agencies may realize the commercial value of the data that is gathered for the purpose of public administration and offer that data to provide economic development opportunities in their communities. ICTs are changing the speed and efficiency of many industries, including cities. ICTs enable cities to personalize marketing media to individual organizations seeking to invest/relocate to a city.

Investing in the technology infrastructure can improve a city's services and operations and, therefore, enable it to effectively meet important stakeholder outcomes such as advancing health, safety and welfare. To illustrate, in the police and emergency areas, systems that monitor key performance indicators can significantly improve services such as response time. Computer assisted dispatch and mobile data terminals combined with global positioning systems enable reduced response times by providing the geographic information and route in the field. Similarly, field reporting systems that allow officers to generate reports on offenses and incidents real time improve description accuracy and efficiency.

The strategy map example developed in Figure 1 is a strategic tool that provides an illustration of how city planners can drive improvements in key performance indicators. Developing a strategic group map is part of strategic management and should reflect a city's mission, vision and values and be based on an analysis of the internal and external environment (strengths, weaknesses, opportunities and threats) as well as key success factors for a given city (Matherly, El-Saidi & Martin, 2008) . For instance, the vision articulates the image a city seeks to attain in the future and a community survey could determine what the overall image/reputation of the city is with key stakeholders. Collecting and analyzing data on each of the performance indicators in each category will reveal whether the causal paths are correct. For example, the implementation of specific ICT applications and marketing initiatives should result in improved operations. Improvements in operations, such as timelier turnaround for service and accuracy in transactions, are predicted to result in a better reputation and image for a city with internal stakeholders. Similarly, investments in customer relationship management and external marketing should result in improvements in external stakeholder reputation and therefore, more targeted economic development.

CASE STUDY APPLICATIONS

There are numerous examples of successful applications of ICTs in city management and marketing. In Killeen, Texas, U.S.A., a city of 110,000+ in central Texas, over 89% of the population uses ICTs. Citizens perform a myriad of activities on the city's website such as:

- obtain permits and licenses
- view council meetings or review past minutes
- check city documents and/or regulations
- obtain police accident reports
- verify book availability at the library
- view pets available for adoption
- look up and pay their utility bills
- obtain demographic information
- check airline flight schedule/status
- check for upcoming events
- register for park and recreation events
- obtain records requests

Using CRM, the city can track and evaluate the effectiveness of solicitation campaigns. By integrating ICT and marketing applications, the CRM system provides more effective outreach, tourism, and recruiting campaigns, resulting in targeted economic development. GIS capabilities allow citizens to determine the location of utilities, schools, churches, etc. Other forms of ICT include a government television channel, automated telephone systems, email and mass email services, text messaging and internet streaming. Websites bring a host of information to the citizens, promote city activities, enhance citizen involvement, aid in the adoption of pets using online files and result in greater citizen participation in city programs.

Thousands of internal and external users access web-based services daily affording the city new opportunities to market itself. This marketing outreach would not have been possible before the advent of ICTs. GIS fosters collaboration among service providers. Any street address can be displayed in GIS including work orders, building permits, code enforcement cases, occupational licenses and garage sales. New development websites target developers, homebuilders and prospective property buyers. These websites become portals of information for prospects and display sites for development review files including, for example, subdivision master plans, plats and commercial site plans. They give the city a competitive advantage by saving customers a trip to city hall.

The city of Charlotte, North Carolina uses the balanced scorecard and strategic group maps to facilitate communication and strategic planning as well as drive improvements in key performance indicators (Kaplan, 1999). One of the objectives on the city's corporate balanced scorecard is to promote growth in targeted types of business. By using GIS, the police department was able to improve services and reduce the crime rate, i.e., advance the health, safety and welfare of the community and encourage economic growth. The ICT application facilitated the mobilization of municipal resources to address specific local problems and to track the condition of neighborhoods. Ultimately, the police department was able to determine the reasons for higher incidents of crime in targeted areas. Computer aided dispatching (CAD) and the use of lap-top computers enabled police to query information while traveling to their destination or before questioning the driver of a car stopped for a traffic violation.

The National League of Cities (NLC) of the United States (2007) cites several examples of stakeholder benefits from ICTs in its highlighted city practices. Albany, New York has an interactive map of the downtown area on its web site with links that provide more information about Albany such as investment opportunities, living in Albany, current news about Albany as well as links to City of Albany resources, economic development, government, media, professional affiliations and travel and tourism. The Downtown Albany Business Relocation & Development Package provides comprehensive information for stakeholders who want to invest in the future downtown area. Topics include: Empire Zone Benefits, Tech Valley Investments, Quality of Life, Parking/Transportation, Market Data, Financing Programs, Headlines/Testimonials, Entertainment District, Downtown Living, and Downtown Development. Clay County, Kansas, seven cities, and a water conservation district collaborated to create a suite of web sites with a shared events database. The web sites provide expanded opportunities for marketing and economic growth. Rock Hill Rocks is a sports marketing campaign to showcase the city of Rock Hill, South Carolina, to promote its world-class venues and to attract visitors from across the country. The campaign includes a sports web site and sports marketing brochure. Adel, Georgia invested in the technology infrastructure to provide high-speed wireless Internet services to its citizens. The city used the existence of the service, as well as its reputation for having a high level of service, as a marketing tool to attract new businesses and encourage economic growth.

Additionally, Fort Wayne, Indiana implemented lean manufacturing and six sigma (quality improvement) by bringing business applications and philosophies to city management (George, 2003). Claiming that providing excellent services to its citizens is part of "e-City," the city launched a total of 60 projects over a 3 year period that saved almost $3 million. Fort Wayne's free wireless network covers 85 percent of its citizens, including 87 schools, 2000 teachers, 54,000 students, and all libraries and airports. The broadband network facilitates online learning for teacher training and makes it easier for parents and teachers to communicate. Innovative programs undertaken include virtual diabetes diagnosis with retinal scans and the "Net Literacy" program, in which young people teach seniors about computers.

The NLC in 2008 provides additional examples of creative ICT and marketing applications that resulted in improvement in strategic performance indicators such as economic growth--examples from Colorado, Texas and California are discussed in the following paragraphs. Englewood, Colorado's Citywide Computer Coaching Network is a cost-effective approach for developing employees and meeting the internal training needs of city employees. Computer training is delivered by peer-trainers through traditional classroom instruction, brown bag sessions, and one-on-one coaching. Coaches are not technology professionals, but city employees who volunteer their time to teach the practical skills they use on an everyday basis. By leveraging the knowledge and skills of internal resources, the City is able to deliver effective training at a fraction of the cost typically associated with technical training. This unique approach to internal training has dramatically reduced the costs associated with technical training because expenses are limited only to the costs of copying handouts and materials.

In response to a low unemployment rate and surplus of new jobs and companies, Austin, Texas shifted the focus of its economic development strategy from attracting new businesses (a lagging indicator) to recruiting and training workers (a leading indicator). AustinAtWork.com is an online recruitment tool which gives a job applicant Web access to search for jobs and submit a confidential skills profile. Job postings and profiles are matched based on pertinent criteria, and both employer and job seeker are notified. The software also allows employers to conduct on-line interviews and skill testing with job candidates. In its first year, over 1,000 jobs were posted and over 20,000 candidates (15 percent from outside the area) visited AustinAtWork.com.

Sunnyvale, California's Patent and Depository Library, which had been in operation since 1963, was outmoded and expensive to operate. To maintain and update the service, the city partnered with the U.S. Patent and Trademark Office to create the Sunnyvale Center for Innovation, Invention and Ideas (SCI3). The Center (1) assists entrepreneurs and start-up businesses to use new technologies and (2) helps established firms maintain their competitiveness through better access to technological information which increased the number of technological jobs in the region (economic growth). SCI3 uses new technology to provide timely, accurate, and cost-effective patent, trademark and intellectual property information. It also offers direct on-line image access to the patent database, and has video conference capabilities.

Littleton, Colorado's New Economy Project uses the idea of "economic gardening," or growing jobs locally by creating a nurturing environment for entrepreneurs. The program provides sophisticated information services as well as tracking of best ideas, best practices, and best technology of select high growth companies. Some examples of services are tracking construction bids for architects, developing profiles for multimedia companies on their competitors, and finding investors for foreign companies. In addition, the city subscribes to GIS and database research services, keeping track of statistics on local businesses, running focus groups, and monitoring legislation, new product releases and trends in order to share marketing and other information with businesses. The project also seeks to increase networks and connections between industry, research facilities, universities, competitors, suppliers, and customers. As part of the New Economy Project, the city sponsors the "econ-dev" Internet mail list of 300 economic developers worldwide interested in economic gardening. The investments in the technology infrastructure significantly led to more growth in the region.

The Glasgow City Marketing Bureau has been using leading-edge technology to promote Glasgow nationally and internationally. The prestigious Institute of Electrical and Electronic Engineers (IEEE) International Conference on Communications was broadcast live on Glasgow's Convention Bureau Website and viewed by more than 400 technology enthusiasts from around the world. The number of monthly page views on www.seeglasgow.com has grown from 800,000 to 1.8 million in 2007 (Glasgow, 2007).

The OECD (2003) provides numerous examples of international case study applications. Germany has implemented e-government, and in order to facilitate the smooth flow of information between citizens, business and the federal government has developed uniform, government wide standards, procedures and architecture for e-government applications. Given the complexity and coordination challenges across agencies, they recognized the importance of using standard procedures for a multitude of electronic services. Italy provides e-literacy training aimed at providing managers with the skills necessary to meet the organizational needs relating to e-government and innovation plans. IT literacy and technical skills are necessary to implement e-government, which results in better government. Delays in implementing new technologies will penalize economic development in a competitive, global and rapidly changing market.

These case study applications represent only a small portion of successful implementations of ICT and marketing initiatives but depict the importance and potential of marrying technology with marketing to improve internal processes, promote a more favorable image and meet stakeholder expectations. The effectiveness of specific ICT and marketing initiatives may vary depending on the municipality. So as to achieve improvements in lagging strategic performance indicators, each city should hypothesize and verify the major categories and variables in a strategic group map. By integrating the appropriate ICT and marketing initiatives in a causal path, a city will be better positioned to meet their performance excellence targets.

RESEARCH ON THE FUTURE ROLE OF ICTS AND CITY MARKETING

In the new electronic marketplace, selecting the appropriate technology requires taking a calculated risk and success is contingent on senior management support. Competitive advantage comes from integrating and aligning ICTs with the overall strategy and marketing plan—and doing so better and faster than the competition. However, implementing ICT initiatives can be expensive and difficult when there are project cost overruns and service failures (OECD, 2003). Descriptive research can determine what ICT and marketing applications are used most frequently across different municipalities. For example, a survey conducted in Mecklenburg County, North Carolina indicated that 44% of respondents in a community survey had accessed the County's website and were familiar with e-government services (2007). For those respondents who had used e-government services in the previous twelve months, the survey assessed their experience in four areas: convenience, navigation, accuracy and up-to-date information, and the likeliness to use the service again. Overall ratings averaged ninety percent customer satisfaction (Mecklenburg Community Survey, 2007).

Whether a city is successful in driving positive stakeholder outcomes needs to be verified by collecting data/research on the factors identified in the strategic group map. Causal research should investigate which applications are "best practices" and drive improvements in lagging indicators such as operations, service, or image and in the end, economic growth, e.g., those specified in the strategic group map in Figure 1. Research that uses path analysis which allows variables to act as both independent and dependent variables will be required to test a given strategic group map model (Byrne, 2001). For example, in a study on city management of cities > 50,000, West and Berman (2001) used a nonrecursive structure model and found that the use information technology was a significant predictor of management practices (e.g., management that promoted openness, support and risk taking) which, in turn, increased organizational effectiveness. However, controlling for management practices, information technology was not positively related to organizational effectiveness, nor was there a direct relationship between management practices and information technology.

Some fundamental issues to guide future descriptive and causal research posed as thought-provoking questions follow:

1. How do different cities use ICTs to improve service and market/ communicate their image? What are the most frequently used forms of ICTs for internal services/operations and external marketing?
2. What do we really know about how stakeholders make choices? How suitable is a city's website for meeting the divergent needs and wants of multiple stakeholders?
3. What do target stakeholders want from the city and an ICT? Working back from the customer, how well does the current system meet those needs?
4. How well does a given city's ICT capability compare to rivals—both now and in the future? Who are the "best in class" organizations worth benchmarking against?
5. What are the most effective ways for cities to reach and serve their markets? How effective are different uses and forms of ICTs in ultimately affecting stakeholder outcomes? What are the implications for technical expertise requirements and education?
6. How do stakeholders, e.g., potential investors, use information from the website? Can exchanges that create mutual value expand global and long-term stakeholder relationships that benefit the city? What is really known about traffic on the internet and it's potential value to the organization?
7. Who is accessing the city's website? How can that information be used to develop interactive relationships with stakeholders?
8. What specialist expertise and knowledge is necessary to incorporate rapid developments in ICTs? How are processes and services coordinated and aligned with shifting market requirements? How can an organization effectively adapt to changing customers, relationships, and markets?
9. What is the added value of and return on ICT applications? What determines the success or failure of an ICT initiative?
10. Do managers have the education and expertise to effectively integrate ICTs in strategic planning and marketing? How can this intellectual capital be increased?
11. How can stakeholder needs and priorities be incorporated into the latest communications, networking and interactive software and hardware?

CONCLUSION

The overall benefits for a city in integrating the use of ICTs and marketing as part of a strategic plan are effective direction of scarce resources to key business drivers that impact stakeholder satisfaction. In general, a strategy map provides a process for the city to articulate and execute its mission with regard to its key stakeholders by identification of key issues and focus on priorities, strategic activities, budgets and projects. By linking key performance indicators such as marketing and ICT initiatives to strategic areas of focus, management can provide the impetus for proactive, focused process improvement in internal processes and ultimately, stakeholder satisfaction. Future studies should examine the impact of investment in marketing and ICT initiatives on brand and image perceptions of a city. The results of stakeholder surveys on customer service, satisfaction and perceptions of the city identity are key performance indicators that can be reported on city scorecards.

Once the primary goals of a marketing plan are established, ICTs can be used to help improve a city's image and positively position a city in the evaluation of visitors, residents and businesses. Organizations will need an internet strategy and expertise to prosper in the new environment. It is incumbent upon management to ascertain if the objective and value are cost effective or to find the most effective communication mix at the least possible cost (Kerin and Peterson, 2007). The ability of the internet and ICT to disseminate large amounts of information to large numbers of stakeholders in an effective and efficient manner across the globe often results in a high value/cost ratio or a reasonable return for the investment.

Cities and countries differ in the extent of access to ICTs—wealthier countries have more investments in technology and are more accessible to external marketing communications (Shih, Kraemer & Dedrick, 2008). Improvements in a country's ICT infrastructure, human capital, institutional environment, e.g., economic freedoms and entrepreneurial activities determine the readiness of an emerging market to adopt the ICTs. Known as the digital divide that separates countries by the extent of access to ICTs (Gregorio, Kassicieh & De Gouvea Neto, 2005), cities on the less developed side of ICTs may find it difficult to market their cities on a regional or global basis while cities on the more developed side may be able to utilize first mover advantages that result in early adoption and improvement of key performance indicators such as economic growth. Recognizing the challenge of global connectivity and regional differences in ICT services, the International Telecommunication Union and European Commission committed to (1) support the development of human and organizational learning capital in technology, (2) standardize market and information policies across regions as well as (3) build the technology infrastructure for Africa, Asia-Pacific and the Caribbean (2008).

The development of ICTs in city management has profound effects on image marketing, communication and services while opening the paths to improve customer relationship management on an international scale. Successful deployment of ICT initiatives and investments in the technology infrastructure requires integration across organizational functions and relationships so that an organization's strategic approach reflects what is valued by the stakeholders.

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Chapter 4.6

Managing Executive Information Systems for Strategic Intelligence in South Africa and Spain

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ABSTRACT

Strategically important information for executive decision-making is often not readily available since it may be scattered in an organization's internal and external environments. An executive information system (EIS) is a computer-based technology designed in response to specific needs of executives and for decision-making. Executives having the "right" information for strategic decision-making is considered critical for strategic intelligence (SQ). SQ is the ability to interpret cues and develop appropriate strategies for addressing the future impact of these cues. In order to gauge the current situation in respect of information in an EIS and for managing future EIS development, the authors research EIS in organizations in two selected countries: South Africa and Spain. From their EIS study, parallelisms and differences are identified and implications for SQ are discussed. Some practical implications for future EIS development are given. The authors suggest these should be considered so that SQ for executive decision-making is facilitated.

INTRODUCTION

The focus of this chapter is twofold: (1) to discuss executive information systems (EIS) for strategic intelligence (SQ); and (2) to present EIS research from studies in South Africa and Spain and to discuss the SQ implications thereof when considering future EIS development in these countries.

This chapter is organized as follows: The concepts of strategic information and executive information systems (EIS) introduced. Executives having the "right" information for strategic decision-making is considered critical for SQ. A survey of EIS in organizations in South Africa and Spain is undertaken to identify the nature and sources of information included in these surveyed organization's EIS. The implications of this information for SQ for executive decision-making is then discussed. Some future EIS trends are noted and a conclusion is given.

Organizations use a wide range of technologies and products to help users make better business decisions. Strategic decision-making is often the result of collaborative processes. Strategically important information for executive management decision-making is often not readily available since it may be scattered in an organization's internal and external environments. Strategic information systems (IS) provide or help to provide, strategic advantage to an organization (Turban, McLean & Wetherbe, 2004). An increasing number of organizations are recognising the strategic significance of their information technology (IT) resources (Maier, Rainer, & Snyder, 1997).

An EIS is a computer-based technology designed in response to the specific needs of executives and for making both strategic and tactical decisions. An EIS is used by executives to extract, filter, compress, and track critical data and to allow seamless access to complex multidimensional models so that they can see their business at a glance. This facilitates executives making strategic and tactical decisions thereby leading to strategic excellence for their organizations. EIS have been successfully implemented in many organizations and in many countries.

SQ is defined as "*the ability to interpret cues and develop appropriate strategies for addressing the future impact of these cues*" (Service, 2006, p. 61). SQ systems are IS designed to provide information about competitors and the competitive market environment which can be helpful in making strategic management decisions (Mockler, 1992). The notion of SQ leads to strategic excellence (Service, 2006). Strategy is a journey of planning, implementing, evaluating and adjusting while paying attention and focus on the "right" things. Strategy does not deal with future decisions—it deals with decisions for the future. Executives must progress from strategic planning, to strategic thinking to strategic leadership through developing better SQ. In the past, strategy has been too much of a mechanical process and should shift away from a process-centered to a people-centered approach of thinking. However, it is somewhat harder for executives who are process-centered analyzers rather than people-centered synthesizers, who focus on the present rather than the future, to develop SQ. The first step is for executives to recognize that SQ exists and its importance for their organizations. One approach for accomplishing this is through scanning of the external IT environment.

Scanning is the behavior executives perform when they are browsing through data in order to understand trends or sharpen their general understanding of the organization (Vandenbosch & Huff, 1997). Empirical evidence suggests that a significant portion of executive time is spent scanning for information. Environmental scanning acquires data from the external environment for use in problem definition and decision-making.

An effective way to evaluate the success of an EIS is to obtain opinions from the executive users (Jirarchiefpattana, Arnott, & O'Donnell, 1996). Since managing EIS is important for organizations, the objective of this chapter is to present the empirical results of quantitative surveys on EIS in a sample of organizations in South Africa and Spain. Such results may serve to underpin managing future EIS development with a need to focus on strategically important information from internal and external environments for SQ. It remains the challenge for IS professionals to design IS to support and enhance the strategic scanning behaviors of executives in complex and turbulent environments. Information is the fuel for planning and "strategizing." Strategic focus on the "right" things, leads to developing a better SQ for executives; executives become better strategists and thereby provide strategic advantage to their organization. Most EIS facilitate search and scanning behaviors for executives.

In the next section, the background to strategic information (including strategic information systems) and executive information systems (EIS) are introduced. Thereafter EIS development, some EIS issues, Web-based systems and the right information are discussed.

BACKGROUND TO STRATEGIC INFORMATION AND EXECUTIVE INFORMATION SYSTEMS

Concepts of Strategic Information and Strategic Information Systems

Information is data that have been organized so that it has meaning and value to the recipient. The recipient (e.g., an executive) interprets the meaning and draws conclusions and implications from the data. Data items are typically processed into information by means of an IS application. Strategic information refers to the long-term nature of the processed data and to the significant magnitude of advantage it is expected to give to the organization. Strategically important information (intelligence) for executives is often not readily available and furthermore it is scattered in an organization's internal environments.

From the literature, there appears to be two types of strategic scanning information that can be identified for executives:

- **Accommodation information:** This is general surveillance information which is not necessarily coupled with a specific threat or opportunity to an organization; and
- **Assimilation information:** This is more specific and likely to be coupled to identifying strategic threats and opportunities to an organization.

Strategic IS (SIS) are systems that facilitate an organization gaining a competitive advantage through their contribution to the strategic goals of an organization. SIS is characterised by their ability to significantly change the manner in which business is conducted in order to give it an organizational strategic advantage. Any IS that changes the goals, products, processes or environmental relationships to help an organization gain competitive advantage (or reduce competitive disadvantage) is a SIS. An EIS is an example of a SIS.

Executive Information Systems (EIS)

EIS have experienced significant expansion since the 1990's as a result of facilitating internal and external pressures. In 1977 the first paper "Building EIS, A Utility for Decisions" by D. R. Nash appeared in the *DataBase* journal (Nash, 1977). Watson, Rainer, and Koh (1991) then set a landmark in the study of EIS practices by describing a useful framework for EIS development which encompasses three elements: (1) a structural perspective of the elements and their interaction; (2) the development process; and (3) the dialogue between the user and the system.

Following there, from several contributions in the literature show that a general view on EIS usage in different countries can be found (Allison, 1996; Fitzgerald, 1992; Kirlidog, 1997; Liang and Hung, 1997; Nord and Nord, 1995, 1996; Park, Min, Lim, & Chun, 1997; Pervan, 1992; Pervan and Phua, 1997; Thodenius, 1995, 1996; Watson, Rainer, & Frolick, 1992; Watson, Watson, Singh, & Holmes, 1995). Several other contributions show a general view on EIS use in different countries for example South Korea, Spain, Sweden, Turkey, United Kingdom, and the United States of America. While our EIS study in this chapter adopts a comparative approach and which is not frequent in EIS literature, comparative EIS studies by Park et al. (1997) and Xu, Lehaney, Clarke, and Duan (2003) do exist.

EIS grew out of the development of IS to be used directly by executives and used to augment the supply of information by subordinates. EIS is the only known mature IS dedicated to business executives (Tao, Ho & Yeh, 2001). Definitions of EIS are varied and all identify the need for information that supports decisions about the business as the most important reason for the existence of EIS. In this chapter EIS is defined as a computer-based system intended to facilitate and support the information and decision-making needs of executives by providing easy access to internal and external information relevant to meeting the strategic goals of the organization. While a definition is useful, a richer understanding is provided by describing the capabilities and characteristics of EIS.

Earlier studies described EIS capabilities which are focused on providing information which serves executive needs. Srivihok (1998) reports that these capabilities are concerned with both the quality of the system (e.g., user friendliness) and information quality (e.g., relevance). Sprague and Watson (1996) identify the following capabilities or characteristics of EIS:

- Tailored to individual executive users
- Extract, filter, compress, and track critical data
- Provide online status access, trend analysis, exception reporting, and “drill down”
- Access and integrate a broad range of internal and external data
- User-friendly and require little or no training to use
- Used directly by executives without intermediaries
- Present graphical, tabular and/or textual information

Other researchers suggest additional capabilities and characteristics of EIS:

- Flexible and adaptable (Carlsson & Widmeyer, 1990)
- Should contain tactical or strategic information that executives do not currently receive (Burkan, 1991)
- Facilitate executives’ activities in management such as scanning (see, for example, Frolick, Parzinger, Rainer & Ramarapu (1997) for a discussion on environmental scanning), communication and delegating (Westland & Walls, 1991)
- Make executive work more effective and efficient (Friend, 1992)
- Assist upper management to make more effective decisions (Warmouth & Yen, 1992; Chi & Turban, 1995)
- Incorporate an historical “data cube” and soft information (Mallach, 1994). A data cube is a structure in which data is organized at the core of a multidimensional online analytical processing (OLAP) system and soft information includes opinions, ideas, predictions, attitudes, plans, and so forth (Watson, O’Hara, Harp, & Kelly, 1996)
- Provide support for electronic communications (Rainer & Watson, 1995a)
- Enhanced relational and multidimensional analysis and presentation, friendly data access, user-friendly graphical interfaces, imaging, hypertext, Intranet access, Internet access, and modeling (Turban, McLean, & Wetherbe, 1999)

EIS may include analysis support, communications, office automation, and intelligent support (Turban, Rainer & Potter, 2005). From this data, executives are able to glean cues which may be used towards achieving SQ in an organization. It is therefore important that EIS are developed to facilitate information cues for executives. EIS development is now discussed.

EIS Development

Decision-making is recognized as one of the most important roles of executives. Executives are facing a business environment characterised by escalating complexity and turbulence. Given this environment, there is a need to have a clear understanding of the terms "complexity" and "turbulence" when developing EIS. These two terms are now discussed.

- **Complexity** generally refers to a large number of variables (many of which are perceived to be uncontrollable) making up a system. Complexity is defined as the degree to which an innovation is perceived as relatively difficult to understand and use. Unstable environments create strategic uncertainty for executives.
- **Turbulence** implies complexity with a high degree of change or dynamism added. Ansoff and McDonnell (1990) suggest that four characteristics contribute to the turbulence of the environment:
    - **Complexity** (the variety of factors that management must consider when making decisions)
    - **Novelty** (the discontinuity of successive challenges that an organization encounters in the environment)
    - **Rapidity of change** (the ratio of the speed of evolution of changes to the speed of the organization's change)
    - **Visibility of the future** (the predictability of information about the future, available at the decision time). The characteristics of information in a turbulent environment are complicated, novel, dynamic, or ambiguous (Wang & Chan, 1995)

Strategic uncertainty caused by business environment turbulence leads to increased demand for strategic information. Forsdick (1995) found that the overwhelming consensus of executives surveyed was that complexity implied a lack of understanding of the factors impacting on their organizations and that complexity was increasing over time. This researcher reports that approximately half the respondents in his survey saw turbulence as referring to the rate of change in uncontrollable external variables. Despite the availability of comprehensive reports and databases, executives take decisions based on their interactions with others who they think are knowledgeable about issues.

EIS development in organizations usually follows an evolving (or adaptive) approach instead of the traditional linear systems development life cycle. The initial application of the EIS should be small so that EIS developers can deliver a system quickly. A portion of the EIS is quickly constructed, then tested, improved and enlarged in steps. What makes EIS development particularly interesting and challenging is the unique combination of considerations that affect the effort. Watson et al. (1995) suggest three factors which are particularly relevant:

- An organization's senior executives are seldom hands-on computer users as they "*probably are of an age to have missed the computer revolution*" and may question the need for them now.
- Executives perform highly unstructured work that is difficult for them to describe with sufficient precision to identify information requirements.
- An EIS is typically a new type of application for systems analysts and often requires learning and using new technology and understanding managerial work.

From the above, it is evident that EIS development is a complex task which requires a large investment of time and money.

Some EIS Issues, Web-Based Systems and the "Right" Information Issues

It is critical that when an IS is defined it meets specific executive or manager information requirements. This is particularly true in EIS development. In the development of an EIS in an organization, one issue that should be considered is flexibility (Barrow, 1990; Srivihok, 1998). Salmeron (2002) reports that if this were not so, EIS would soon become a useless tool which would only deal with outdated problems and would therefore not contribute to decision-making. Without new or updated information, executives will be unable to ascertain whether their views of the environment and their organization's position within it remain appropriate. With the correct problem formulation, information assists executives establish options and select courses for action. Without the "right" information cues, executives may develop inappropriate strategies for addressing the future impact of these cues. SQ will therefore not be manifested.

Another issue is that EIS are high-risk information technology (IT) investments. Remenyi and Lubbe (1998) indicate that there is an increasing amount of IT investment and substantial evidence of IS failures in organizations. EIS has become a significant area of business computing and there are increasing amounts of money being invested by organizations in EIS development projects. Since EIS are highly flexible tools and since executives may behave in various ways to retrieve information from them, managing their successful development becomes that much more critical. Executives need to receive the "right" information cues from their organization's EIS.

A third issue is that EIS should be flexible to support different classes of business data: external, internal, structured, and unstructured. Examples of external data are from customer relationship management systems (systems intended to support customers) or news items (from external data sources). Enterprise resource planning (ERP) systems capture operational (internal) data in a structured format—SAP® is an example of an ERP system. Business processes represent internal data. Structured and unstructured data may be found in e-mails and Web sites. Web sites deal with both external (e.g., extranet) and internal (e.g., intranet) data sources. For example, EIS provide executives with access to external information such as news, regulations, trade journals, and competitive analysis. Some executives use their EIS to scan broadly across a wide variety of information external to the organization's databases (Vandenbosch & Huff, 1997). Organizational scanning activities can therefore be placed on a continuum from irregular to continuous scanning.

EIS products as a standalone application have started to disappear. Nowadays they tend to be included in larger IS or as a module integrated in ERP systems (e.g., SAP®). Furthermore there is a blurring of management IS (MIS), decision support systems (DSS) and EIS to business intelligence (IS) systems. According to Negash (2004) "*BI systems combine data gathering, data storage, and knowledge management with analytical tools to present complex internal and competitive information to planners and decision makers*" (p. 178). A key driver behind the uptake of BI solutions is the need to remove a degree of the uncertainty from an organizational business process and replace it with genuine intelligence. According to Cook and Cook (2000), the Achilles heel of BI software is its inability to integrate unstructured data into its data warehouses or relational data bases, its modelling and analysis applications and its reporting functions. In BI, intelligence is often defined as the discovery and exploration of hidden, inherent, and decision-relevant contexts in large amounts of business and economic data.

One problem with EIS development is that there may be technical issues to deal with, such as integrating EIS with an organization's existing business systems for access to internal, structured and unstructured data.

Another problem is that there are issues of trust and credibility of information that can be found in an EIS which mitigates against intensive executive reliance on IS. For example, if an executive is not receptive to new and unexpected accommodation or assimilation information; or if new information does not emerge during the scanning process, creative insights and improved decision-making may not arise. This may then result in an executive not paying attention and focus on the "right" things.

Web-Based Systems

With the emergence of global IT, existing paradigms are being altered which are spawning new considerations for successful IT development. Web-based technologies are causing a revisit to existing IT development models, including EIS. The Web is "a perfect medium" for deploying decision support and EIS capabilities on a global basis (Turban et al., 1999). Organizational success in accomplishing strategies is a function of how one arranges, develops, changes or uses an organization's systems. These systems, for SQ, should extend beyond automated MIS, IS and IT to include all (including Web-based) organizationally related systems. This is evident from the business environment since "the relevant physical and social factors outside the boundary of an organization that are taken into consideration during organizational decision-making" (Daft, Sormunen, & Parks, 1988).

The "Right" Information

Salmeron (2002) reports that "*it is surprising that external information is so seldom included in Spain*" (p. 43) for tactical decision-making or strategic decisions. This can be possibly accounted for by the fact that most large Spanish organizations which have implemented EIS, are first-generation EIS (Salmeron, 2002). The external environment has been found to be an important predictor of EIS use (Watson et al., 1991). Executives need information from outside the organization about facts and things happening in their external environment. Research into environmental scanning highlights the outside view of an organization's boundary and recognizes that strategic thinking begins with a study of the external environment.

The business environment is seen as a source of information that continually creates signals and messages that organizations should consider important. Continuous scanning is a deliberate effort to obtain specific information that follows pre-established methods. It is characterised by a proactive, broad in scope, part of an organization's planning process. While the external dimension of the business environment has been emphasised with respect to strategic uncertainty and strategic information scanning, the question arises around the "nature" of the information included or held by EIS. This question is of critical importance for SQ since without an executive being able to focus on or interpret cues from the "right" information, the executive cannot make appropriate strategic planning decisions for addressing the future impact of these cues. It is therefore important that EIS should contain the "right" types of information and sources of this information (whether it be scattered in an organization's internal and/or external environments) should facilitate strategic decision-making for executives. In order to gauge the current situation in respect of this information in EIS and for managing future EIS development, the authors decided to undertake research, using questionnaire surveys, on EIS in organizations in two selected countries: South Africa and Spain. The findings from this research will serve to contribute to our understanding and knowledge of current EIS (as used towards SQ by executives) and for future EIS development.

In the next section, the EIS research undertaken in South Africa and Spain is described. A comparative analysis and discussion of the authors' results is then given.

EIS RESEARCH UNDERTAKEN IN SOUTH AFRICA AND SPAIN

The authors compared two studies of EIS implementations in organizations in South Africa and Spain. The rationale for the comparative EIS study in these two selected countries is to identify any similarities and differences with respect to:

- Types of information included in EIS
- How information is held by EIS in organizations
- Sources of information that support EIS in organizations

This is useful as any information shortcomings identifies which do not facilitate SQ for executives can then be meaningfully addressed in future EIS development. The research methodologies adopted in these EIS survey studies in South Africa and Spain studies are now discussed.

Research Methodology in South African EIS Survey

A survey questionnaire was developed based on previous instruments used in published research papers. The instrument was validated using expert opinion. Four academics participated in separate field tests. A similar process was undertaken by Rainer and Watson (1995b) who solicited expert opinion for "additions, modifications and/or deletions to the survey" instrument. A survey instrument was submitted to three EIS software vendors (Cognos®, JDEdwards®, and ProClarity®) in South Africa. A senior employee (e.g., managing director) from each vendor independently furnished some suggestions regarding the survey instrument. Using the "snowball" sampling method (Biernacki &Waldorf, 1981), the survey instrument was administered to an EIS representative in 31 organizations in South Africa during the period May to June 2002. The representatives were from the following three constituencies:

- EIS executives/end-users who utilize EIS
- EIS providers (i.e., persons responsible for developing and maintaining the EIS in the organization)
- EIS vendors or consultants in the EIS arena

These three constituencies were identified and used in EIS research by Rainer and Watson (1995a). The use of multiple perspectives is frequently suggested in IS research.

Organizations considered for survey were chosen over a spread of industries (e.g., banking, manufacturing, retail). Where an organization had implemented more than one EIS, the most recent EIS implementation was selected for survey purposes. All respondents were computer proficient and were able to provide a meaningful business perspective on their organization's EIS implementation.

From the previous EIS studies reflected in Table 1, it will be noted that this study of 31 organizations exceeds the previous EIS survey sample size in South Africa (during 1995 I. J. Steer surveyed 24 organizations) and the majority of EIS sample sizes in other countries.

For brevity in this chapter, this EIS study in South Africa is referred to as the Averweg (2002) study. The research methodology adopted in the EIS study in Spain is now discussed.

Research Methodology in Spanish EIS Survey

A survey instrument was used to gather data to develop the EIS study in Spain. The questionnaire used was based upon previous EIS literature—mainly the works of Watson et al. (1991), Fitzgerald

Table 1. Investigations about EIS with descriptive endings

Authors	Year	Investigation	Country	Replies (n)
Watson, H.J., Rainer, R.K., Jr., & Koh, C.E.	1991	*Executive Information Systems: A Framework for Development and a Survey of Current Practices*	United States of America	112 suitable replies of which 50 have an EIS in operation or in an advanced stage of implementation
Fitzgerald, G.	1992	*Executive Information Systems and Their Development in the U.K.*	United Kingdom	77 questionnaires received, 36 of whom are proceeding with an EIS
Watson, H.J., Rainer, R.K., Jr., & Frolick, M.N.	1992	*Executive Information Systems: An Ongoing Study of Current Practices*	United States of America	68 questionnaires received of which 51 indicated they have an EIS
Steer, I.J.	1995	*The Critical Success Factors for the Successful Implementation of Executive Information Systems in the South African Environment*	South Africa	24 questionnaires from organizations with EIS implementation
Thodenius, B.	1995	*The Use of Executive Information Systems in Sweden*	Sweden	29 replies from organizations with EIS implementation
Watson, H.J., Watson, T., Singh, S., & Holmes, D.	1995	*Development Practices for Executive Information Systems: Findings of a Field Study*	United States of America	43 suitable questionnaires from organizations with EIS implementation
Allison, I.K.	1996	*Executive Information Systems: An Evaluation of Current UK Practice*	United Kingdom	19 suitable questionnaires received from organizations with EIS
Park, H.K., Min, J.K., Lim, J.S., & Chun, K.J.	1997	*A Comparative Study of Executive Information Systems between Korea and the United States*	Korea and United States of America	27 suitable questionnaires from organizations with EIS implementation
Pervan, G.P., & Phua, R.	1997	*A Survey of the State of Executive Information Systems in Large Australian Organizations*	Australia	12 suitable questionnaires from organizations with EIS implementation
Poon, P., & Wagner, C.	2001	*Critical success factors revisited: success and failure cases of information systems for senior executives*	Hong Kong, China	6 suitable questionnaires from organizations with EIS implementation

(1992), Watson and Frolick (1993), Thodenius (1995, 1996) and Watson et al. (1995) were analyzed. Questions and items were translated and adapted to the EIS context in Spain.

The survey was carried out in Spain from January to June 1998. A pilot test of the survey was conducted in order to assess content validity. The instrument was pretested with four EIS consultants and three business and IS professors. Suggestions were incorporated into a second version that was then tested by two other management professors. No additional suggestions were made. Bias in response from misinterpretation of the survey instrument was therefore reduced.

The sample was selected following the "snowball" sampling method obtaining an initial list of 178 organizations based on the contributions of seven software development and distribution organizations and 4 consulting organizations. Between March and June 1998, the manager in charge of the EIS implementation was contacted via telephone. In this survey the existence of an operative EIS (or at least an EIS under development and implementation) was confirmed. After explaining the study's objectives to the persons responsible for EIS implementation, they were asked for their collaboration. Following this communication process, cooperation of 136 organizations was achieved.

Valid responses from 75 organizations were obtained—this represents a participation of 55.2%. After analysing the EIS situation in this group of entities, 70 questionnaires which could be analyzed were selected. These questionnaires represented organizations with EIS, operative or in a development/implementation stage sufficiently advanced as to enable the answering of the questions asked. This number of valid questionnaires is higher than any obtained in previous EIS descriptive studies—see Table 1. For brevity in this chapter, this EIS study in Spain is referred to as the Roldán (2000) and Roldán and Leal (2003a) studies.

Comparative Analysis and Discussion of Two EIS Surveys

Tables 2 to 7 presented in this chapter were extracted from the Averweg (2002), Roldán (2000), and Roldán and Leal (2003a) studies and refer to the EIS surveys conducted in organizations in South Africa and Spain respectively.

The number of permanent employees in organizations participating in the EIS study in South Africa and Spain is reflected in Table 2.

From Table 2, 64.6% of organizations surveyed in South Africa had more than 500 employees. Some 53.3% of organizations surveyed had a gross annual turnover exceeding ZAR500 million (approximately U.S. $72 million).

In the case of the EIS study in Spain, according to the European Union classification, most of the participating entities were large organizations and 71.0% had more than 500 employees (see Table 2). Some 62.0% of organizations surveyed had gross revenues exceeding U.S. $139 million.

A rank descending order of applications for which EIS is used in organizations in the Averweg (2002) study is given in Table 3. Research has found that the accessibility of information is more important than its quality in predicting use (O'Reilly, 1982). It has been shown that accessibility of information has a significant influence on perceived usefulness and perceived easy of use of EIS (Pijpers, Bemelmans, Heemstra, & van Montfort, 2001). Furthermore, Roldán and

Table 2. Number of permanent employees in organizations: Frequency and percentage

	South Africa (N=31)	**Spain (N=69)**
More than 5,001 employees	6 (19.5%)	12 (17.4%)
Between 2,001 and 5,000 employees	5 (16.1%)	9 (13.0%)
Between 501 and 2,000 employees	9 (29.0%)	28 (40,6%)
Between 251 and 500 employees	5 (16.1%)	12 (17.4%)
Between 51 and 250 employees	5 (16.1%)	6 (8.7%)
Less than 51 employees	1 (3.2%)	2 (2.9%)

Table 3. Rank descending applications for which EIS is used: Frequency and percentage (multiple answer question)

	South Africa (N=31)
Access to projected trends of the organization	23 (74.2%)
Access to current status information	22 (71.0%)
Performing personal analysis	16 (51.6%)
Querying corporate and external data bases	16 (51.6%)
Office automation activities	5 (16,1%)
Measuring Key Performance Indicators (KPIs)	1 (3.2%)

Leal (2003b) report that EIS service quality has a greater effect on EIS user satisfaction than EIS information quality. Therefore, access to updated online information is a basic characteristic of EIS (Houdeshel & Watson, 1987; Martin, Brown, DeHayes, Hoffer, & Perkins, 1999).

The different types of information included in an EIS in an organization is given in Table 4. From Table 4, for organizations surveyed in South Africa, financial information (90.3%) appears as the most important item followed by business/commercial sales (74.2%) and then strategic planning (35.5%). In the Roldán and Leal (2003a) study, the three highest ranking types of information held by an EIS in an organization are business/commercial sales information (82.9%), financial information (65.7%) and production information (55.7%). While previous research studies agree in presenting these three types of information (sales, financial, and production) as the most relevant ones (Allison, 1996; Kirlidog, 1997; Thodenius, 1995), the Averweg (2002) study partially support these findings with business/commercial Sales (74.2%) and finance (90.3%) types of information. Executives taking cues from trends of the organization is an integral component of SQ.

Holding strategic planning information in EIS in organizations in South Africa appears to have a higher importance than holding production information (Averweg, Erwin, & Petkov, 2005). In this respect, the low percentage in EIS in Spain that include strategic planning information (14.3%) seems to indicate the systematical failure of many EIS to support scanning, processing and providing of meaningful information to managers engaged in strategic decision-making (Xu & Kaye, 2002). Environmental scanning is a basic process of any organization since it acquires data from the external environment to be used in problem definition and decision-making. The low percentage in the Spanish EIS situation can be a potentially dangerous weakness, since it was found that the EIS success is linked to the support provided by the system to organizational strategic management processes (Singh, Watson, & Watson, 2002).

Watson et al. (1996) recognise that executives require information (often provided informally) for decision-making. Soft information is “fuzzy, unofficial, intuitive, subjective, nebulous, implied, and vague” (Watson et al., 1996, p. 304). Watson et al. (1996) found that soft information was used in most EIS but the Averweg (2002)

Table 4. Types of information included in EIS: Frequency and percentage (multiple answer question)

	South Africa (N=31)	Spain (N=70)
Finance	28 (90.3%)	46 (65.7%)
Business/commercial sales	23 (74.2%)	58 (82.9%)
Strategic planning	11 (35.5%)	10 (14.3%)
Inventory management/suppliers	10 (32.3%)	14 (20.0%)
Human resources	9 (29.0%)	31 (44.3%)
Production	8 (25.8%)	39 (55.7%)
Quality	7 (22.6%)	22 (31.4%)
Soft information	4 (12.9%)	25 (35.7%)
Trade/industry	4 (12.9%)	14 (20.0%)
Competitors	3 (9.7%)	16 (22.9%)
External news services	1 (3.2%)	9 (12.9%)
Stock exchange prices	1 (3.2%)	5 (7.1%)

study (12,9%) does not support this (Table 3). One possible explanation is that it is often policy not to allow unsubstantiated rumours into IS without a reference to a source and tagged by the individual entering the information (Turban & Aronson, 1998).

Nowadays, databases exist for just about any kind of information desired—from competitor sales and financial matters to overall statistics. These can be used for a wide range of strategic management purposes to augment SQ for executive decision-making. From Table 4 it can be observed that the information that appears predominantly in EIS has an internal characteristic (Preedy, 1990). Some authors have defended the inclusion in the EIS of further reaching information with multiple perspectives and including a set of financial and nonfinancial, external and internal indicators (Taylor, Gray, & Graham, 1992). However, it can be observed that the information that appears predominantly in these systems has an internal characteristic.

External information obtains low response levels: Trade/industry (12.9%), external news services (3.2%), competitors (9.7%) and stock exchange prices (3.2%). Roldán and Leal (2003a) report similar low response levels. Other studies agree in presenting this scenario (Allison, 1996; Kirlidog, 1997; Salmeron, 2002). According to Xu et al. (2003), this internal orientation with low response level for external information is the main reason for dissatisfaction with EIS. An organization's environmental scanning process must be able to identify and differentiate among a variety of external issues if the organization's strategic responses are to predict the direction in which environmental elements may be moving that is for identifying trends. In SQ, executives need to develop strategies for addressing the future impact of these trend cues.

Some reasons that may shed light on this significant predominance of internal information are:

- It is much easier to provide internal data since it usually already exists in some form in the organization (Fitzgerald, 1992).
- Some executives will not really know how to use external EIS data, particularly data which is relatively soft and difficult to validate (Fitzgerald, 1992).
- The expense of electronically supporting and maintaining infrequently updated external information may not be justifiable in most situations (McAuliffe & Shamlin, 1992).
- The automated collection process of external data may tend to deliver too much unfiltered data to be useable by general management (McAuliffe & Shamlin, 1992).
- Research suggests that senior executives choose to do much of their own environmental scanning because they feel that

Table 5. Types of soft information included in EIS: Frequency and percentage (multiple answer question)

	Spain (N=25)
Predictions, speculations, forecasts, estimates	13 (52.0%)
Explanations, justifications, assessments, interpretations	12 (48.0%)
News reports, industry trends, external survey data	6 (24.0%)
Schedules, formal plans	5 (20.0%)
Opinions, feelings, ideas	1 (4.0%)
Rumours, gossip, hearsay	0 (0.0%)
Other	3 (12.0%)

subtleties exist that only they will see (El Sawy, 1985).

Executives often prefer doing this task personally instead of delegating it to staff since senior managers find great value in filtering external data through their own mental models (Rockart & DeLong, 1988). Therefore they try to develop and maintain its own external information sources, which are frequently rich and personal media of communication.

The literature suggests that periodical and newspaper reviews are a frequently used source of competitive intelligence. Considering the hard/soft information continuum proposed by Watson et al. (1996), in organizations surveyed in Spain, Roldán, and Leal (2003a) observe those types of qualitative information more quoted are included in a halfway house between hard and soft information: predictions (52.0%) and explanations (48.0%) (Table 5). Roldán and Leal (2003a) emphasise the absence of cases for the soft information extreme of the continuum (i.e., rumours, gossip, and hearsay) and suggest some explanations for this situation:

- This kind of information can be considered too sensitive
- It can jeopardize competitive plans
- It could expose the organization to legal risks (Watson, Harp, Kelly, & O'Hara, 1992)

How information is held by EIS in an organization is given in Table 6. From Table 6, information is generally presented by products (71.0%), operational/functional areas (64.5%) and geographical areas (58.1%). Roldán and Leal (2003a) report similar findings for operational/functional areas (62.9%), products (61.4%) and geographic areas (52.9%). Roldán and Leal (2003a) note that "*information according to processes ranks quite low, existing in only 20% of participating entities*" (p. 295). From Table 6 there is a striking commonality with the Averweg (2002) study of 19.4%. This situation was highlighted by Wetherbe (1991) as one of the traditional IS problems for top managers that is these systems are considered as functional systems rather than being considered as systems crossing functions. Nevertheless, this result is understandable since the most important EIS user groups are top functional managers and middle managers.

The different types of sources of information that support an EIS in an organization are given in Table 6. One of the capabilities or characteristics of EIS is the filtering, organization, and consolidation of multiple data sources (Nord & Nord, 1996). This quantitative data stems from

Table 6. How information is held by EIS in organizations: Frequency and percentage (multiple answer question)

	South Africa (N=31)	**Spain (N=70)**
By products	22 (71.0%)	43 (61.4%)
By operational/functional areas	20 (64.5%)	44 (62.9%)
By geographic areas	18 (58.1%)	37 (52.9%)
By key performance areas	14 (45.2%)	33 (47.1%)
By company	11 (35.5%)	not available
By strategic business units	10 (32.3%)	37 (52.9%)
By processes	6 (19.4%)	14 (20.0%)
By projects	5 (16.1%)	11 (15.7%)
By customers	1 (3.2%)	0 (0.0%)

corporate data bases (80.6%) and operational data bases (64.5%).

Table 4 reflects that the information that appears predominantly in EIS has an internal characteristic. Table 7 shows that a significant majority of the information came from internal sources. External sources have a low presence: external databases (25.8%) and Internet, Intranet or Extranet (16.1%). This trend towards internal sources supports the results obtained in previous research studies (Basu, Poindexter, Drosen, & Addo, 2000; Kirlidog, 1997; Roldán & Leal, 2003a; Watson et al., 1991; Watson, Rainer, & Frolick, 1992; Xu et al., 2003). Salmeron, Luna, and Martinez (2001) suggest "the extent to which information coming from the environment is included in the EIS of Spanish big businesses should reach higher figures, due to the fact that all elements that currently form economy are interrelated" (p. 197).

Given the presence of Web-based technologies and from Table 6 it is therefore somewhat surprising that the Internet, Intranet and Extranet rank as the lowest source of information which support an EIS in organizations in the Averweg (2002) and Roldán and Leal (2003a) studies. This tends to suggest that future EIS development and implementation should focus on developing an organization's external sources for strategically important accommodation and assimilation information. This will serve to promote a systematic scanning of the external environment. Xu (1999) suggests that an organization should differentiate and selectively identify the most influential environmental factors for scanning. Scanning does not imply only collecting competitor's information. Environmental factors such as changes in economic conditions, cultural and social patterns, political climate and legal representations, and technology should be selectively monitored since they may significantly affect developing an executive's SQ.

Making important strategic decisions must be based on accurate data. The data held by EIS must facilitate SQ for executives. While new Web-based architectures may replace old architectures or they may integrate legacy systems into their structure in organizations, from this study it is evident that EIS in South Africa and Spain are in a state of flux and future EIS development will require new emerging features for SQ.

From the above EIS survey results in South Africa and Spain, the findings that emerged between these two countries are now summarized. Two parallelisms were identified:

- External information (e.g., trade/industry, external news services, competitors, and stock exchange prices) in EIS have low internal presence.
- There are similar trends in how information (e.g., by products, operational areas, and geographical areas) is held by EIS in an organization.

Table 7. Sources of information that support EIS in organizations: Frequency and percentage (multiple answer question)

	South Africa (N=31)	**Spain (N=70)**
Corporate databases	25 (80.6%)	61 (87.1%)
Operational databases	20 (64.5%)	29 (41.4%)
Individuals	12 (38.7%)	23 (32.9%)
External databases	8 (25.8%)	19 (27.1%)
Documents or reports	7 (22.6%)	24 (34.3%)
Internet, Intranet or Extranet	5 (16.1%)	2 (2.9%) (only Internet)

With the low internal presence of external information, it appears that environmental scanning is not being actively pursued by executives and the advantages of Web-based technologies are not being utilized. These apparent "shortcomings" need to be incorporated in future EIS development.

Two significant differences between the EIS survey in organizations in South Africa and Spain were identified:

- Holding strategic planning information in organizations in South Africa appears to have higher importance than holding production information.
- There is a higher presence of holding soft information in organizations in Spain but this is less than when compared to organizations surveyed in North America.

The implications of the above parallelisms and differences are that:

- It may provide a research agenda for an in-depth study of these parallelisms and differences.
- This information is useful for IT practitioners when considering future EIS development in these countries.

Some practical implications for future EIS development will now be given.

SOME PRACTICAL IMPLICATIONS FOR FUTURE EIS DEVELOPMENT

Executives place substantial requirements on EIS. Firstly they often ask questions which require complex, real-time analysis for their answers. Hence many EIS are being linked to data warehouses and are built using real time OLAP in separate multidimensional databases along with organizational DSS. There are also efforts to use data warehouse and OLAP engines to perform data mining.

Secondly, executives require systems that are easy to use, easy to learn and easy to navigate. Turban and Aronson (1998) report that current EIS generally possess these qualities.

Thirdly, executives tend to have highly individual work styles. While the functionality of the current generation of EIS can be moulded to the needs of an executive, it is more difficult to alter the general look and feel or method of interaction with a system.

Fourthly, any IS is essentially a social system. Turban and Aronson (1998) note that one of the key elements of EIS is the electronic mail capabilities it provides for members of the executive team. Nowadays, the electronic mailing of multimedia documents is becoming critical. Given this scenario, EIS of the future will look significantly different from today's systems.

Nord and Nord (1995) report that developers of decision support technology for executives must be alert to the needs of top executives and EIS evolution. Like most other IS, EIS have migrated to the networked world of the technical workstation and Intranets. The advent of Web services now allows interaction between software and systems that would previously only have been possible with extensive systems development.

Turban and Aronson (1998) describe some of the features that have been emerging or likely to appear in the next generation of EIS:

- **A toolbox for building customized systems:** To quickly configure a system for an executive, the builder of the system requires a toolbox of graphic and analytical objects that can be easily linked to produce the system. Commander EIS LAN®, Forest and Trees® and Pilot Decision Support Suite® are examples of such tools.
- **Multimedia support:** The requirement that an EIS can be configurable also requires support of multiple modes of output and

input. The current generation provides text and graphic output with keyboard, mouse, or touch screen input. The rapid proliferation of databases supporting image data, voice, and video will no doubt mean that future EIS will be multimedia in nature. Audio and video news feeds (soft information) via the Internet through local area networks are currently a reality.

- **Virtual reality and 3-D image displays:** The development of virtual reality standards, the ability to examine megabytes of data on a landscape or in a map form via 3-D visualization, and higher resolution monitors are beginning to affect EIS. As these tools are deployed for general use executives will adopt them to assist in their data visualization for information evaluation and decision-making. By scanning the IT environment and interpreting such visual cues, this process may serve to enhance SQ for executive decision-making.
- **Merging of analytical systems with desktop publishing:** Many reports prepared for executives contain text, graphs, and tables. To support the preparation of these reports, some software companies have merged desktop publishing capabilities with various analytical capabilities. In keeping with multimedia features, EIS have the capability to cut and paste data and graphs from various windows and to ship that document (via e-Mail) to other executives or post it to a Web site.
- **Client/server architecture:** This approach is extremely important for EIS as the server provides data to client software running on the executives' workstation. The original architecture of EIS was the client/server environment and it has now been adopted for many IS applications including data warehousing and Web technology. For a technical discussion of Web client/server communication, see, for example, Schneider and Perry (2000).
- **Web-enabled architecture:** Web browser software is the cheapest and simplest client software for an EIS. This is leading toward Web-enabled EIS. The current generation of software supports information delivery via the corporate Intranet and is evolving into the norm rather than the exception. Some examples are: Comshare provides Commander DecisionWeb®, Pilot Decision Support Suite® contains an Internet publishing module and the SAS Institute provides Internet support for its flagship enterprise software suite.
- **Automated support and intelligence assistance:** Expert systems and other artificial intelligence systems are currently embedded or integrated with existing database management system or DSS. Clearly this adds more automated support and assistance to the analytical engines underlying EIS. The researchers indicate that one is also likely to see other forms of intelligent or automated assistance. One such form is the intelligent software agent. An agent can learn how the executive uses an EIS and adopts the appropriate screens in the executive's preferred order. Other agents are actively used in Web search engines and can be deployed in Web-enabled EIS.
- **Integration of EIS and group support systems:** Much of the technology developed for group support systems (i.e., groupware) can be used effectively by executives for a number of managerial tasks. For example, Haley and Watson (1996) document ten cases where Lotus Notes® was specifically chosen for EIS development.
- **Global EIS:** As organizations become more global in nature, providing information about international locations around the world is becoming critical to organizations' success. The accuracy and timeliness of information for decision-making become critical. The challenge has become to find ways to

> integrate information across the enterprise. The transparency of the integration of the information process is what makes Web technology so effective. Palvia, Kumar, Kumar, and Hendon (1996) investigated the types of data that executives require in two scenarios: (1) introducing a new service or product into other countries; and (2) distribution channel expansion into other countries.

Most of the executive information requirements include demographic and marketing data from public sources and soft information from personal contacts. Palvia et al. (1996) indicate that EIS can be used to provide the soft information. Soft information that is provided in EIS can be classified in groups according to their softness (Watson et al., 1996). This classification helps the executive user judge them.

In the next section, future EIS trends are presented. Thereafter the conclusion for this chapter is given.

FUTURE EIS TRENDS

Strategically important information for executives may be scattered in an organization's internal and external environments. The main issue facing the successful development and implementation of EIS in an organization is the importance of clean, organized source data. This is applicable to both structured data and unstructured data.

One future trend is that the processes of acquisition, cleanup, and integration will have to be applied for both structured and unstructured data. Furthermore, structured and unstructured data types are further segmented by looking at the internal and external data sources of the organization. These two dimensions are data type and data source. However, the transition between structured and unstructured data types and between internal and external data sources is not currently defined in absolute terms. This will require further investigation. Problem-pertinent data will be available from external as well as internal sources (Forgionne, 2003).

Another future trend is the challenge of EIS to deal with soft information. While the authors report that 12.9% and 35.7% soft information is held in EIS in organizations in South Africa and Spain respectively (see Table 4), it is envisaged that the future trend will be to pay militant attention to this (soft) information so that users will ultimately get to a single version of the truth. Rigorous data standards may need to be deployed. There also needs to be a secure delivery of accommodation and assimilation information to the EIS.

Another trend will be a greater focus on learning phases that users have to go through to ensure they receive the information they thought they will be receiving. Mental modes are important not only for decision-making but also for human-computer interaction (Turban et al., 2004). Organizations will need to ensure that users understand how to use EIS so that they do not draw the wrong conclusions (or insights) from data because they submitted incorrect queries or misused the results. This will lead to poor strategic decision-making by executive users and SQ will thereby not be facilitated.

With more and more information becoming available in electronic form, organizations have increasingly carried out environmental scanning using EIS linked to online databases (Vandenbosch & Huff, 1997). This trend is likely to grow as the borderless nature of the Internet suggests that organizations may be able to scan a greater variety of information sources that cover a wider range of environmental sectors (Tan, Teo, Tan, & Wei, 1998). In a business environment characterised by complexity and turbulence, scanning by executives will become more important for their SQ. Environmental scanning often initiates a chain of actions that lead to organizational adaptation to environmental changes (Hambrick, 1981).

The viability of an organization depends on its ability to stay ahead of environmental challenges and thus environmental scanning can be considered a vital organizational task (Boyd & Fulk, 1996) and this soft information is needed for successful competition and survival (Turban & Aronson, 1998). Some scanning of news stories, internal reports, and Web information is performed by intelligent agents. The ease of access to information on the Internet and as a borderless information resource which transcends traditional boundaries and notions for information acquisition and use, may change the way executives conduct environmental scanning (using EIS) in the future (Tan et al., 1998). Nonetheless, executives will still need to interpret the cues so that they can develop appropriate strategies for addressing the future impact of these cues.

CONCLUSION

The accessibility, navigation, and management of strategic data and information for improved executive decision-making is becoming *critical* in the new global business environment. As decision-making is being facilitated from anywhere at any time, future EIS development will be significantly impacted. This is an important consideration as there is an need for EIS to effectively facilitate SQ for executive decision-making.

Chapter Summary

In this chapter the concepts of strategic information, EIS and SQ were discussed. A survey of EIS in organizations in South Africa and Spain was undertaken to identify the nature and sources of information included in the surveyed organization's EIS. The implications of this information for SQ for executive decision-making was then discussed. Some practical implications for future EIS development were given. Future EIS trends were then noted.

Key Findings

Four key findings from this EIS research can be summarized as follows:

- In both the South African and Spanish studies, external information (e.g., trade/industry, external news services, competitors, and stock exchange prices) in EIS have low internal presence.
- In the South African and Spanish studies, there are similar trends in how information (e.g., by products, operational areas, and geographical areas) is held by EIS in an organization.
- Holding strategic planning information in EIS in organizations in South Africa appears to have higher importance than holding production information. In organizations in Spain, the converse holds true.
- When compared to organizations in South Africa, there is a higher presence of holding soft information in EIS in organizations in Spain but this is less than when compared to organizations surveyed in North America.

Management Implications

Web-based systems which began to emerge in the mid-1990s, deliver business applications via the Internet. Many of the innovative and strategic systems found nowadays in medium and large organizations are Web-based. Using their browsers, employees in organizations collaborate, communicate and access vast amounts of information by means of Web-based systems. There is therefore both scope and need for research in the particular area of EIS being impacted by Web-based technologies. Executives need systems that provide access to accommodation and assimilation information so that they can interpret the cues from this information and formulate strategies for addressing the future impact of these cues.

EIS are becoming more enterprise-wide with greater decision support capabilities and also gaining in intelligence through the use of intelligent software agents. EIS are going through a major change to take advantage of Web-based technologies in order to satisfy sense-making information needs of an increasing group of executive users. As these users need IS that provide access to diverse types of strategic information which may be scattered in both internal and external environments, there is also a need for research in the area of managing future EIS development so that SQ for executive decision-making is in manifested in these SIS.

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Chapter 4.7

Using Information Technology for Strategic Growth from Single-Mission Transportation Company to Multi-Faceted Global Logistics Corporation

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ORGANIZATION BACKGROUND

The brainchild of Chairman and CEO John A. James, **O-J Transport** acquired its name from the first initials of James' surname and that of Calvin Outlaw, his paternal uncle and co-founder. They started the company during a time when very few, if any, minorities were involved in the transportation industry in the United States because of widespread discriminatory practices. From humble beginnings, they migrated north from rural Mississippi to find jobs in the automotive industry—James in labor relations at Chrysler Corporation and Outlaw as a mechanic at Hertz Truck Rentals. Serving as president and vice-president, respectively, of the embryonic business, James and Outlaw possessed complementary business styles that contributed greatly to the success of the company.

Significantly, O-J Transport grew out of another minority business, Skypak, a malt liquor distributorship that needed a common carrier to transport its products from Milwaukee, WI, to Detroit, a niche that James used to his advantage while employed in Labor Relations at Chrysler. This need provided the opportunity for him to fulfill a lifelong ambition, that is, to go into business for himself, according to James (interview, March 14, 2006). Little did he know, however, that the trucking industry was "a closed entity" that was heavily regulated; consequently, the greatest challenge was to obtain licensing authority to enter the business before being able to compete with the "insiders" on an uneven playing field.

Shortly after incorporation of the company, the owners of O-J Transport discovered that they needed to file an application for an operator's license with the Interstate Commerce Commission (ICC), a government agency formed during the latter part of the 19th century to regulate railroads. Later, in 1935, it began regulating the trucking industry. To James' dismay, O-J Transport received only temporary authority—180-day permits—while the application was pending approval. These permits allowed transportation of malt liquor from Milwaukee to Detroit but prevented a backhaul of goods on the return trip. This process, that is, hauling one way and returning with an empty truck, was called "deadheading" (interview, January 5, 2007) according to James; and it limited his ability to do "serious borrowing" (Booth, 1983, p. 60) to expand the business.

Determined to increase his profit margin, and thereby grow the company, James surmised that he needed either to haul beer in a westward direction or to transport a totally different commodity. Realizing the potential for profitability in Detroit—the automotive capital—James made a strategic move in 1972 when he contacted several of the large auto manufacturers soliciting their business to backhaul automotive parts in addition to seeking their support for common carrier certification from the ICC. American Motors, the smallest of the Big Four car manufacturers at the time, was the first company that he approached; but they were reluctant to enter uncharted territory, that is, allowing an African American into the all-white trucking industry, unless General Motors, Ford or Chrysler were willing to support the application as well. After literally knocking on doors at General Motors for several months with no success, and being told that they were satisfied with using the existing carriers, James went the World Headquarters of Ford Motor Company where he met Harvey Warburton, supervisor of transportation analysis.

Impressed with James' integrity and honesty, Warburton (interview, July 23, 2007) not only pledged Ford's support but also suggested that he retain a transportation law attorney if he intended to challenge the ICC's ruling. Providing assistance in this effort, he offered three names, from which James chose Robert McFarland, a young attorney at the beginning of his career in 1972, who has continued to represent James in legal battles related to his businesses over the ensuing 34 years. Armed with support from American Motors and Ford Motor Company, along with General Motors who later signed on, O-J Transport filed application for permanent authority with the ICC in 1972 with Atty. McFarland as counsel. This was the beginning of a protracted legal battle of denials, partial orders, reversals, reconsiderations and appeals that were costly and time-consuming and that spanned several years.

Following denial of more than seven applications, the ICC finally granted partial authority in 1973. But the battle was not over. Essentially the decision was overturned, prompted by protests from over twenty-five of the largest trucking companies in the United States claiming that O-J Transport must show the need for its service by proving "public convenience and necessity," a legal maneuver designed by the ICC to favor those protected by a "grandfather clause" in the trucking industry. Essentially the ICC "grandfathered" in anyone already in the business back in 1935 and issued certificates; however, anyone desiring entrance afterward had to apply for permission, with the burden of proof being on the applicant to prove a public need for their service (interview with Attorney McFarland, March 15, 2006). Regardless of letters of support from prospective customers, such as Ford and General Motors, O-J Transport had to fight against protests from those in the trucking industry determined to keep African Americans out. Such hostility was displayed most graphically when one of O-J Transport's trucks was torched about one-and one-half block from James' home. According to Attorney McFarland, this act of vandalism was a "message from someone about what we were trying to do."

The years during the early 1970s proved to be trying times for the company financially. Seemingly outnumbered by giants in the trucking industry, James could have given up the struggle. Undeterred, however, he tenaciously used what could have been a stumbling block as a stepping-stone not only to survive but to thrive. Through sheer determination, hard work, and sacrifice, James sought to further his business interests when he set out to prove not only the need for the services of O-J Transport but also to open the doors of the transportation industry for other minority carriers throughout the United States. Therefore, in 1976, he appealed his case all the way to the U.S. Supreme Court. However, in its decision the Court remanded the case to the Sixth Circuit Court of Appeals, stating that authority should be granted by the legislature (Spink, 1977).

Concurrent with the ICC challenge, for several years O-J Transport was also pursuing operating authority from the Michigan Public Service Commission (MPSC) to transport auto parts within the state. Though this intrastate application was also protested by large trucking companies, the MPSC ruled in favor of O-J Transport with the issuance of the MPSC Common Carrier Motor Certificate in 1978. This decision received nationwide publicity, earning O-J Transport the distinction of being the first African American trucking company to be granted intrastate authority by the MPSC for transporting automobile parts, a feat that ICC Administrator Bernard Gaillard heralded as "a giant step" for the trucking industry. He stated further, "I applaud your persistence and fortitude … which will benefit minority truckers throughout the State of Michigan" (letter to James, January 26, 1978). Later that year, James quit his job at Chrysler and took the first step to expand his company when he purchased the Hertz Trucking Company site where his uncle, Calvin, previously worked as a mechanic, establishing O-J Transport's first terminal. The company's new home was equipped with modern office facilities, complete maintenance service, and a fully fenced yard for its equipment. James also bought 23 used trucks from Ford Motor Company. In 1979, Ford assisted in his entrepreneurial venture by providing him with twelve diesel tractors and the services of a consultant (letter of thanks from James to Ford Motor Company president, October 29, 1979).

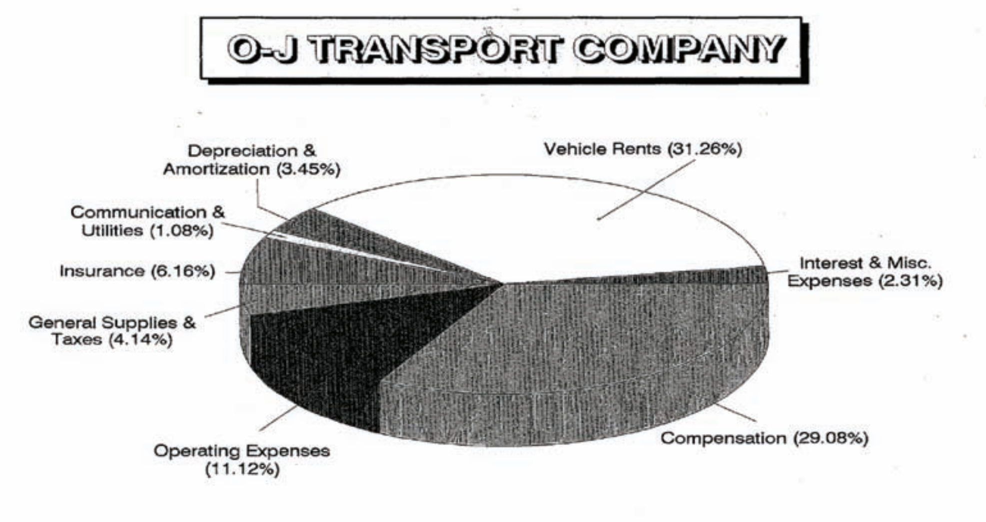
In the ensuing years, after more than 16 additional applications to the ICC were denied, O-J Transport was finally granted permanent carrier authority, but only after the Interstate Commerce Act was amended and greatly liberalized to include within its National Transportation Policy the participation of minorities in the transportation industry. This landmark legislation, S. 2245, the Motor Carrier Act, was signed by President Jimmy Carter in 1980, essentially disbanding the ICC. This was not only a benchmark date for O-J Transport but also an historic moment for the United States. In the summer of that year, President Carter's Assistant, Anne Wexler, wrote on behalf of the President a letter of appreciation to James for his "contribution to this landmark legislation" (letter dated July 1, 1980). Despite what to some would have been considered setbacks along the way, James used these potholes in the road to success to propel him toward his destiny in the automotive supplier industry.

Consequently, rising from its humble beginnings with one Ford heavy-duty truck and annual sales of less than $50,000, O-J Transport by the late 1980s had developed into a multi-million-dollar corporation. As a full-time, Tier I auto parts carrier, it continued to thrive, with Ford Motor Company as the major customer. By 1986 O-J Transport owned a dispatching facility conveniently located in the I-75 and I-94 interchange area. This 10.5-acre-facility also featured a rail spur and a 30-ton gantry crane with piggyback rail shipping capabilities and a warehouse with 90,000 square feet of capacity. Possessing a vast fleet of over 300 multi-axle tractors and trailers with a wide variety of features such as drop-frame jumbo vans and side-unloading trailers, O-J Transport was poised to meet its customers' needs. As a U.S. Customs bonded carrier, the company was able to handle shipments from Canada and other foreign shipping ports. This success resulted, largely, from the leadership, managerial expertise and exceptional entrepreneurial skills of James, whose former administrative assistant, Gerri Carter, describes as a "genius" and a "visionary" who envisioned where the company could go and "just made it happen" (interview, April 25, 2005).

But this success was punctuated by loss. Following a lengthy illness, Calvin Outlaw, James' uncle, passed away in 1998. Earlier in the 1990s, the Big Three automakers—General Motors, Chrysler and Ford—adopted "lean production" systems, that, according to Charles Hill (2005), were based upon "innovations that reduced setup times for machinery and made shorter production runs economical (p. C51)." Lean systems, therefore, yielded increased "gains in productivity" and quality of products. Within this same timeframe, auto manufacturers also encouraged their suppliers to locate their facilities in proximity to assembly plants. This practice allowed delivery of inventory to the assembly line on a "just in time" basis. As a supplier, James had to "step up to the plate" to remain competitive; therefore, he implemented both the lean systems and "just in time" inventory with remarkable success. As a result, business increased. According to Stephen Larson, manager of the supply diversity program at Ford, O-J Transport at one time during the early 90s "hauled more loads for Ford than any other carrier in the country" (Interview, January 12, 2007). From 1979 to 1993 the company's business with the Big Three automakers steadily increased, with Ford Motor Company having the lion's share of O-J Transport's business. Revenues increased phenomenally from approximately $1 million in 1980 to over $12 million by 1988. By 1992, the company reported revenues exceeding $29 million (James Group International Archives, January 2007). Because of the lack of information technology (IT) capability, that is, only a little more than one per cent of the budget being allocated to communications in 1993 (see Figure 1), James mainly outsourced IT services to its customers. This situation would change dramatically when the company later expanded.

Following a downturn in the trucking business by the mid-1990s, James strategically changed the direction of the company from its original designation as a single-mission trucking company and expanded its capabilities into a full-service firm. His diversification included the formation of several companies, and during the latter 1990s the firm evolved to become The O-J Group, a multi-service transportation and logistics enterprise encompassing six units with divisions in ocean, land, logistics, assembly, import and export, and supply chain management. James sold the trucking portion of the business because of lack of profitability. By 1997, reported revenues for the O-J Group were $52.3 million, and, as Ron Butler, executive director of administration reports (interview, November 2007), the company has been listed every year since in *Black Enterprise Magazine* among the Black Enterprise Top 100 "Service/Industrial" Businesses. Through several strategic moves James continued to expand the company; consequently, by 2002 the O-J Group had expanded and evolved to become James Group International (JGI), a global logistics corporation with domestic operations in Michigan (Detroit and Warren) and Park City, KY. Currently, it also ships out parts to over twelve countries, including Japan, Venezuela, Australia, Brazil, China and South Africa. Listed below are the companies that comprise JGI and the dates they originated:

Figure 1. O-J Transport budget with IT allocations, 1993 (Source: O-J Transport Archives, 1993)



- 1991 — **Motor City Intermodal Distribution (MCID)**, a marine terminal and Foreign Trade Zone company involved in truck, rail and sea operations.
- 1993 — **Motor City Logistics (MCL)**, a warehousing and parts sequencing operation in Romulus, MI, that receives auto parts from Asia. These parts are then deconsolidated and shipped to customers across the United States. Bowling Green, Kentucky, is the site of a more recently built MCL facility involved in receiving, warehousing, and sequencing Corvette headlamps for General Motors. Accommodating GM's just-in-time requirements, MCL is located near the Corvette plant.
- 1998 — **Renaissance Global Logistics (RGL)**, a global consolidation operation that packs and exports automotive components, as CKD (complete knock-down), to South Africa, South America, Australia, Asia Europe, and other foreign countries.
- 2000 — **JASCO International**, a joint venture with Sumitomo Corporation of America and Sumitrans which currently has three operations—two deconsolidation centers for inventory arriving from Japan, Malaysia, Spain, the United Kingdom and Korea; and a sub-assembly operation in Park City, KY.
- 2001 — **Motor City Express (MCX)**, an operation providing truckload transportation services.

The flagship company of JGI is Renaissance Global Logistics (RGL), a 400,000-square-foot warehouse facility located in Detroit's Empowerment Zone, a designation by the government to "empower" desolate, blighted areas of the city (called "brown fields") that had been abandoned by industry. Desiring to stimulate business in the empowerment zone, Ford Motor Company selected JGI to undertake the operation. When JGI acquired the contaminated property, it was a trash dump surrounded by desolation and neglect. Through his acquisition and development of the land as well as the establishment of RGL with over 400 employees, however, James initiated an economic revival in the area. Being the first to locate in and rebuild this previously neglected area, JGI began a "renaissance" in business revitalization with RGL that prompted other companies, such as Federal Express, Vitech, Hispanic Manufacturing, and Johnson Controls, to establish facilities there.

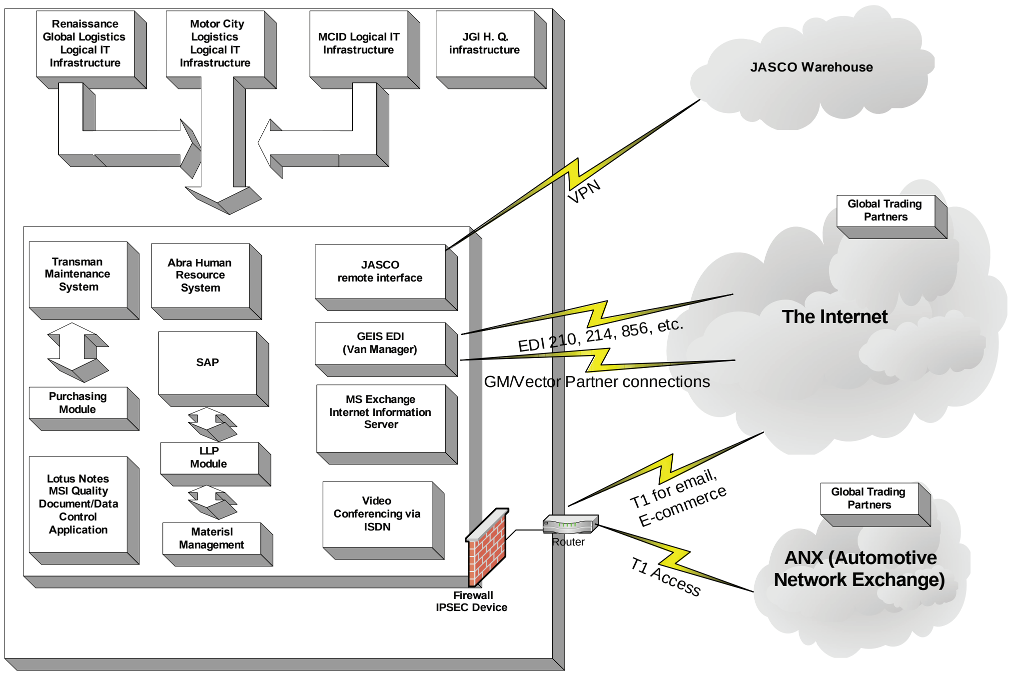
SETTING THE STAGE

When the company began in 1971, it had only one employee and two pieces of equipment, a tractor and a trailer. However, as the company grew management recognized the importance of IT. By 1986, the office support team was equipped with electronic scheduling, tracking and billing systems. And the trucks were stocked with cellular phones to support "just-in-time" product delivery. In 2000, the company adopted OmniTRACS, a mobile communications system that uses mobile, two-way satellite technology to support text messages between drivers and dispatchers. In 2002, JGI purchased a major information system: an enterprise resource planning (ERP) system. The IT director selected SAP R3 with the hopes that it would enable JGI to become a leader in supply chain management (SCM).

In addition to using technological advancements to improve employee and company performance, the company also uses technology to improve customer satisfaction. For example, in 2004 JGI implemented an automated real-time vehicle information system (ARVIS), which is an electronic inventory and shipment management program designed to improve accuracy and accountability between warehouses. Accurately capturing shipping information to ensure that customers are not over-billed, the ARVIS system receives customer information through electronic data interchange (EDI). The system uses this information to create advanced shipping notices (ASNs) which it then e-mails to customer destinations before delivery. Providing accurate, timely information, ARVIS enables the customer to develop better strategies to manage its distribution network.

Currently, JGI has two full-time IT personnel. The company maintains its centralized IT infrastructure in-house; only 10 percent of the IT work load is outsourced. Figure 2 illustrates JGI's IT infrastructure. The first four boxes represent the IT infrastructure of the companies that comprise JGI. The middle section illustrates the interaction

Figure 2. James Group International logical IT infrastructure (Source: James Group International Information Technology Department, December 2006)



of JGI's major information systems, including its ERP system (SAP), human resource system and data control application.

Additionally, it depicts the company's use of computer-aided tools such as video conference and EDI, and JGI's use of security measures such as firewalls and virtual private networks (VPNs) to protect transactions between its global trading partners.

CASE DESCRIPTION

The purpose of this study is to assess the level of e-government adoption in JGI, a global, multi-million dollar firm. Although the company has adopted several mainstream systems that support SCM, ERP and EDI, this international powerhouse has yet to take advantage of e-government initiatives. Government-to-business (G2B) services can help companies manage corporation tax, new company registration, contractor registration, government auctions, wage reporting and patent/trademark development. Yet, despite the benefits of G2B, such as faster data transmission, greater data accuracy, and improved clerical efficiency, companies have been slow to adopt this innovation. The literature suggests that G2B adoption is still in its infancy (Devadoss et al., 2002; Mahmood, 2007; Tung & Rieck, 2005). In the European Union (EU), the majority of transactions between government and business are paper-based (ICT 2007). Reddick (2004) states "there is much room for improvement" in the area of G2B adoption (p.74).

The Ministry for Investment, Industry and Information Technology (MIT&I, 2006) suggests that agencies should set a goal of making all interactions between businesses and government possible electronically within the next two years. In an effort to assess the progress of e-government initiatives, several studies have proposed models of e-government development. Hiller and Belanger (2001) explain growth in terms of the major types of e-government relationships, such as government delivering services to individuals (G2IS), government to business as a Citizen (G2BC), and government to business in the Marketplace (G2B-MKT). Layne and Lee (2001) present a four-stage model of e-government growth that includes the following phases: cataloging, transaction, vertical integration and horizontal integration. The first stage involves the agency establishing a Web presence and presenting information online. In the second stage, the agency supports electronic transactions. Vertical Integration enables municipalities to interact electronically with higher levels of government in similar areas, while horizontal interaction refers to integration across various government functions. Windley (2002) proposes an e-government maturity model that includes four levels: (1) simple website, (2) online government, (3) integrated government, and (4) transformed government. The first level is similar to Layne and Lee's cataloging phase; it includes static web pages and downloadable forms. The second level includes e-mails, online payments, online surveys, FAQs, account inquiry, and so forth. The third level includes automated procurement, cross-departmental information sharing, automated advice/problem solving, and Web-based training. The final level, transformed government, supports business process integration and community-centric intergovernmental processes (Windley, 2002).

As aforementioned, the purpose of this study is to assess the level of e-government adoption in JGI. Based on previous research (Alvai & Carlson, 1992; Denzin & Lincoln, 2005; Myers & Newman, 2007), we used employee interviews and company archives to collect data. To obtain general information about the company and the role of technology, the CEO contacted several key employees and set up times for us to meet with them. These interviews were audiotape recorded and then transcribed. To obtain more specific information about the IT infrastructure we interviewed the IT director, James Herrmann. These sessions were conducted over the phone and via e-mail. In addition to interviews, the CEO allowed us to review the company's archives that contain information (files, letters, charts, graphs, etc.) dating back to 1971 when O-J Transport was incorporated.

After applying Windley's (2002) maturity model to the data, it is clear that JGI, like many companies, is at level one. James Herrmann, the current IT director, states "I am not aware of any systems or processes set up for e-government services" (Response to interview questions, November 9, 2007). Herrmann's statement is consistent with the literature. Reddick (2004) identifies the lack of information about e-government applications as a major barrier to adoption. The literature also suggests that a lack of expertise and a limited IT staff minimize e-government adoption (Reddick 2004). Currently, JGI has only two employees dedicated to IT. Considering the complex systems that these two employees maintain, it is understandable that they may not have the time to explore a relatively new initiative such as e-government.

Although JGI does not use transactional e-government services, it does use e-commerce systems. As depicted in Figure 2, the company uses electronic data interchange with its global trading partners. As a result of its e-commerce transactions, JGI has the IT infrastructure necessary to support e-government transactions. The company also has software and hardware that support a large-scale ERP system, and it uses security measures such as firewalls and virtual private networks (VPNs) to secure electronic transactions. Technologically, the company is well equipped to capitalize on the benefits of electronic transactions with the public sector.

According to Mr. Herrmann, JGI does correspond with the government via e-mail. This correspondence suggests the company is beginning to enter the second level of e-government maturity: online government. Makolm (2002) posits that frequently e-government initiatives begin as information applications; however, that is only a starting point since the availability of ample information creates the demand for interaction. Currently, JGI uses the Internet to interact with the government sparingly. However, as public awareness about G2B services and their benefits increases, it is conceivable that JGI will utilize its IT infrastructure to implement e-government initiatives.

CURRENT CHALLENGES / PROBLEMS FACING THE ORGANIZATION

Supply Chain Management

Supply chain management can be described as a path of value creation from basic producer through customer, including all transportation and logistics services that connect them. Several stages are involved in the chain, the first being the basic producer who extracts raw materials from natural resources. The converter is the second stage of product value creation. The third stage consists of the fabricator, or manufacturer, who converts the input into components used by the assembler. Products are then transferred to the retailer and the consumer. Along these stages in the chain, transportation, storage, distribution and warehousing are important—all of which constitute logistics (Finch, 2006). Some companies have their own transportation and warehouse services. However, today, as corporations initiate lean systems, they are outsourcing the services to companies known as "third party logistic[s] firms," or 3PLs. It was estimated two years ago that at least 73 percent of high-volume shippers were outsourcing transportation and logistics services (Hoffman, 2006). Some companies provide a single service, such as warehousing or transportation. James Group International, however, provides all these services along the supply chain.

Transportation Logistics

Common wisdom in the industry is that the transportation infrastructure is aging and needs an overhaul. Logistics costs have risen significantly over the past few years, from approximately $500 billion in 1985 to $1.18 trillion in 2005. Inventory carrying costs rose 17 percent, the largest jump since the 1980s, an increase resulting from higher interest rates and increases in the amount of inventory that companies carry (*Industrial Engineer,* 2006). Also, within the transportation logistics industry there is more integration than ever before. New and better software and communications links on the internet have greatly reduced problems involved with integrating supply chain systems. Today, transportation management systems aggregate data and report it to enterprise resource planning and other applications to provide more complete visibility and control of all information available for logistics decision making (Hoffman, 2007).

Additionally, more 3PLs are offering integrated services as part of their package of services. Consequently, the need for supply chain technology integration has grown, as manufacturers, vendors and retailers seek to use technology to reduce cost and increase response time. The logistics industry has to deal with surging fuel costs, a severe shortage of drivers, escalating security costs, and chronic rail and port capacity shortfalls. According to industry consultants, "everything is going up." As a result several trucking and transportation specialists recommend that transportation companies and shippers work together to improve the efficiency of logistics. Transportation costs are rising faster than rates. Traffic congestion has worsened, adding extra time and higher fuel expenditures. Another factor affecting trucking costs has been the shortage of drivers, a problem that continues to worsen.

E-Government

The General Services Administration (GSA) (2001) states there are several challenges that may hinder the progress of G2B adoption. The first major challenge entails determining who can and should do what. Should initiatives be spear-headed by government agencies or by the private sector? Hence, should government regulations and policies guide e-initiatives or should the needs and resources of the private sector guide the growth and development of electronic interactions? Perhaps the public and private sectors could work together to promote G2B adoption.

Secondly, there are numerous institutional and cultural factors that may hinder the massive systemic change needed to adopt new business practices and business models (GSA, 2001). If necessary, is JGI ready to re-engineer its business process to take advantage of e-government services? Simply automating existing processes may not be the most efficient and effective way to employ this innovation. JGI should be willing to re-evaluate its procedures and implement strategic changes to capitalize on e-government technology.

In addition to institutional and cultural challenges for the private sector, there are also several issues that the public sector must consider. For instance, are government agencies willing and able to provide intuitive, seamless e-services that are easy to adopt? E-government Web sites should be designed so that even novice computer users can find information and complete transactions. These sites should be accessible to people with disabilities. Indeed, those with special needs should be able to access e-government services as readily as the non-disabled. The sites should also be interoperable (Fang, 2002) and provide links to other relevant, up-to-date e-government websites. Government agencies should work together to present a unified and accurate system to its constituents. Moreover, businesses should be able to easily navigate government websites without encountering broken (out-dated) links.

Finally, once government agencies make e-services available, they still must establish initiatives that promote awareness and adoption. Previous studies have focused on e-service adoption by small and medium-sized firms (Reddick, 2004). However, few studies have explored the adoption of G2B in large firms. As indicated by this study, although large firms may have an IT infrastructure that's capable of supporting e-government, many IT directors are not aware of these services and their benefits. Government agencies may want to provide face-to-face and web-based training on their electronic options for business.

CONCLUSION

In their ongoing quest to deliver supply chain and logistics services to the transportation industry, the James Group International group of companies must face these challenges that plague the industry and meet the ever-changing needs of its customers in America and abroad to compete in these dynamic times. The company must be flexible, adjusting to the needs of customers as well as changes within the transportation industry. Based on past performance JGI is poised to fulfill its obligations to its customers as well as turn a profit. Featured recently as one of the “champions” among *Black Enterprise Magazine*’s “Top 100 Businesses” (Hughes, 2006), James attributes a substantial growth in revenues to business with foreign as well as domestic automakers. In 2006 JGI was listed as No. 52 on the BE 100’s list with revenues of $78.3 million; while in 2007 the logistics and supply chain giant has moved up to No. 47 with reported revenues of over $88 million (Jefferson & Hughes, 2007). Three of the companies that comprise JGI—RGL, MCX and MCID—are all ISO 9001:2000 MMBDC certified, attesting to the highest quality performance in the industry. Additionally, in 2006 MCX received the “General Motors Global Supplier of the Year Award,” and in 2007 James Group International received what has been touted as the “Academy Award of the Auto Industry”—The Urban Wheel “Supplier of the Year” Award at the North American International Auto Show in Detroit. This track record, along with continuing expansion of and new initiatives in information technology, will enable JGI to remain competitive into the future.

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Chapter 4.8

Adoption and Implementation of IT Governance:

Cases from Australian Higher Education

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ABSTRACT

This chapter introduces key IT governance concepts and industry standards and explores their adoption and implementation in the higher education environment. It shows that IT governance processes, structures and relational mechanisms adopted by these institutions generate value through improvements in a number of key focus areas for IT management. It is hoped that the study will inform both practitioners and researchers and lead to a better understanding of the relationship between IT governance structures, processes and relational mechanisms and business benefits.

INTRODUCTION

Over the past decade, IS/IT governance has become a key issue of concern for senior IT decision makers around the world. The underlying goals for adopting formal IT governance practices are improvement of business performance and conformance with regulations. This exploratory study examines how IT governance is implemented in two Australian institutions through a number of structures, processes, and relational mechanisms and how industry best practice frameworks such as CobiT, ITIL, ISO17799 and ISO/IEC20000 have been utilized in the implementation. The study reveals a number of important findings in the context of the implementation of IT governance in the higher education environment. The relationship between IT governance adoption and implementation and business benefit issues will also be discussed in the chapter. The next few sections of this chapter contains a detailed literature review regarding IT governance, and the important IT related issues in the Australian higher education sector. This is followed by a discussion of the research questions and methodology and then the case study institutions are described. Finally, the findings from the study are presented and the conclusions and directions for future work are discussed.

BACKGROUND

Corporate and IT Governance

Corporate governance has become increasingly important worldwide, especially in the wake of the Enron and MCI WorldCom incidents in the US. The Australian Stock Exchange Corporate Governance Council defines corporate governance as *"... the system by which companies are directed and managed. It influences how the objectives of the company are set and achieved, how risk is monitored and assessed, and how performance is optimised"* (ASX, 2003). IT governance has increasingly become a key area of concern under the umbrella of corporate governance because of the pervasive influence of information systems and the associated technology infrastructure in every area of an organization's activities. The IT Governance Institute describes IT governance as being an integral part of the corporate governance which consists of "the leadership and organizational structures and processes that ensure an organization's IT sustains and extends the organization's strategy and objectives" (ITGI, 2003).

Previous Research in IT Governance Implementation

The term IT governance, started to appear in the research literature towards the late 1990's, with its main proponent being the IT Governance Research Institute (De Haes & Van Grembergen, 2005). Recent surveys suggest that the need to implement and improve IT governance has been receiving growing recognition amongst senior IT management across the world. A survey of top 10 priorities for senior IT management by Gartner Inc. in 2003, found the need for improving IT governance to be included in the list for the first time (De Haes & Van Grembergen, 2004). Surveys of members of the Society of Information Management (SIM) in 2003, 2004 and 2005 also revealed that IT governance was amongst the top ten concerns of IT executives (Luftman, 2005; Luftman, Kempaiah & Nash, 2006). However, implementing IT governance can be an extremely complex undertaking (Brown, 1997; De Haes & Van Grembergen, 2004; Duffy, 2002; Marshall & McKay, 2003; Sambamurthy & Zmud, 1999; Weill & Ross, 2005). In 2003, a survey conducted by the IT Governance Institute through PricewaterhouseCoopers of 335 CEO/CIO level executives around the world showed a lag in practice (ITGI, 2004). The survey found that while 75% executives recognized the requirement for implementing IT governance only 40% were taking any action in this direction. This may be explained by the complexities of implementing IT governance.

While previous research on IT governance implementation focussed on IT governance structures and associated contingency factors (e.g., Brown, 1997; Sambamurthy & Zmud, 1999), later work has identified a number of different mechanisms for implementing IT governance (De Haes & Van Grembergen, 2004; Weill & Ross, 2005). This chapter adapts the framework presented by De Haes & Van Grembergen (2004) to explore IT governance implementations in the higher education sector. Based on the work of Peterson (2004), De Haes and Van Grembergen (2004) propose that IT governance can be implemented through a framework of structures, processes, and relational mechanisms. Structures include the existence of well defined roles and responsibilities and IT steering committees. Processes involve strategic decision making and the use of various IT governance frameworks and standards (e.g., CobiT and ITIL) which can provide the IS organisation with the means of examining its activities and its value to business. Relational mechanisms include shared learning and strategic dialogue between business and IT, and ensuring proper communications at all times.

The structures, processes and relational mechanisms are also divided into tactics or roles and mechanisms or means to implement IT governance (De Haes & Van Grembergen, 2004). For example, the tactics for structures are to form IT executives, committees and councils. The mechanisms are to ensure that there is an IT organisation structure; roles and responsibilities are assigned, a CIO appointed, and the formation of an IT strategy or steering committee. As for processes, the tactics are to ensure that strategic IT decision making and monitoring are formed. This may be accomplished by setting mechanisms such as strategic information systems planning, balanced IT scorecards, service level agreement, COBIT, ITIL and IT alignment of governance maturity models, that would enhanced the processes of implementing IT governance. Finally, relational mechanisms are required to ensure participation from stakeholders, businesses and IT. This is required to ensure an on-going dialogue with the main players. The mechanisms to ensure a smooth running of this include a shared understanding of business/IT objectives, nonavoidance conflict resolution, crossfunctional business/IT training, and crossfunctional business/IT job rotation.

International Standards and Commercially Available Frameworks for IT Governance and Management

A number of IT best practice frameworks and standards such as Control Objectives for Information and Related Technology (CobiT), ISO/IEC 17799, IT Infrastructure Library (ITIL) and Capability Maturity Model (CMM) are available to IT organizations to help them improve their accountability, governance, and management. CobiT is designed by the IT Governance Institute as a high-level "umbrella" framework for IT governance and it works very well with other frameworks like ITIL and ISO/IEC 17799 which focus on specific aspects of IT management. The framework identifies 34 IT processes over 300 control objectives across four IT domains: (1) planning and organization, (2) acquisition and implementation, (3) delivery and support, and (4) monitoring (ITGI, 2000; 2005). The planning and organization domain addresses strategic and tactical issues and how IT can optimally contribute to achieving business goals. The acquisition and implementation domain deals with the development or acquisition of IT solutions, as well as their implementation and integration with business processes. This domain also covers the maintenance of existing systems. The delivery and support domain covers the actual delivery of services ranging from security and continuity related operations to training. Support processes are required to ensure the delivery of services. The monitoring domain addresses the issue of management oversight of the organization's control processes and the need for independent audits. The IT Governance Institute has recently published the fourth edition of CobiT, the first update since 2000. It is described as an incremental improvement on CobiT 3.0 and provides a number of useful additions to the older version (Bodner, 2006; Symons, 2006).

The IT Infrastructure Library (ITIL) is a comprehensive documentation providing guidance regarding best practices for IT service management (ITIL, 2007a; 2007b). The Central Computer and Telecommunication Agency (CCTA) in the UK established the Information Technology Infrastructure Library (ITIL) in 1989 (Sallé, 2004) in order to improve its IT organization. At present the UK's Office of Government Commerce (OGC) is responsible for managing ITIL. ITIL is also supported by the IT Service Management Forum (itSMF). In 2000 the OGC, in collaboration with the British Standards Institution (BSI) and itSMF, revised ITIL in order to integrate it with the BSI Management Overview, the BSI specification for service management (BS 15000-1) and the BSI code of practice for service management (BS150000-1) (ITIL, 2007a). The BSI Management Overview provides a high level introduction to ITIL, while the ITIL books expand on the information and provide guidance regarding the subjects addressed within BS150000. BS15000 has now been replaced by ISO/IEC 20000:2005. Like its predecessor, ISO/IEC 20000 is a two part standard (1SO, 2005a). The first part specifies requirements for IT service management while the second part provides a code of practice. The ITIL documentation, now available in version three, takes a lifecycle approach to guidance (ITIL, 2007b). It is organized around five core titles: (1) Service Strategy which provides a view of ITIL that ensures that all elements of the Service Lifecycle is focused on customer outcomes, (2) Service Design which provides guidance for producing and maintaining IT architectures and policies and documents for designing appropriate IT infrastructure service processes and solutions (3) Service Transition which provides guidance for the transition of services in the business environment, (4) Service Operation which details control and delivery activities for achieving excellence in daily operations, and (5) Continual Service Improvement which focuses on the process of identifying and introducing improvements to service managements.

Another standard that can be implemented alongside CobiT and ITIL is ISO/IEC 17799:2005 (expected to be renamed ISO/IEC 27002 in 2007/08). The standard was originally developed from BS 7799 which provides a code of practice for developing information security standards in an organization (ISO, 2000). However, unlike CobiT and ITIL, it was not designed to be a certification standard. It has recently released a companion standard, ISO/IEC 27001 that can be used for the purpose of certification instead of the older and superseded BS 7799-2 on which it is based (ISO, 2005b). A new risk management standard BS 7799-3:2006 is also presently available from the British Standards Institute. This standard provides support and guidance for the risk management aspect of ISO/IEC 27001:2005.

In addition to these frameworks and international standards, Australian organizations have three local standards available to guide their IT governance and management practices. These are AS 8015-2005 (ICT governance standard), AS ISO/IEC 20000.1-2007 (specification for ICT service management) and AS ISO/IEC 20000.2-2007 (code of practice for ICT service management).

The ICT governance standard, AS 8015-2005, provides a set of guiding principles for senior business decision makers regarding the effective and efficient use of information and communication technology (ICT) within their organizations, irrespective of the industry sector. The standard addresses the governance of ICT resources for the provision of information and communication services within the enterprise (Standards Australia, 2005). The standard is currently in the process of being developed into an international standard. It has been accepted as a Draft International Standard (ISO/IEC DIS 29382) by the ISO in early 2007 (ISO, 2007).

Standards Australia (2007a; 2007b) provides a two part service management standard AS ISO/IEC 20000-2007. The first part (AS 20000.1-2007) outlines the requirements that a service provider needs to fulfil in order to deliver an acceptable quality of managed service to customers, while the second part (AS 20000.2-2007) recommends a common terminology for IT service providers, so that effective processes may be established. AS 20000.1-2007 is identical to ISO/IEC 20000.1-2005 and AS 20000.2-2007 is identical to ISO/IEC 20000.2-2005. They supersede AS 8018.1-2004 and AS 8018.2-2004.

Implementation of these frameworks may vary from one region to another. A recent Forrester Research survey of 135 IT managers in North America revealed that about 20% rely on CobiT while another 20% use ITIL (Dubie, 2005). A survey of 110 respondents by Cater-Steel and Tan (2005) at a recent Australian itSMF conference showed that while all respondents were at different stages of implementing ITIL, less than a third are also implementing CobiT. These frameworks are not necessarily mutually exclusive and increasing the value of IT from a business perspective requires an understanding of their strengths, weaknesses and focus (Symons, 2005). IT governance frameworks are being increasingly adopted around the world because they not only assure conformance with regulations but also help in ensuring performance (Liew, 2006). Organizations may benefit from adopting what they find useful from each framework rather than just adopting a single one (Chickowski, 2004).

There are, however, very few academic publications examining the issues and problems with the adoption and implementation of these frameworks and standards. Ridley, Young, and Carroll (2004) found that this to be particularly true in the case of publications related the CobiT framework, a majority of which tend to be practitioner publications. Cater-Steel and Tan (2005) make a similar observation regarding the available publications on ITIL.

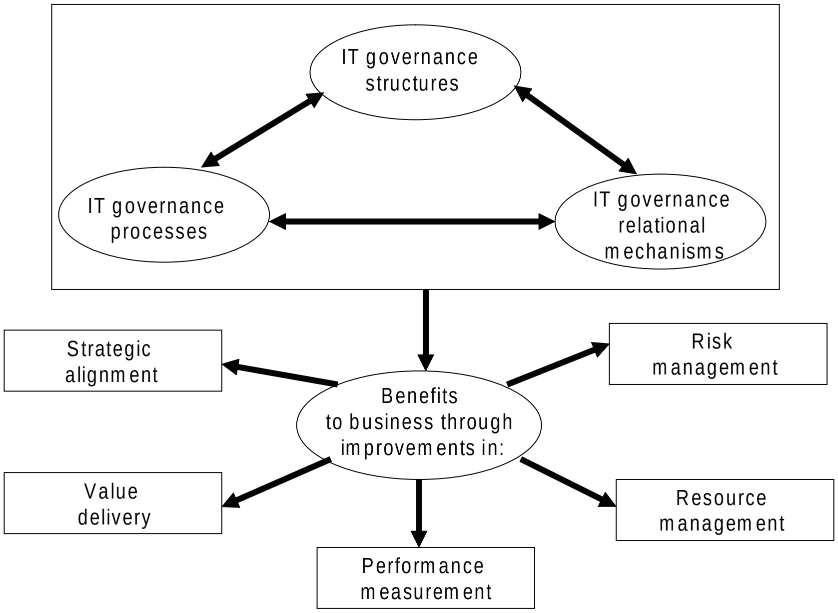
Emergent Framework of IT Governance Mechanisms and Focus Areas

The IT Governance Institute has identified five focus areas of IT governance (ITGI, 2005): (1) strategic alignment, (2) value delivery, (3) resource management, (4) risk management, and (5) performance measurement.

According to ITGI (2005, p. 6): Strategic alignment is about ensuring the linkage of business and IT plans; on defining, maintaining and validating the IT value proposition; and on aligning IT operations with enterprise operations. Value delivery is about executing the value proposition throughout the delivery cycle, ensuring that IT delivers the promised benefits against the strategy, concentrating on optimising costs and proving the intrinsic value of IT. Resource management is described as the optimal investment in, and the proper management of, critical IT resources in applications, information, infrastructure and people. Key issues of resource management relate to the optimisation of knowledge and infrastructure. Risk management is concerned with risk awareness by senior corporate officers, understanding of compliance requirements, transparency about the significant risks to the enterprise, and embedding of risk management responsibilities into the organisation. Performance measurement is about tracking and monitoring strategy implementation, project completion, resource usage, process performance and service delivery, using, for example, balanced scorecards that translate strategy into action to achieve goals measurable beyond conventional accounting.

The two primary concerns of IT governance, value delivery and risk management, are driven by strategic alignment and accountability concerns respectively. Both require adequate resources and need to be measured against the objectives of the business.

Figure 1. The emerging IT governance and business benefits framework



The emergent framework as illustrated in Figure 1 combines the framework of De Haes and Van Grembergen and the IT governance focus areas. In order for a business to be effective, the framework indicates that an organization's IT governance structures, processes and relational mechanisms must be set in place.

As mentioned previously, IT governance structures identify various roles and responsibilities in the context of IT governance in an organization (De Haes & Van Grembergen, 2004). Processes describe how those with appropriate responsibilities are involved in the governance rather than the day-to-day operational management of IT. Relational mechanisms ensure the success of structures and processes by addressing ways of improving the relationship between business and IT (De Haes & Van Grembergen, 2005). This suggests a dynamic relationship between these three components of IT governance as shown in Figure 1. Optimizing the balance between structures, processes and relational mechanisms could lead to substantial benefits for business through improvements in the five focus areas of IT governance identified by the IT Governance Institute (ITGI, 2005).

This study uses the framework presented in Figure 1 to explore the IT governance implementations in two institutions of higher education.

IT Governance in Australian Institutions of Higher Education

Higher education is a multibillion dollar industry in Australia, and as such, it is of vital importance to the country's economy (Higher Education IT Consultative Forum, 2000; Nelson, 2002). It is both a major consumer of IT products and services as well as a major provider of services using ICT. IT has helped the improvement of a range of activities including research, teaching, learning and administration in the higher education environment. Significant developments have been made by these institutions in the area of online teaching and learning. The demand for IT based products and services, has also increased as a result of the rapid increase in student population in the last 15 years.

There is much work that needs to be done by university governing bodies and policy makers in order for these universities to continue tapping emerging information technologies in order to maintain their competitive positions internationally (Higher Education IT Consultative Forum, 2000). The issues range from infrastructure, applications, delivery and services to staffing and appropriate regulatory frameworks. IT applications have also not yet penetrated all aspects of university teaching and more effort is required to bring about improvements in this area. However, despite the wide range of concerns facing IT governing bodies in Australian universities in the information economy, there has been very little research regarding how IT governance may be suitably implemented in these institutions in order for them to provide optimal benefits to higher education.

RESEARCH QUESTION AND METHODOLOGY

The chapter investigates the adoption and implementation of IT governance in two Australian institutions for higher education. The research question is:

How is formal IT governance adopted and implemented within the higher education environment in Australia?

As suggested by Benbasat, Goldstein, and Mead (1987), the case research method is useful for addressing the "*how*" questions, that is, in the exploratory stage of knowledge building. This is particularly useful for a study on IT governance in the context of institutions of higher education in Australia, where the knowledge of researchers regarding new methods, techniques, problems and prospects lags that of practitioners. A case research strategy is expected to provide rich insight in this context.

Two leading institutions of higher education in Australia in different stages of adopting and implementing formal IT governance practices were selected for the study based on the availability of senior IT and business decision makers in these institutions for participating in this research. The study was undertaken in 2006. In keeping with participants' requests for anonymity, the institutions will be referred to as Institution A and Institution B in this chapter. The data collected was primarily qualitative in nature. The data was gathered from semi-structured interviews with senior IT and business decision makers in both institutions as well as from relevant documents obtained from interviewees and the websites of the institutions. The interviews were recorded and later transcribed and analysed. The data sources from the institutions are summarized in Table 1.

Table 1. Data sources from the two case study institutions

Institution	Interviewees	Documents
Institution A	- 2 senior IT decision makers - 2 senior business decision makers	- Overall strategic plan and strategic IS plan - Disaster recovery plan - Organizational chart and committee structures - Security policies and procedures - Personnel statistics - Student satisfaction surveys
Institution B	- 2 senior IT decision makers - 1 senior business decision maker	- Overall strategic plan and strategic IS plan - Proposed IT governance model - Organizational chart and committee structures - Security policies and procedures - Personnel statistics

THE CASE STUDY INSTITUTIONS

Institution A was established in the 1960's. The institution has over 3,000 academic and administrative staff members and over 30,000 students. Its primary goals are to achieve excellence in teaching, learning, research and development. Its present priorities include providing flexible learning opportunities, developing facilities and technological infrastructure to support research priorities, forming partnerships with industry and government and improving its revenue generation. The institution has an overall strategic plan as well as a number of divisional plans and maintains a balanced scorecard. It has six academic divisions which are subdivided into several schools, centres and departments, as well as a number of support areas including central IT services, finance, and student and staff services. The institution is publicly funded, with annual revenue of around A$400 million, 10% of which is spent on IT. The institution's IT history began in the 1960's, with the acquisition of a computer for the mathematics department. In the early 1970's, a computer system was installed primarily for teaching purposes. This was followed by the in-house development of an accounting package, signalling the first move towards corporate applications. The institution decided on continued development of both teaching and administrative applications, although these were to be handled separately. Since the various teaching and administrative divisions had specific application needs, the decisions regarding the procurement or development of applications lie with the divisions. In the late 1980s the institution received its first Australian Academic and Research Network (AARNET) connection and the use of email followed soon after.

Institution B was established in the early 1900's. It has over 2000 academic and administrative staff members and over 16,000 students. Like Institution A, it aims to advance teaching, learning and research. It has nine academic divisions and a number of support areas. The institution has an overall strategic plan and a number of divisional plans. The publicly funded institution's annual revenue is around A$500 million about 1.5% of which is spent on central IT and about 4.5% across the divisions. Divisional IT services and the library have separate IT budgets. Historically IT has been devolved to central administration, the academic divisions and the library.

In 1999 Institution A had an ICT review conducted by an external consulting firm. The review identified a devolved IT structure. A number of key issues including the negative impact of divergent IT directions in the divisions on overall corporate effectiveness, inadequate strategic planning and coordination related to ICT across the institution, inadequate ICT resources and lack of leadership at the senior level of senior management were reported in the review. As a direct result of the 1999 review, they adopted CobiT in the year 2000 to evaluate the current IT processes within the institution.

Institution B has recently adopted a formal IT governance model. In early 2006 they commissioned a new Strategy Manager and Director of IT to set up their IT governance model with an aim to centralize their IT governance structure. The next three sections explore the adoption and implementation of IT governance through a mixture of structures, processes and relational mechanisms in these two institutions.

As proposed in Figure 1, the institutions implement IT governance through a combination of structures, processes and relational mechanisms in different focus areas.

IT GOVERNANCE STRUCTURES

IT governance structures include clearly defined roles and responsibility of IT executives to manage the IT structure within the organization (De Haes & Van Grembergen, 2004). This may include setting up of IT committees to oversee various IT strategies and functions of IT within the organization.

Institution A

Currently, Institution A has about 200 staff members employed in the IT area. Of the 200 staff members, 100 are located in the central IT services and the other 100 within the divisions. Despite the observations made in the 1999 review it has not been possible to integrate the ICT across the institution into a single unit due to lack of an institution wide support for such a change. However, some enterprise wide standards for ICT have been developed and the need for compliance by the divisions has been recognized. Duplication of some services across the divisions remains a cause of significant concern and it is believed that considerable cost savings could result from avoiding such duplication.

Institution A has a formal reporting channel whereby the Director of central IT services reports to the Pro-Vice Chancellor. The role of the Director is primarily that of a technology professional though there is a growing realization of the need for the role to be more business oriented. The Director of central IT oversees three Associate Directors who are responsible in the infrastructure, applications and services areas respectively. A recent development has been the formation of the IT strategy committee, which reports to and advises the institution's planning and management committee. The IT strategy committee in its present form was established in mid 2005. It currently includes the Director of central IT services, representatives of all divisional IT groups, the Director of Finance, representatives from R&D, the Pro-Vice Chancellor and key stakeholders. The committee makes recommendations regarding the alignment of ICT with the goals of the institution, monitors the activities of the central and divisional IT service providers and fosters effective communication amongst them.

The formation of the IT strategy committee in mid 2005 and the development of the enterprise wide standards reflect the recognition by senior business and IT decision makers of the need for a formal IT Governance model to support a centralized decision making structure. The shift from a devolved or decentralized IT structure to a centralized structure in Institution A is consistent with the results of a survey by Mendez (2005) of IT executives in Europe which showed a significant shift in the IT organization structure from decentralized or federated models to centralized ones.

Telecommunication and network related decision making in the institution has been centralized since the beginning. However, this has not been the case with desktop computers and servers because of the IT revolution in the 1980's. This has continued to this day, resulting in the institution's federated IT organization structure. There are six divisional IT groups which manage their own servers and desktop PCs independently of central IT. The divisional IT groups have independent funding and decision-making structures from central IT. Although they provide the same kind of services as the central IT group, their standards and practices may vary from those of central IT. Over the past year central IT has moved towards developing good relationships with divisional IT managers. This has helped in the achievement of some alignment between the central and divisional IT groups.

Institution B

In Institution B, there are about 70 IT staff in central IT and a similar number spread over the nine divisions and the library. As in the case of Institution A, this structure has led to considerable duplication of IT staff efforts. IT has five major areas – administration including budget and staffing, strategy and governance, client services including desktop and student Internet support, systems services including database support and systems development, and technical services looking after network and servers. The managers of these areas report to the Director of IT who reports to the Director of Finance.

Unlike Institution A, the role of the Director of IT in Institution B is that of a general business manager rather than a technology professional. This shift in the role for the Director of IT was decided in 2005 by the new Director of Finance based on his experience in the resources sector. It was believed that the position of the Director of IT required someone who clearly understood the business needs of the institution and has an overall technology focus.

A formal IT governance model specifying the various roles and responsibilities based on CobiT 4.0 was adopted at the beginning of 2006 when the new Strategy Manager was appointed. This model is now in the process of being implemented. The adoption of the model has led to a significant improvement in the involvement of business in IT decision making. The IT steering committee is expected to meet on a quarterly basis and provide an opportunity for communication on key IT issues amongst IT and business decision makers. The IT steering committee is advised by a technical advisory group which is comprised of all the central and divisional IT managers. Smaller working groups are also constituted from the divisional stakeholders and central IT staff as and when required for specific projects. The IT Director and Strategy Manager are responsible for decisions regarding standardization of IT infrastructure strategies and architecture. Decisions regarding business application needs are made by business decision makers with input from IT.

A summary of IT governance structures in Institution A and Institution B, based on the De Haes and Van Grembergen framework is shown in Table 2.

IT GOVERNANCE PROCESSES

IT governance processes involve strategic decision making and the use of various performance monitoring frameworks and tools such as Strategic Information Systems Planning, CobiT, ITIL, Balanced Scorecard, Information Economics and others (De Haes & Van Grembergen, 2004).

Institution A

The institution has an overall strategic plan and follows a balanced scorecard. ICT has an ICT enabling plan, which is regularly updated. An important issue in this regard is that this ICT enabling plan is not directly associated with a budget for strategic expenditures. The present budget allocation for ICT is for staff, software licenses, site licenses, and refreshing the IT infrastructure. Although the need for a new document management system has been recognized by both IT and business decision makers, in order for the institution to improve its record keeping, appropriate funds for such procurement are yet to be acquired.

IT management decision making within the institution is influenced by the guiding principles of the Australian ICT governance standard AS 8015-2005 and the service management standards AS 8018.1-2004 and AS 8018.2-2004. CobiT 3.0

Table 2. A summary of IT governance structures in the case study institutions

	Structures	Institution A	Institution B
Tactics	– IT executives and accounts – Committees and councils	– Yes – Yes	– Yes – Yes
Mechanisms	– Roles and responsibilities – IT organization structure – CIO on board – IT strategy committee – IT steering committee(s)	– Yes (evolving) – Yes (evolving) – No – Yes (recent) – No	– Yes (evolving) – Yes (evolving) – No – No – Yes (recent)

has been adopted since the year 2000 for assessing and improving the institution's IT governance processes. A direct effect of this has been the realization by senior IT decision makers that the effective utilization of CobiT across the institution requires a more centralized IT governance environment. However, given the size of the CobiT 3.0 framework, only a small number of processes and objectives are identified for review each year. The objectives were initially based on a large number of interviews conducted across the campus in 2000 by IT staff. In subsequent years, objectives have been identified based on the original interviews and results of an annual survey of student and staff satisfaction on IT issues.

ITIL is used as the standard for service management. A number of operational level staff members have ITIL Foundation level training. The current focus is on getting better at incident management, change management, problem management, IT strategic planning and managing the IT architecture. The progress made has also been assessed against CobiT and ITIL. Consultative, Objective and Bi-functional Risk Analysis (COBRA), a software package, based on ISO17799 is being used for facilitating risk management.

Since CobiT requires the use of a standard project management methodology, Project Management Body of Knowledge (PMBOK) has been selected as the guide in this regard. Based on the perceptions of business decision makers, in the last two years IT has shown considerable maturity in project management and delivery. This is the result of adopting a strong project management methodology.

People Capability Maturity Model (P-CMM) is used as the standard of IT staff management and development. However, a lot of work is required in the area of staff development.

The value to business from the implementation of best practice frameworks has been in terms of reducing the number of ad-hoc processes, bringing a lot of discipline to IT support activities and improving accountability. Whilst IT has made significant strides since the year 2000, the IT management recognizes that there is a long journey ahead.

One problem that has been faced in implementing the best practice frameworks like CobiT, which have high resource requirements, has been the shortage of adequate staff. The demand for staff time and services are also increasing. Most of the central IT teams find it difficult and at times challenging to achieve their operational objectives. Staffing in the server support area, for example, consists of about 10 people supporting 300 servers of various kinds, implementing changes to the infrastructure as well as managing large applications being used by thousands of people. Despite the staffing issue, however, process improvements continue to take place because of the continued commitment of senior IT management.

Another key area of difficulty has been that of finding appropriate performance metrics measurement. Currently, technical measures being used include percentage downtime, percentage access failure, the number of students accessing their email on a regular basis on the official communications channel and so on. One particular measure, the number of available desktops in the computer laboratories per student was found to be not particularly useful. It was found that when the number of desktops was doubled based on survey responses; the satisfaction level was actually lower than in the previous year. Management decision makers in the institution attribute this to the increasing expectations from ICT facilities with the rapid advances technology. The institution continues to work on developing balanced business-IT metrics.

Institution B

While Institution A has been using CobiT 3.0 to evaluate and improve key IT processes, Institution B has utilized CobiT 4.0 to develop its overall IT governance model and outline the various roles and responsibilities. The development of the IT governance model has resulted in substantial involvement of business decision makers in making decisions regarding IT investment, risk and priorities. This has made it easier for business decision makers to appreciate the value of key decisions regarding IT. The initial problem faced in the implementation of the model was the lack of IT governance concepts amongst business decision makers and the resistance to change. This is gradually being overcome and the need for accountability for IT related decision making across the institution is better accepted. This is achieved by communicating to business decision makers their roles and responsibilities in IT related decision making for the benefit of the business, without making it necessary for them to know any technical details regarding CobiT.

CobiT is also being used for risk assessment and management. While ISO17799 provides guidance on what needs to be done in the context of security, CobiT guides management on how these goals should be achieved. The IT security manager has been trained in ISO17799 and will additionally undertake the security management training program provided by the developers of CobiT.

The institution has an overall strategic plan and central IT undertakes strategic information systems planning under the supervision of the IT steering committee. Service level agreements are in place for hosting and managing application systems including the student system, the facilities management system, the HR and finance system.

At present there is a lack of enterprise-wide standards for infrastructure and applications. The key issues that IT intends to tackle over the next year include the lack of standards and controls and the existence of multiple help desks. As part of the central IT service desk project, it is planned to implement ITIL to handle change and incident management over the next few months. As part of the ITIL implementation service desk staff will be required to undertake ITIL Foundation level training. Capability is also being built up in the project management and business process analysis domain to reduce the current dependence on external consultants.

As in the case of Institution A there is difficulty in deciding on which metrics to measure. Current metrics being used include the number of service calls being answered to completion, the number of network and database administrators and the ratio of total IT cost to organizational cost. However, there is a realization that these metrics are not adequate for representing the value of IT to business.

A summary of IT governance processes in Institution A and Institution B, based on the De Haes and Van Grembergen framework is shown in Table 3.

Table 3. A summary of IT governance processes in the case study institutions

	Processes	Institution A	Institution B
Tactics	–Strategic IT decision making –Strategic IT monitoring	–Yes –Yes	–Yes –Yes
Mechanisms	–Strategic IS planning –Balanced IT scorecards –Information economics –Service level agreements –CobiT and ITIL –IT alignment/ governance maturity models	–Yes (improving) –No (some technical measures) –No –No –Yes along with other standards since 2000 –No (considered early days for maturity models)	–Yes (improving) –No (some technical measures) –No –Yes –CobiT with ISO17799 since early 2006 –No (considered early days for maturity models)

IT GOVERNANCE RELATIONAL MECHANISM

Relational mechanisms according to De Haes and Van Grembergen (2004) include shared learning and strategic dialogue between business and IT, and ensuring proper communications at all times.

Institution A

The key stakeholder groups for central IT include teaching staff, students, business process owners, research and development, and divisional IT management whilst those for divisional IT include teaching staff and students. There are efforts being made by central IT to improve the quality and frequency of communications with these groups.

Communications often take place at the tactical level. For instance, if a significant outage of services is being considered, divisional IT contacts and business process owners are informed and their responses are used to guide appropriate decision-making. In case of policy changes, e-mails are sent out by the particular group within IT that is responsible for that policy. The senior IT decision maker responsible for infrastructure also meets with the divisional IT management on a monthly basis. Over the last couple of years there has been emphasis on strategic level dialog. The monthly meetings of the newly formed ICT committee are also helping to improve communications between business and IT. This increased effort made by IT decision makers to liaise with business, has led to a growing perception of IT as a valued service provider rather than just a cost of doing business.

An area requiring further attention is staff development. Currently there is no staff retention program for IT staff and no opportunity for cross-training. There is also a need for increasing staff numbers in central IT. While an integration of IT services centrally might help solve the problem of staff shortage, opposition at the divisional level has yet to be overcome.

Institution B

Communication with key stakeholders is being considered to be of vital importance over the coming months in order to successfully implement the new IT governance model. The principal stakeholder groups for IT include the teaching staff, students, research and development, university administration, and the library. Communication with these groups is carried out through informal discussions, working groups and committee meetings. Unlike in previous years, conflicts between central IT and divisional IT are now actively resolved through discussions at the steering committee meetings.

The understanding of IT by business and vice versa is improving gradually and IT is emerging as an asset and a valued service provider. There has been a recent policy shift geared towards more balanced business and technical hiring within central IT.

A summary of IT governance relational mechanisms in Institution A and Institution B, based on the De Haes and Van Grembergen framework is shown in Table 4.

FINDINGS

A Comparison Between Institutions A and B

The chapter addresses the question of how formal IT governance practices can be adopted within the higher education environment. The increased dependence of IT in the higher education environment has also led to the awareness of the need for adopting formal IT governance practices. As seen in the previous sections both institutions have been implementing IT governance through a mixture of structures, processes and relational mechanisms.

Table 4. A summary of IT governance relational mechanisms in the case study institutions

	Relational Mechanisms	Institution A	Institution B
Tactics	– Stakeholder participation – Business/IT partnerships – Strategic dialog – Shared learning	Improving on all counts	Improving on all counts
Mechanisms	– Active participation by principal stakeholders – Collaboration between principal stakeholders – Partnership rewards and incentives – Business/IT co-location – Shared understanding of business/IT objectives – Active conflict resolution (non-avoidance) – Cross-functional business/IT training – Cross-functional business/IT job rotation	– Improving – Improving – No – Improving – Improving – Recent attempts – No – No	– Improving – Improving – No – Improving – Improving – Recent attempts – No – No

Based on the experiences of Institutions A and B, the following findings emerge with regard to the implementation of IT governance:

1. Professionals in both institutions agree that while an institution of higher education has to deal with low staffing levels, this should not be a deterrent in adopting industry best practices. They also agree that instead of adopting any one best practice framework, it is important to evaluate the strengths and weaknesses of the business and selectively adopt a combination of the relevant elements of best practice frameworks and standards such as CobiT, ITIL, ISO17799, AS 8015-2005, AS 8018.1-2004 or AS 8018.2-2004 that are necessary to support the business.
2. The two institutions vary in their approach in implementing CobiT and in the version of CobiT being implemented. The application of CobiT 3.0 for improving individual processes was an important eye-opener for management in Institution A because it focused attention on the need for centralization of decision making, having well defined IT governance roles and responsibilities, and developing enterprise-wide standards. In Institution B the overall IT governance structure is being implemented based on the CobiT 4.0 framework. It is believed that this approach would help in the utilization of CobiT 4.0 for improving processes across the university rather than just at central IT.
3. Institutions of higher education may benefit from experiences gained in IT governance implementation in other industries. In the case of Institution B, the background of the Director of Finance in the resources sector helped in identifying the need for the role of the Director of IT to be more business oriented (a need also being gradually recognized in Institution A). The Strategy Manager's background in the finance sector helped in developing the governance model for the institution fairly quickly based on the CobiT 4.0 framework.
4. CobiT requires the use of a good project management methodology. Institution A's adoption of CobiT has led to its adoption of PMBOK. This was particularly important as the institution's IT staff does a considerable amount of the project implementation and delivery work in-house.
5. A key difference between CobiT and ITIL noted by professionals in both organizations is in the availability and cost of documentation. There is a considerable amount of CobiT related documentation and research papers available free of cost from the Information Systems Audit and Control Association (ISACA) Website and additional information is available through mailing lists. ITIL

documentation, on the other hand, is considerably more expensive.

6. Both institutions have realized that although the use of multiple learning management systems and multiple email systems may be the existing norm in the divisions, this leads to duplication of ICT staff efforts without increasing the satisfaction of staff and students across the institution. A consolidation of systems could potentially help in the reduction of staff numbers (leading to reduced costs) while providing a better direction for staff efforts.
7. In both institutions, the disparity in ICT services across the institutions lead to difficulties in managing the perceptions of students and staff. In Institution A, student dissatisfaction with ICT services at the divisional level is reflected on their perception of ICT in general in the annual surveys. A consolidation of services (e.g. helpdesks, printing) could help in maintaining the same standards of services across the institution (in both cases) and make it easier to manage perceptions.
8. In both institutions improving communication between central IT and divisional IT groups are helping in the general acceptance of central IT standards.
9. In both institutions improving communication between IT and business has led to the gradual acceptance of IT as a valued service provider rather than just a cost of doing business, in an institution whose core business is not IT.

The Relationship Between Structures, Processes and Relational Mechanisms

As discussed previously, De Haes and Van Grembergen (2004) provide a broad framework for implementing IT governance through a mixture of structures, processes and relational mechanisms. However they do not explicitly discuss the relations between these three and how they relate to business benefits. The findings of the study support the emerging framework presented in Figure 1.

The study suggests that the development of IT governance structures (eg. IT strategy committee) leads to improved relational mechanisms and the adoption of IT governance processes (eg. the implementation of best practice frameworks such as ITIL) across the enterprise. The findings associated with Institution A suggests that there is a need to have a formal IT Governance structure with clearly defined roles and responsibilities in order to facilitate the adopted IT governance processes. As discussed in the findings, Institution A is shifting to a centralized IT governance structure. By adopting a formal IT Governance structure, Institution A strives to strengthen relational mechanisms. Improving relational mechanisms through formal and informal communications ensures broader support for improving IT governance structures and processes. The findings associated with Institution B affirms the framework as shown in Figure 1 in that they used COBIT to guide, develop and establish a formal IT Governance model including various structures, processes and relational mechanisms. Whilst Institution B presently lacks enterprise-wide standards (e.g., architectural, service management), they plan to implement ITIL as the service management standard with their IT staff requiring to undertake ITIL Foundation level training. Institution B has also considered key stakeholders to be vital and this has resulted in a policy geared towards a more balanced between business and IT hiring within central IT. While the institutions are in the early stages of experiencing business benefits from their evolving structures, processes and relational mechanisms, a longitudinal study would shed further light on the benefits of their IT governance practices.

The study also suggests that the range of structures, processes and relational mechanisms implemented by each organisation may differ from those presented in the De Haes and Van Grembergen (2004) framework.

The Five Focus Areas of IT Governance

The focus of IT governance implementation in the two institutions seems to be on five key areas as shown in Figure 1.

IT governance in the two institutions is implemented through a number of processes, structures and relational mechanisms in the context of these five areas. The focus area of strategic alignment in the four institutions appears to be addressed through processes such as strategic IS planning and the adoption and implementation of industry frameworks such as ITIL and CobiT that help in the attainment of business objectives. Structures like steering committees are used to involve business decision makers in strategic level IT decision-making. This growing interaction between business and IT is helping to build a shared understanding between business and IT on key issues. This is an important relational mechanism in the De Haes and Van Grembergen framework (2004).

With respect to value delivery (Figure 1), the adoption of standards such as PMBOK and ITIL for improving project management and service delivery was found to be an important process. While ITIL has been adopted by both institutions, PMBOK appears to have been adopted by institutions A only. Attention given by management to ensure staff training was found to be an important relational mechanism.

CobiT and ISO17799 were found to have been adopted by institutions A and B for risk management purposes. The adoption of P-CMM is guiding the management of human resources in institution A. It must be noted that although both institutions had reasonably well understood roles and responsibilities for the management of key resources such as business applications and supporting infrastructure, the institutions are all yet to have a formal documented governance model in place clearly outlining these structures.

As in other industries measuring the performance of IT remains a big challenge for IT decision makers in institutions of higher education and suitable measures are gradually being developed. CobiT has been used for evaluating IT process maturity in Institution A.

While there has been progress in all five focus areas, the development of formal governance models with input from key business decision makers could help in continuing to generate value for business in the two institutions.

LIMITATIONS AND FUTURE WORK

The study focuses on the implementation of structures, processes and relational mechanisms in two institutions of higher education and the focus areas for these implementations. It does not seek to address specific educational market drivers influencing IT governance implementations or the operational management issues that a well designed IT governance model helps to facilitate. Future research in these directions as well as on the integration of IT and corporate governance in the higher education sector would help in strengthening the findings. Further longitudinal investigations of IT governance practices in the higher education sector would help in testing the IT governance-business benefits framework presented in Figure 1 and addressing the present limitations of the study.

CONCLUSION

The chapter highlights some key issues regarding the adoption of formal IT governance practices in the higher education sector for the benefit of practitioners, academics, and researchers. As discussed in the previous section, the findings of study provide support for the framework presented in Figure 1. Institutions A and B were found to have implemented IT governance through a combination of various structures, processes and relational mechanisms. Benefits to business in the two institutions were found to arise from improvements in strategic alignment, value delivery, performance measurement, resource and risk management as the various mechanisms of IT governance evolve in these institutions. However, it must be noted that as both institutions are in the process of developing their formal governance models and the extent of benefits from IT governance may become more clearly understood in the future. One of the institutions has already received feedback from the authors regarding the findings of the study and is in the process of implementing some of the recommendations.

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Chapter 4.9

Enterprise Resource Planning (ERP) Implementations:

Theory and Practice

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ABSTRACT

Enterprise resource planning (ERP) systems have been widely implemented by numerous firms throughout the industrial world. While success stories of ERP implementation abound due to its potential in resolving the problem of fragmented information, a substantial number of these implementations fail to meet the goals of the organization. Some are abandoned altogether and others contribute to the failure of an organization. This article seeks to identify the critical factors of ERP implementation and uses statistical analysis to further delineate the patterns of adoption of the various concepts. A cross-sectional mail survey was mailed to business executives who have experience in the implementation of ERP systems. The results of this study provide empirical evidence that the theoretical constructs of ERP implementation are followed at varying levels. It offers some fresh insights into the current practice of ERP implementation. In addition, this study fills the need for ERP implementation constructs that can be utilized for further study of this important topic.

INTRODUCTION

Enterprise resource planning (ERP) systems are widely implemented as the backbone of many manufacturing and service firms. They are designed to address the problem of information fragmentation or "islands of information" in business organizations (Muscatello, Small, & Chen, 2003). A typical ERP system integrates all of a company's functions by allowing the modules to share and transfer information freely (Hicks & Stecke, 1995; Chen, 2001). In addition, all information is centralized in a single relational database accessible by all modules, eliminating the need for multiple entries of the same data. Customers and suppliers with network security clearance are allowed to access certain types of information by way of an external communication interface.

ERP systems offer tremendous opportunities to more consistently provide information to organizations in a standardized, centralized, and cost efficient manner (Olson, Chae, & Sheu, 2005). Many industry reports extol the virtues of ERP and its multiple benefits for those firms that can successfully implement these systems. One of the primary objectives for installing ERP is the ability to integrate business processes (Brakely, 1999; Davenport, 1998, 2000). ERP has also been found to be effective in reducing inventory costs, improving efficiency, and increasing profitability (Appleton, 1997; Brakely, 1999). In addition, ERP has been credited with reducing manufacturing lead times (Goodpasture, 1995; Davenport & Brooks, 2004). Other potential benefits of ERP include drastic declines in inventory, breakthrough reductions in working capital, abundant information about customer wants and needs, and the ability to view and manage the extended enterprise of suppliers, alliances, and customers as an integrated whole (Muscatello, Small, & Chen, 2003). Clearly, the integrated information technology of ERP software has the potential to provide manufacturing firms with extensive new competitive capabilities, especially since the real-time information can improve the speed and precision of enterprise response. Given the widespread popularity of ERP software, and the spectacular successes achieved by a few firms, an open question remains: Why has the effective deployment of ERP systems proven to be elusive for the majority of firms (Stratman & Roth, 2002)?

Implementation of an ERP does not come without significant technical and managerial challenges, huge financial investments, and a great deal of organizational change. Operational problems at Hershey Foods, Whirlpool, FoxMeyer Drugs, and more recently Hewlett Packard, have been blamed on poor implementations of ERP solutions (Becerra-Ferandez et al., 2005). ERP also has the reputation of being notoriously over-sold and under-delivered (Millman, 2004). Cliffe (1999) even reported that 65% of executives believed that ERP could be harmful to their organizations.

Researchers have attempted to identify the set of factors that are critical for ensuring success with ERP implementations. Most of these authors, however, have developed their list of critical success factors from a small number of case studies. For example, Holland and Light (1999) and Motwani, Mirchandani, Madan, and Gunasekaran (2002) offered a list of critical factors using two case studies. More recently, Kumar, Maheshwari and Kumar (2003) identified several success factors based on data collected from 20 Canadian firms. Employing a large scale survey, this article seeks to ascertain how businesses receive these concepts and, more specifically, which concepts are practiced widely and which are not. With this goal in mind, pertinent constructs of ERP implementations based on a critical review of business and managerial literature are first identified and developed in the second section. The research design, including data collection is then explained in the third section. The fourth section presents the results along with implications of the study findings. In the concluding section, the limitations of the study are highlighted along with guidelines for future research.

THEORETICAL CONSTRUCTS

This section identifies key factors of ERP implementations based on a critical review of both scholarly and managerial literature. These constructs include strategic initiatives, executive commitment, human resources, project management, information technology, business process, training, project support and communications, and software selection and support. The constructs developed by the authors are very similar to the ones developed by Stratman and Roth (2002), further validating the research effort undertaken here.

Strategic Initiatives

Successful integration of the internal functions of the business does not necessarily guarantee business success. End-to-end processes that transfer information from module to module will not in themselves improve cost effectiveness and efficiency. The ability to use the information to drive the business is the key to successful integration. Performance measurements must be developed to measure the impact of the ERP system on the business. It has been suggested that an ERP system that is not strategically tied into the supply chain will lack the ability to provide the type of business intelligence that is needed to grow the business (Hickes & Stecke, 1995; Koch, 1999; Carr, 1999; Melnyk & Stewart, 2002; Davenport & Brooks, 2004). Therefore, it is essential that firms must have strategic goals in place before undertaking an ERP implementation (Motwani et al., 2002).

Executive Commitment

Top management is often advised to look beyond the technical aspects of the project to the organizational requirements for a successful implementation. It is consistently identified as the most important success factor in ERP system implementations (Bancroft, Seip, & Sprengel, 1998; Davenport 1998; Sumner, 1999; Bingi, Sharma, & Godla, 1999; Welti, 1999; Gupta, 2000; Rao, 2000). It can be inferred from the literature that executives and managers believe that ERP systems help their company achieve greater business benefits. However, they are mystified as to how to design, implement, and manage an ERP project. When it comes to ERP projects, Fortune 500 companies are beginning to sound like children in the back seat of a car on a long drive—"Are we there yet? Are we done yet? No! We're not there and we are not done. And we may never be done" (Koch, 1999).

Any executive planning the implementation of an ERP system needs to make some savvy decisions, from identifying what business needs the ERP system must meet to preparing for post-implementation maintenance and user support (Musson, 1998). Many executives are having a hard time understanding that ERP implementation is not simply a package installation. It is a long journey of fine-tuning, upgrading, and continual learning, not a sprint. Therefore, it may lead to a sense of frustration and anger at the system and in some cases total abandonment. Unlike any other software project, an ERP system does not merely change employees' computer screens the way previous generations of software did; it changes the way they do their jobs and how the company does business. Top management, therefore, must fully understand the degree of the changes and supports needed for the new project and be comfortable with the fact that the decisions their planners make will have a profound impact on the entire supply chain (Chen, 2001).

Human Resources

The most recurring theme in management literature concerning the failure of ERP systems is the inability of firms to take into account the new organizational, interdepartmental, and personnel aspects of work organizations. Unintended consequences include the emotional fallout when employees are suddenly given much greater responsibilities. Managers sometimes neglect to assess not only the skill development needed by employees but also the organizational changes required of them (Appleton, 1997). Small firms often lack financial resources and may be forced to adopt, at best, a piecemeal approach to integrating the typically expensive ERP systems into their facilities (Ferman, 1999). This can be very difficult for employees as the project seems to be 'never ending.' It is also felt that the low information technology (IT) staff levels in smaller enterprises are inadequate for the rigorous and extensive IT training and development requirements of an ERP project (Hill, 1997). In many cases of ERP implementations, consultants are required to help meet the projects' needs (Muscatello et al., 2003).

Project Management

A project team must be flexible and deal with the problems as they arise in the implementation process. Anyone who revisits the charter documents of a large-scale ERP project will see that the ultimate product is almost always shaped by unanticipated and late breaking circumstances. It is a fact of business life that important things come up later rather than earlier in complex new projects (Cliffe, 1999). However, these interruptions should not encourage "scope creep," when processes or functions are added after the project has begun. As mentioned, unanticipated circumstances are the norm; however, wholesale changes such as adding an additional process, module, or department after the project has been scoped and started may lead to a "never ending" project. To prevent scope problems, firms need to make sure a project charter or mission statement exists. It is paramount to nail down the project requirements and have them documented and signed by the senior management and users. Furthermore, it is essential for firms to clearly define change control procedures and hold everyone to them. Tight change control procedures may end up causing tension between the project team and those who do not get the changes they want. Ultimately, though, the project will not be successful if the project team is trying to hit a constantly moving target (Trepper, 1999).

A survey by the Meta Group found that it takes an average of 31 months before an ERP system will show benefits (Muscatello, 1999). There is no magic in implementing ERP systems, but, when they are carefully conceived and executed, ERP systems can radically changed the way companies do business. In many companies, it would now be unthinkable to manage financials, customer relationships, and supply chains without ERP (Oliver, 1999).

Information Technology

Deloitte Consulting (2000) reports that the second largest ERP implementation challenge related to people issues is internal staff adequacy. If a firm's existing technology will run the new ERP system, then the technology training may be an upgrade of the skill set. If a wholesale change is required, such as moving from an IBM mainframe to a Sun Microsystem, then an in-depth hardware and software training program must be implemented. In fact, some firms have selected their ERP systems based on their current technology and business process, and research has showed this approach to be a mistake since it is very limiting (Anderson, 2000). Because some firms may not be willing to change current technology, they may consequently report a lower significance on technology training for ERP implementation. Firms who account for business processes first and technology fit second reflect IT training positively (Davenport, 2000).

Managers cannot minimize the importance of technology training regardless if it is an upgrade of current software and hardware or a complete technology change. An upgrade of current software usually includes new file structures, report writers, functional modules, and other changes. An upgrade of current hardware usually involves a re-installation of the operating system or at least installing the operating system changes, new functionality, and new modules. If a complete technology change (hardware and/or software) is required, then a much larger commitment must be undertaken to insure that the proper employees can manage the technology after going live. In either case, managers must be proactive in securing the technology training to insure that their technical employees can run the ERP system effectively. The consequences of not having enough technical training can be catastrophic and lead to outright failure of the ERP system (Evangelista, 1998; Hill, 1997).

Business Process

As suggested by Hammer and Champy (1993), reengineering of business process activities focuses the firm on identifying and improving the efficiency of critical operations, on restructuring important non-value-adding operations, and on eliminating inefficient processes. Reengineering should be undertaken to insure that the strategic objectives mentioned earlier are feasible. The reengineering effort should create a uniform response from all aspects of the business. When goals are common, improvement becomes a shared task (Hill, 2000). Using reengineering techniques to develop a homogeneous vision depicting the company's processes after the ERP implementation, a firm is more likely to minimize uncertainty and achieve success. Researchers have found a strong correlation between the attention paid to business process improvement and the likelihood of ERP success (Muscatello et al., 2003; Motwani et al., 2002; Carton & Adams 2003; Millman, 2004; Olson et al., 2005).

Training

ERP skills have been in acute shortage because of the high demand for people with good understanding of business and ERP systems. This and the radical process changes brought about by ERP implementation have made providing sufficient and timely training to project persons and users a critical requirement in ERP implementation (Davenport, 2000). Assessing the needs for training usually uncovers several training and skills deficiencies. Rectification of training deficiencies can be accomplished in three ways: reassignment, outsourcing or replacement of staff, hiring of new personnel with substantial knowledge in ERP systems, or training of managers and key employees. In most cases, a firm implementing ERP engages in two types of training: fundamental ERP systems education and technical training in the usage of the ERP software (Evangelista, 1998; Muscatello, 2002; Yusuf, 2004; Sarkis & Sundarraj, 2003). In international cases, language and cultural barriers can be a technical hindrance that requires additional training (Al-Mashari, 2000).

Project Support and Communications

ERP applications lock the operating principles and processes of the adopting organization into software systems. If organizations fail to reconcile the technological imperatives of the enterprise systems with their business needs, the logic of the system may conflict with the logic of business processes (Davenport, 1998). Needless to say, managers have found ERP implementation projects the most difficult systems development projects (Kumar et al., 2003). Thus, upfront and ongoing communication to all employees affected by the new ERP system is a must. Olsen et al. (2005) found that it is necessary to inform organizational employees of how the system can help them do their jobs better. They also found that all retained employees are going to find their jobs changed. People are naturally resistant to change and it is very difficult to implement a system within an organization without some cooperation. Effective communication and ongoing support has also been noted by several researchers (e.g., Motwani et al., 2002; Muscatello et al., 2003; Sarkis & Sundarraj, 2003).

Software Selection and Support

ERP systems are software packages generically designed, keeping the industry-wide needs and best practices in mind (Kumar et al., 2003). One of the major challenges an adopting organization faces is that software does not fit all their requirements (Davenport, 1998). A systematic "needs assessment" therefore must be commissioned to determine the specific ERP modules, subsystems, and hardware that are required to achieve the desired level of systems integration. Where there is a lack of internal knowledge of ERP systems and their operating requirements (either at the corporate or division level), management should solicit the help of knowledgeable outside consultants for the assessment (Chen, 2001; Davenport, 2000; Booker, 1999). Firms that analyze their software "fit" and individual module needs can enhance the likelihood of a successful ERP implementation (Yusuf, Gunasekaran, & Althorpe, 2004).

RESEARCH DESIGN

Data Collection

Based on a thorough review of the literature, the theoretical constructs identified by this study are well grounded in existing theory (Muscatello et al., 2003). The theoretical constructs are made up of four or more items using a 7 point Likert scale with a score of 1 labeled "not important" and a score of 7 labeled "very important."

A cross sectional mail survey was conducted in the United States, during 2006, drawing from members of the American Production and Inventory Control Society (APICS), The National Association of Accountants (NAA), the American Productivity and Quality Center (APQC), and the Institute for Supply Management (ISM) because of their potential involvement in an ERP implementation. The survey was very clear that only those with ERP implementation experience should respond.

A modified version of Dillman's total design method was followed in order to increase the response rate (Dillman, 1978). All mailings were first class mail including a cover letter, survey, and postage paid return envelope. Three weeks after the initial mailing, reminder cards were sent to all potential respondents. Of the 973 surveys mailed, 28 came back due to address discrepancies. From the new sample size of 945, 203 were received resulting in a response rate of 21.5%. A total of six were discarded for incompleteness/damage for an effective response rate of 197/945 or 20.8%. Considering that this is a lengthy survey, this response rate is acceptable and correlates well with recent empirical studies in operations management (OM) and supply chain management (SCM) (e.g., Paulraj & Chen, 2005, 23.2%; Krause et al., 2001, 19.6%).

Respondent and Firm Profiles

The profile of the final sample of 197 included top executives (17%), middle managers (73%), and others (10%). Almost half of the firms had been in business for over 30 years (48%) and

Table 1. Respondent profile

Title	Count	Percent
Manufacturing/Business Executives	34	17%
CEO, CFO, COO, CIO		
President, Vice-President, Director		
Manufacturing/Business Middle Manager	143	73%
Purchasing Manager		
Operations/production Manager		
Other	20	10%
Buyers, Planners		
Supervisors		

most were engaged in end product manufacturing (49%), followed by subassembly (30%), components (19%), and others (2%). Firm size was fairly evenly distributed between large and small firms with respondents with sales of over $20B (6%), $1B~$20B (31%), $500M~$1B (30%), $100M~$500M (19%), $10M~$100M (6%), and under $10M (8%). Most firms employed 500 or more employees (81%). The vast majority of the respondents were working on their first ERP system (78%) with some (22%) on their second or third system. Furthermore, most had not worked on multiple ERP systems (87%), but some had multiple systems in the same facility (13%). The distribution of the sample regarding respondent and firm profiles is presented in Tables 1 and 2, respectively.

RESULTS AND DISCUSSIONS

Exploratory factor analysis (EFA) was performed to empirically test the nine strategic ERP constructs included in this study using the principle component method. Items with a factor loading of 0.3 or greater were retained for further analysis (Flynn, Schroeder, & Sakakibara, 1994; Hair, Anderson, Tatham, & Black, 1998). Reliability analyses were performed to test whether random measurement errors varied from one question to another (Judd, Smith, & Kidder, 1991). Reliability was measured using Cronbach's alpha internal consistency method where reliability coefficients of 0.60 or higher are considered acceptable (Cronbach, 1951). All of the reliability coefficients are greater than 0.658 after the removal of questions 2 and 3 from the "Human Resource" construct and question 9 from the "Software Selection and Support" construct. Reliability statistics and factor loadings are shown in Appendix A.

All questions were analyzed using a seven point Likert scale with a score of 1 labeled "not important," a score of 4 labeled "neither important nor unimportant," and a scale of 7 labeled "very important."

Table 2. Company profile

Years in Operation	Count	Percent
Less than 5	55	28%
6-15	39	20%
16-30	8	04%
30 or more	95	48%
Types of Products Produced	Count	Percent
Components	37	19%
Sub Assemblies	59	30%
End Products	97	49%
Other	4	02%
Annual Sales Volume	Count	Percent
Less than $10m	16	08%
$10m-$100m	12	06%
$100m-$500m	37	19%
$500m-$1b	59	30%
$1b-$20b	61	31%
Greater than $20b	12	06%
Number of Employees	Count	Percent
Less Than 100	14	07%
101-250	14	07%
251-500	10	05%
501- Up	159	81%
Number of ERP Implementations	Count	Percent
1	154	78%
2	35	18%
3 or more	8	04%
Multiple ERP Systems in the Same Facility	Count	Percent
No	171	87%
Yes	26	13%

This study uses simple mean-based ranking of the indicators within each theoretical construct. Further analysis was conducted to provide additional insight into the results. The following sub-sections present the current state of practice for each of the theoretical constructs.

Strategic Initiatives

Table 3 presents the results for strategic initiatives. The mean response for the seven indicators ranged from 5.33 to 5.79. This result is a pleasant surprise in that many researchers have written about ERP implementations being relegated to the information technology departments; to the contrary, this research shows that firms are now attaching a strategic component to their ERP implementations and that the decision to implement an ERP system is now being made at a cross functional executive level which includes inputs from all functional business areas. Further, the respondents concur that the ERP implementation should be tied to achieving strategic goals. The fact that two-thirds (67%) of the respondents came from firms with sales in excess of $500 million may further explain the increased desire for a strategic component. Larger firms have the resources to fully integrate ERP systems as opposed to just automating processes (Muscatello, 2002). These larger firms may have access to information and research that smaller firms do not and thus have common strategic goals and when goals are common, improvement becomes a shared task (Hill, 2000). The low standard deviation further shows the uniformity of this opinion.

Executive Commitment

Executive commitment has been documented to be of great importance in achieving any major business improvement project. The response to this survey re-confirms the need for executive commitment for ERP implementations identified by on past research. Seventy three percent (73%) of the respondents classified themselves as middle-managers and 17% classified themselves as director or above. However, a test of the means between the respondents produced no discernable difference, verifying that all levels of management consider executive commitment important. Table 4 presents the results for executive commitment and support. The mean response for the seven indicators ranged from 4.68 to 5.53. The highest responses came from the question on long-term executive commitment showing the high regard they have for executives who realize the complexity and time commitment necessary for a successful implementation. The lowest indicator showed that while executives deemed the ERP implementation very important, they still expected the operational concerns to be addressed in the interim.

Table 3. Strategic initiatives

Indicator		Mean	Std Dev
1)	IT capabilities are constantly reviewed against strategic goals	5.79	1.148
2)	Strategic IT planning is a continuous process	5.60	1.260
3)	Written guidelines exist to structure strategic IT planning in our organization	5.33	1.369
4)	Strategic IT planning includes inputs from all business functional areas	5.49	1.244
5)	ERP is integrated into the strategic plans of all business functional areas	5.53	1.210
6)	ERP was chosen to support the organization’s strategic plans	5.59	1.124
7)	Managers evaluate the potential of ERP when building strategic plans	5.40	1.181

Human Resources

Indicator number 2, ‘low IT skills are an obstacle to successful ERP implementations’ and Indicator 3, ‘executives with little knowledge of ERP should be minimally involved’ were eliminated from the research to improve the Cronbach’s alpha to 0.677 from 0.606. The mean responses of the remaining six indicators ranged from 4.57 to 5.76 and are presented in table 5. From the human resource side, there appears to be strong commitment to gaining the knowledge required to successfully implement ERP systems via training and education of current employees or hiring of outside consulting help. Significant research has noted that ERP education and training is required for successful implementation. This research offers a new insight: respondents saw little difference between gaining the knowledge via education and training or through consulting help. The lowest responses came from the idea of replacing ineffective employees or managers who are not able

Table 4. Executive commitment

Indicator		Mean	Std Dev
1)	The need for long term ERP support resources is recognized by management	5.53	1.100
2)	Executive management is enthusiastic about the possibilities of ERP	5.29	1.144
3)	Executives have invested the time needed to understand ERP’s benefits	5.23	1.222
4)	Executives mandate that ERP requirements have priority over functional concerns	4.68	1.387
5)	Top management has clearly defined the ERP entity’s business goals	5.31	1.378
6)	All levels of management support the overall goals of the ERP entity	5.24	1.313
7)	Executives continuously champion the ERP project	5.07	1.356

Table 5. Human resources

Indicator		Mean	Std Dev
1)	The ability of the IT workforce to learn is critical to an ERP implementation	5.64	1.076
2)	Low IT skills are an obstacle to successful ERP implementations	5.35	1.179
3)	Executives with little knowledge of ERP should be minimally involved	4.86	1.711
4)	Ineffective employees are moved or replaced if they are not able to adapt	4.57	1.396
5)	Ineffective managers are moved or replaced if they are not able to adapt	4.83	1.445
6)	The ERP team members need to understand the project has priority	5.74	1.040
7)	Consultants are used where in-house knowledge is inadequate or not available	5.76	1.135
8)	Compensation and incentives should be given to high achieving team members	5.57	1.170

to adapt to the new system. This could present a problem in some smaller firms where key managers have multiple tasks. Possible explanations for the low response rate for employee replacement includes the reluctance of many firms to terminate people for incompetence if they are well liked and committed. It is noted that Hammer and Champy (1993) also openly reject the idea of eliminating jobs through reengineering. Thus, many managers and consultants may still hold true to this idea.

Project Management

Respondents were asked about ERP project management issues including the responsibilities of project team members and the capabilities of the project leader. Table 6 presents the results for project management. The mean response for the seven indicators ranged from 5.51 to 5.64. This shows a strong commitment for project management skills in project definition, scope, tracking, and status. It reveals that project management skills were grossly underestimated in ERP implementation in the past and are now becoming a critical skill set for ever changing business needs. The fact that 81% of the responding firms had more than 500 employees could also explain this response. Larger firms have more internal expertise to draw from and thus are more likely to be equipped with project management champions.

Information Technology

Software and hardware expertise has been documented to be of great importance to a successful ERP implementation and this survey shows the same high level of importance with a range of the means from 5.41 to 5.69 with very low standard deviations. The results are presented in Table 7. Somewhat unique to this research is the attempt to find out the importance of the skill sets of the current information technology (IT) staff, which are deemed very important, and the use of consultants if the skill sets are not internal. The results show that firms are willing to supplement their IT staff with consultants when necessary. This acceptance of outside help shows an understanding of internal limitations of a firm and a sense of urgency and willingness to acquire it externally.

Business Process

ERP implementation has been referred to as an "organization wide revolution" due to the large number of changes it brings to an organization (Hammer & Stanton, 1999; Bingi et al., 1999). The

Table 6. Project management

Indicator		Mean	Std Dev
1)	The tasks to be performed during the ERP project are clearly defined	5.61	1.149
2)	The responsibilities of project team members are clearly defined	5.64	1.167
3)	There is a formal management process to track external contractor activities	5.59	1.173
4)	Measurements are used to determine the status of project tasks	5.51	1.105
5)	The ERP project leader is able to track project tasks to completion	5.58	1.102
6)	The ERP project leader is experienced in project management	5.60	1.128
7)	The ERP project leader is able to minimize project scope creep	5.57	1.031

Table 7. Information technology

Indicator		Mean	Std Dev
1)	There is a high degree of technical expertise in the IT organization	5.49	1.137
2)	Internal It members understand custom ERP software programs	5.52	1.062
3)	The IT staff are able to efficiently implement ERP system upgrades	5.65	1.036
4)	The IT staff are able to analyze the technical impact of proposed system changes	5.53	1.268
5)	The IT organization provides a service to the business	5.47	1.296
6)	Consultants are hired to supplement internal IT staff when necessary	5.63	1.165
7)	The IT staff is continuously updating their technical skills through training	5.74	1.092

strong connections that researchers have proposed between business process redesigns and successful ERP implementation have been confirmed by our results. The means ranged from 5.45 to 5.74 with low standard deviations are presented in Table 8. Interestingly, the high means for all seven indicators suggest that the connection researchers have preached is being accepted by the practitioners. Ross (1999) suggested that firms believed that ERP software would solve their problems by imposing discipline and process integration on their organization. This research confirms that practitioners now disagree with that assessment and realize that software is not a substitute for good business processes. The "business process" indicators indicate that process knowledge and redesign, cross functional management and driving out inefficiencies that improve customer benefits are all strongly accepted as necessary for a successful implementation. Hammer and Champy's (1993) work on reengineering and the wide-spread use of their practices as a change enabling tool helps confirm the positive use of reengineering in ERP implementations.

Training

The importance of training was echoed by most of our respondents. As expected, based on current research, training was a highly regarded component of ERP implementations. The means of the eight indicators ranged from 5.45 to 5.70 with low standard deviations and are presented in Table 9. Again, the question if external expertise in the form of consulting should be used to supplement internal knowledge was asked and the answer was

Table 8. Business process

Indicator		Mean	Std Dev
1)	Employees understand how their actions impact the operations of other functions	5.45	1.171
2)	There is a high level of business process knowledge within the ERP entity	5.52	1.123
3)	Managers are skilled at analyzing business processes for customer benefits	5.65	1.036
4)	Business process redesign is performed before ERP implementation	5.53	1.268
5)	The operational processes of the ERP entity are formally documented	5.47	1.296
6)	Business process redesign teams are cross functional	5.63	1.165
7)	Redesigned business processes are used to drive out inefficiency	5.74	1.092

Table 9. Training

Indicator		Mean	Std Dev
1)	Specific user training needs were identified early in the implementation	5.70	1.020
2)	A formal training program has been developed to meet the ERP users requirements	5.53	1.276
3)	Training materials have been customized for each specific job	5.45	1.158
4)	Training materials target the entire business task, not just the ERP screens/reports	5.49	1.284
5)	Employees are tracked to insure they have received the appropriate ERP training	5.51	1.194
6)	All users have been trained in basic ERP system skills	5.69	1.130
7)	Consultants are used to supplement training when internal expertise does not exist	5.55	1.239
8)	ERP training and education is ongoing and available to refresh users skills	5.60	1.194

strongly yes. Firms supported the need for formal, customized training on both ERP knowledge and specific job duties. They also strongly supported on-going education programs which has not always been the case for some firms who are risk adverse. The high percentage of respondents in larger firms (81% had 500 or more employees, and 86% had sales over $100 million) may explain the high level of interest in outside consulting help, since larger firms usually have greater access to resources. Smaller firms, without the access to ERP resources, need to establish whether or not they can obtain the resources or postpone the implementation since it is documented that overcoming an ERP failure is difficult and often fatal (Muscatello et al, 2003).

Project Support and Communications

Lack of strong support for a massive project like ERP creates enormous challenges for the project team such as buy-in from users. A recent study revealed that 25% of organizations adopting ERP systems faced significant resistance from staff and that 10% of the organizations also encountered resistance from managers (Kumar et al., 2003). Table 10 presents the results for project support and communication. The means range from 5.57 to 5.86. This research supports extant research on employee relations and change management in that the respondents felt it very important to actively communicate how employees fit into the new ERP-oriented environment and to actively work to alleviate employee concerns. Respondents also agree that cultural changes need to be managed to ensure shared values and common aims conducive to both employee and firm success. A user support group with employee comments and reactions should be used to help employees manage through the cultural changes.

Software Selection and Support

Even with today's state of the art technology, organizations find that not all their requirements are met by the ERP systems they adopt. The remaining nine indicators are strong with means from 5.64 to 5.86 and the results are presented in Table 11. These indicators confirm current research that shows a strong relationship between successful ERP implementations and software fit. Interestingly, the research again confirms that firms are willing to use outside consultants if software selection experience is not available internally. Again, this set of indicators show a new willing-

Table 10. Project support & communications

Indicator	Mean	Std Dev
Employees understand how they fit into the new ERP entity	5.71	1.112
Management actively works to alleviate employee concerns about ERP	5.65	1.153
The roles of all employees under the ERP system have been clearly communicated	5.57	1.161
An ERP support group is available to answer concerns about ERP job changes	5.57	1.093
Effective communication is critical to ERP implementations	5.63	1.110
User input should include requirements, comments, reactions and approvals	5.86	1.025
Enterprise wide culture and structure change should be managed	5.77	1.033
A culture with shared values and common aims is conducive to success	5.66	1.111

Table 11. Software selection & support

Indicator		Mean	Std Dev
1)	An analysis should be performed to select the appropriate business modules	5.86	1.079
2)	The modules selected should be able to share information freely	5.80	1.137
3)	The ERP system should eliminate the need for redundant entry of data	5.79	1.033
4)	If ERP experience does not reside in house then consultants should be used	5.79	1.135
5)	The overall ERP architecture should be established before deployment	5.66	1.134
6)	The firm should work well with vendors and consultants to resolve software issues	5.64	1.101
7)	Vigorous and sophisticated software testing eases implementation	5.85	1.085
8)	There should be a plan for migrating and cleaning up data	5.64	1.062
9)	ERP software development, testing and troubleshooting is essential	5.83	1.310

ness amongst ERP implementers to realize their firm’s limitations in this difficult endeavor. Also of note is a strong resolve to work with vendors to ensure proper module and process fit, as well as vigorous software testing, troubleshooting, and a plan for migrating and data clean up after the initial installation.

CONCLUSION

Enterprise resource planning systems have experienced a phenomenal growth over the past decade. While some firms declared their ERP implementation success, many others reported negative results. With these developments, there has been a significant amount of research that seeks to identify the success factors associated with the implementation of ERP systems. Most of these authors, however, have based their research on a small number of case studies. This study, therefore, aimed to understand the critical constructs of ERP implementation using a large scale survey. A cross sectional mail survey of business executives with ERP implementation experience was used to capture the degree of adoption of these concepts. Basic statistical methodology was used on this empirical data to examine the adaptation of the various concepts. Although this analysis was based on simple statistical methods, it provides a clear picture of the beliefs of current ERP implementation. These constructs can also help guide future research for academics and practitioners in the ERP environment.

In summary, the results show that the implementation of ERP systems has grown from the belief that it was a simple information system implementation of new software into a realization that it is a strategic and tactical revolution which requires a total commitment from all involved. This is in stark contrast to studies as recent as 5 years ago, which concluded that firms believed that the ERP software would automatically drive the strategic and tactical changes. Firms now realize that business process changes and project management are strongly linked to the success of the ERP implementation. Moreover, they are as important as software and hardware knowledge. Another new finding is that firms now strongly believe that the use of outside consultants to supplement internal staff is an acceptable and desirable practice. This is likely a result of the documented cases of ERP implementation failure where firms failed to take stock of their internal competencies and shortcomings. Taken together, these results suggest that firms are realizing that ERP implementations are a long journey and that results may not be readily apparent until well into the future.

This research has provided insight into the current practice of ERP implementations. It has paved a solid foundation on which to build future research in this area. Nevertheless, it is realized that this effort cannot completely explain all of the issues surrounding an ERP implementation. Additional insights may be revealed through longitudinal studies and by building empirical models.

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APPENDIX A

Reliability Measurements

Item	Cronbach's Alpha
Strategic Initiative	.797
Executive Commitment	.788
Human Resources	.658
Project Management	.784
Information Technology	.818
Business Process	.810
Training	.807
Project Support and Communication	.761
Software Selection and Support	.830

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Chapter 4.10

Diffusion of Enterprise Resource Planning Systems in Taiwan:

Influence Sources and the Y2K Effect

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ABSTRACT

ERP was one of the important developments in the use of information technology for organizations in the 1990s. Y2K rectification was a key driver in the decision to move to ERP software. Based on diffusion-of-innovation models, in this study, the sources of influence of ERP adoption in Taiwan are investigated and if the dawning Y2K can be viewed as a critical point is explored. The results demonstrate that the main influence source of ERP adoption is a mix of influence sources for all adopters. Before the millennium, the internal model shows the higher power of explanation. And after the millennium, the main influences become external influence sources. With different diffusion patterns between, before, and after the millennium, the analysis results confirm that the millennium is a critical point. Besides contributing to the application of diffusion-of-innovation in Taiwan's ERP adoption, the results of this study can provide suggestions for ERP suppliers' marketing strategy.

INTRODUCTION

In the age of the information and knowledge, organizations depend heavily on information systems to support regular operations, solve problems, and make flexible responses to the competition around the world. In the early stages, organizations tended to develop stand-alone systems for a single functional area or business unit; maintaining many different systems led to enormous costs. Organizations faced many problems because of the lack of integration, especially at the global level (Ives & Jarvenpaa, 1993). Recently, enterprise resource planning systems (ERP) which incorporate commercial software packages, also known as integrated enterprise computing systems, attempt to integrate all departments and functions across a company, constitute one of the fastest growing segments in the software market and one of the most important developments in recent years (Sprott, 2000; Seethamraju, 2005). Most of this was clearly attributable to the Y2K effect (Sprott, 2000). Y2K rectification was a key driver in the decision to move to ERP software (Scott & Kaindl, 2000).

The market for ERP software grew a surprising 14% in 2004 to become a $23.6 billion business (Woodie, 2005). And in Taiwan, according to the investigation of MIC, the market for ERP grew from 2.1 billion NT dollars in 1997, to 4.6 billion NT dollars in 1998. During the year 2000, the ERP market grew 26% and the market scale was up to 7.7 billion NT dollars. Nevertheless, the ERP market has generated 9.5 billion NT dollars in year 2003 and only up to 9.8 billion NT dollars in year 2004. MIC indicated that the CAGR (compound annual growth rate) of the ERP market scale would reach 28% for 3 years after 2001, but also that the growth of the ERP market would decrease below 5% after 2004 (MIC, 2004).

The ERP system is the most important development in information technology use in the 1990s (Davenport, 1998). ERP systems have developed for several years, and the number of adoption firms is growing. The diffusion of innovation model (DOI model) is usually applied to explore the spread of new technology. For example, Anat, Ravi, and David (2004) applied the DOI model to investigate adoption of Internet standard IPV6. The DOI model has the potential to investigate ERP adoption. The imitation hypothesis has generally guided researches on the organizational adoption of administrative innovations. The hypothesis states that, within a relevant population of firms, such adoption results in a predictable diffusion pattern. Members of a social system have different propensities for relying on mass media or interpersonal channels when seeking information about an innovation (Mahajan, Sharma, & Bettis, 1988; Rogers, 1995; Rogers, 2003).

In this study, the diffusion-of-innovation perspective to examine the impact of various forms of influence in the adoption of ERP in Taiwan is applied. First, the sources of influence (internal, external, and mixed) that could explain the diffusion pattern of ERP by adopting ordinary least square (OLS) estimation methods and specification tests are examined. Second, because previous research showed that the Y2K effect is a key driver for the adoption of ERP; the millennium is treated as a ‘critical point’ in delineating two regimes: “pre-millennium” and “post-millennium,” to assess the different impacts of the influence sources within each of the regimes.

THEORETICAL PERSPECTIVES

The theoretical perspectives begin with the introduction of ERP system and diffusion of innovation in first two sections, and then why the study regards ERP as an administrative innovation is explained in next section. This is followed by a description of three diffusion models, namely influence sources. In the end, the theoretical perspectives highlight the crucial role that Y2K has had in driving the diffusion pattern of ERP.

Enterprise Resource Planning (ERP)

The term “ERP” was addressed first by the Gartner Group in the early 1990s. It evolved from MRP, closed-loop MRP in the 1970s and MRP II in the

1980s. ERP is designed to manage a production facility's orders, production plans, and inventories. ERP integrates inventory data with financial, sales, and human resources data, and has become the pervasive infrastructure (Markus et al., 2000; Moller, 2005; Seethamraju, 2005).

Unlike the requirements of other IT tools, companies should move out of their traditional "functional silo" mode of thinking to an organizational mode of planning and thinking in the implementation of ERP, because ERP will impact the entire organization (Palaniswamy & Frank, 2002), radically reshaping how business is done and exploiting the new automated, seamless enterprise system capabilities in the process—the real value-adding opportunity offered by ERP. To improve "how business is done" is not just about integrating and creating more efficient transactional processes, the ERP route to business value is dependent also on major human, culture, and organizational changes (Willcocks & Sykes, 2000), see Figure 1.

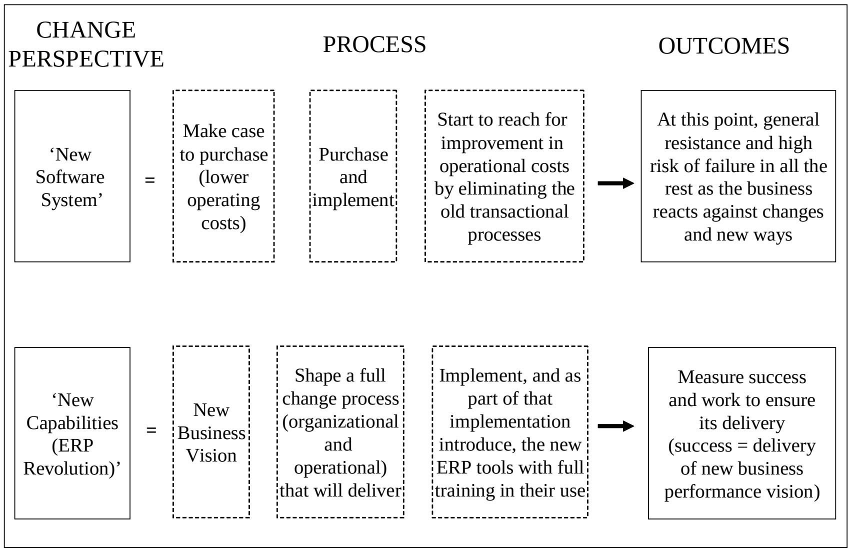
Diffusion-of-Innovation

Since Rogers addressed the diffusion concept in 1962, research on the diffusion of innovations has resulted in a large body of literature. According to Rogers' (1995) definition, "An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption." The perceived newness of the idea determines the individual's reaction to it. Rogers (1995) stated that "Diffusion is the process by which an innovation is communicated through certain channels over time and among the members of a social system." This definition indicates that diffusion is a special type of communication, in that the messages concern a new idea. According to the definition, there are four main elements in the diffusion of innovations: (1) the innovation, (2) communication channels, (3) time, and (4) the social system (Rogers, 1995). These elements are described.

Innovation

A new product or service, a new production process technology, a new structure or administrative system, or a new plan can all be viewed as innovation. Damanpour (1991) argued that an innovation is a means of changing an organization, either as a response to changes in its internal or

Figure 1. ERP: comparing change equations (Source: Willcocks & Sykes, 2000)



external environment or as a preemptive action taken to influence an environment.

Communication Channels

The essence of the diffusion process is the information exchange through which individuals communicate a new idea each other. A communication channel is the means by which messages get from one individual to another. It takes two forms: mass media channels and interpersonal channels. Mass media channels, involving all those means of transmitting messages such as radio and television are often the most rapid and efficient means to inform an audience of potential adopters about the existence of an innovation. Interpersonal channels, involving face-to-face exchanges between individuals, are more effective in persuading individuals to accept a new idea (Rogers, 1995).

Time

Rogers (1995) states that "the time dimension is involved in diffusion (1) in the innovation-decision process by which an individual passes from first knowledge of an innovation through its adoption or rejection, (2) in the innovativeness of an individual or other unit of adoption, that is, the relative earliness/lateness with which an innovation is adopted, compared with other members of a system, and (3) in an innovation's rate of adoption in a system, usually measured by the number of members of the system who adopt the innovation in a given time period."

The Social System

A social system is a set of interrelated units that are devoted to joint problem-solving, to accomplish a common goal (Rogers, 1995). In the diffusion of innovation, it means the community of individuals and/or organizations that are potential adopters of the innovation (Loh & Venkatraman, 1992).

In this study, the innovation is the ERP system and the relevant social system is the set of Taiwanese organizations that potentially adopt ERP systems. The communication channels in ERP take two forms: mass media channels (for example, through promotional efforts by ERP vendors, consulting firms, or trade periodicals) and interpersonal channels (for example, through the members of a social system interacting with one another).

The innovation can be distinguished into two types: administrative innovation and technical innovation. According to Damanpour's (1991) conceptualization, "technical innovations pertain to products, services, and production process technology; they are related to basic work activities and can concern either product or process," whereas "administrative innovations involve organizational structure and administrative processes; they are indirectly related to the basic work activities of an organization and are more directly related to its management."

Similarly, Venkatraman, Loh, and Koh (1994) defined an administrative innovation as "involving significant changes in the routines (or behavioral repertoires) used by the organization to deal with its tasks of internal arrangements and external alignments." Furthermore, the implementation of administrative innovations often involves an enormous change in functions, tasks, responsibilities, systems, and culture (Mahajan et al., 1988).

The diffusion of innovation perspective has been utilized for this study of technical innovations and administrative innovations. Detecting types of innovation is necessary for understanding organizations' adoption behavior and identifying the determinants of innovation in organizations (Downs & Mohr, 1976; Knight, 1967; Rowe & Boise, 1974). The decision-making processes are different between administrative with technical innovations (Daft, 1978).

ERP as an Administrative Innovation

According to the definitions of administrative innovation as described, it captures: (1) the critical opinion of first-time adoption by the organization (Rogers, 1995), (2) the changes in the routines and procedures of organization and management that involve significant "set up" costs and organizational disruption (Teece, 1980), and (3) a broader view of administrative tasks as an organization-environment co-alignment, that reflect both internal arrangements as well as external alignments (Thompson, 1967; Snow & Miles, 1983).

The arguments supporting the consideration of ERP as administrative innovations are described. First, it represents a significant shift in the mode of governance: ERP permits the injection of more discipline into their organizations. Some companies exert more management control and impose more-uniform processes on freewheeling, highly entrepreneurial cultures. Nevertheless, some companies use ERP to break down hierarchical structures, freeing their people to be more innovative and more flexible (Davenport, 1998). For example, a semiconductor company says, "We plan to use SAP as a battering ram to make our culture less autonomous." Union Carbide uses ERP to give low-level managers, workers, and even customers and suppliers much broader access to operating information (Davenport, 1998). In fact, such a shift in the mode of governance is an ally in achieving profound transformations in the strategic and operational mechanisms that are necessary for an organization to position itself within its current mission or scope (Markus et al., 2000; Loh & Venkatraman, 1992).

Second, ERP represents significant changes in the internal processes of the organizations. Generally, business often modified itself to fit the ERP. Therefore, ERP could drive the business process reengineering. Lee (1998) argued that organizations should make reengineering and ERP implementation simultaneously, to maximize value derived from the implementation. Besides, ERP is a software package that manages and integrates business processes across organizational functions and locations. It costs millions of dollars to buy and necessitate disruptive organizational change (Soh, Kien, & Tay-Yap, 2000). It is consistent with Teece's (1980) view of administrative innovation as often involving significant "set up" costs and organizational disruption.

Third, ERP constitutes a significant change in the organizational routines used to deal with the external environment. ERP is evolving to support other functionalities that were offered separately, like supply chain management (SCM), customer relationship management (CRM), professional service automation (PSA), and others (Shakir, 2000). ERP could integrate planning and resources of financial procedures and inter-enterprise collaborative operations. It emphasizes integration enterprise, customers, and supplier chains. Organizations build long-term relationships with partners through the sharing of information.

Influence Sources

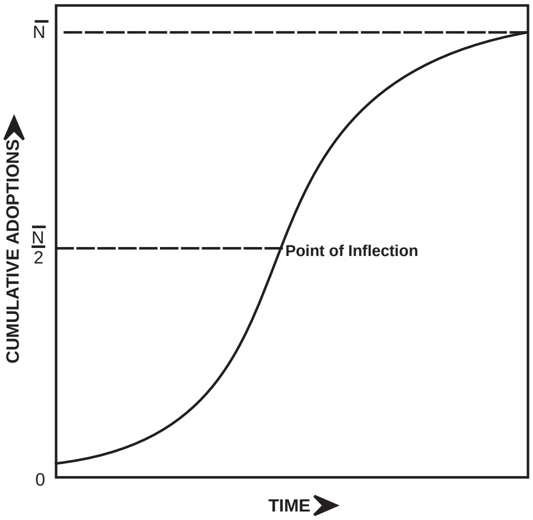
Traditionally, diffusion model has three basic models: internal influence (word-of-mouth or interpersonal communication), external influence (mass-media communication), and mixed influence (Rogers, 1995; Venkatraman, Loh, & Koh, 1994; Loh & Venkatraman, 1992; Mahajan, Muller, & Bass, 1990). A diffusion model permits prediction of the continued development of the diffusion process over time as well as facilitates a theoretical explanation of the dynamics of the diffusion process in terms of certain general characteristics (Mahajan & Perterson, 1985). The essence of the diffusion is the information exchange through which one individual (or other unit) communicates a new idea (or an innovation) to one or several others (Rogers, 2003). Internal and external sources are two influences for adopters. Internal influence source means the unit adopted an innovation that was influenced by the member of the social system (inside). External influence source means the unit adopted an innovation was influenced from outside of the social system. Mass media, vendors, consulting firms, or trade periodicals are usually external influence sources outside of the social system. These factors are explored by an estimation of model fit.

Internal influence. Mansfield (1961) suggested the internal-influence model. It purports that diffusion occurs through channels of communication within a social system and is appropriate for testing the imitation hypothesis. The diffusion is driven from imitative behavior within the social system. The model can be stated as:

$$\frac{dN(t)}{dt} = qN(t)[m - N(t)] \qquad (1)$$

where *N(t)* is the cumulative number of adopters at time *t*, *m* is the total number of adopters who will eventually adopt the innovation, and *q* is the coefficient of internal influence. In this model, the diffusion rate is a function of the number who have already adopted the innovation, and the remaining number of potential adopters. Mahajan and Peterson (1985) argued that the model is structurally equivalent to the imitation model, as seen in Figure 2. Applied to the study, the adoption of ERP in an organization may imitate other organizations which have adopted it.

Figure 2. Internal influence diffusion curve (Source: Mahajan & Peterson, 1985)



External Influence

Much of the popularity of the external-influence model is due to the work of Coleman et al (1966). Diffusion processes are hypothesized as only being “driven” by information from a communication source external to the social system. The model assumes that the rate of diffusion at time *t* is dependent only on the potential number of adopters present in the social system at time *t*. That is to say, the model does not consider interaction between prior adopters and potential adopters (Mahajan and Peterson, 1985). The model can be represented as:

$$\frac{dN(t)}{dt} = p[m - N(t)] \qquad (2)$$

where *p* is the coefficient of external influence and a nonnegative constant. *N*(*t*) with t results in a curve that increases at a decreasing rate, as shown in Figure 3. In our study, external influences on the potential adopters of ERP includes: mass media, vendors, consulting firms or trade periodicals.

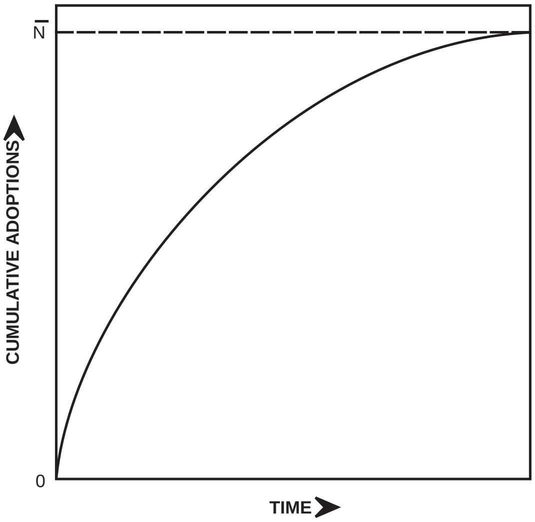
Mixed Influence

This formulation combines both the internal- and external-influence models (Bass, 1969). The mixed-influence model can be stated as:

$$\frac{dN(t)}{dt} = [p + qN(t)][m - N(t)] \qquad (3)$$

The cumulative distribution of the model brings about a generalized logistic curve whose S-shape depends on the coefficients *p* and *q*. The model is the most general form and is widely used to combine both internal and external influences

Figure 3. External influence diffusion curve (Source: Mahajan & Peterson, 1985)



concurrently. The diffusion of the model was due to a combination of coverage by the media and early adoption.

Research Questions

The internal, external, and mixed influence equations provide the foundation for two research questions:

- Research Question #1: *What source of influence best characterizes the diffusion of ERP?*

A second research question looks at the importance, as the literature suggests, of Y2K as an important inflection point in the evolution of ERPs. In the late 1990s, most enterprise information systems included some legacy systems; Y2K was a serious problem for these old systems. ERP systems could provide a solution to fix the Y2K problem for firms. During the last 3 years of the 1990s, the ERP market was one of the fastest growing and most profitable areas of the software industry (Davenport, 1998). Sprott (2000) indicated that most of this was clearly attributable to the Y2K effect. The package software got a huge boost when companies began to realize the full impact of the Y2K problem.

By 1998, nearly 40% of companies with annual revenues of more than $1 billion had implemented ERP systems (Caldwell & Stein, 1998). The largest ERP vendor, SAP Inc., had revenues of $3.3 billion in 1997, which had soared from less than $500 million in 1992 (Davenport, 1998). AMR research predicted that the ERP market would reach $66.6 billion by 2003. But, because many companies have already implemented ERP in response to Y2K concerns, the ERP systems and services of market have cooled somewhat at present (Markus & Tanis, 2000). The Y2K issue provided an added incentive to address the inflexibility of legacy systems, enabling the introduction of ERP. That is, the Y2K problem drove the demand for ERP software packages (Scott & Kaindl, 2000). Based on the discussion, the Y2K is treated as a critical point in the adoption of ERP. In particular, whether the types of underlying influence differ before and after this critical point is tested.

The term “Y2K effect” is used to signify the importance of the Y2K critical point in driving the diffusion pattern of ERP. For this purpose, the period: January 1997 to December 2000 is considered as the first diffusion regime and the period: January 2001 to December 2004, as the second diffusion regime.

A research question to explore the impact of Y2K follows:

- Research Question #2: *What source of influence best characterizes the diffusion of ERP before and afterY2K?*

RESEARCH DESIGN

Based on the discussions, the research methodology used in the study is described.

The Adoption Data

The sample comprises companies which have adopted ERP in Taiwan. The data are collected from the TTS (transmission text retrieval system) Web server. TTS is the products of Transmission Books and Microinfo Co., Ltd. (TBMC). It has been providing various publications and services to academic libraries since 1981. TTS contains indexes of several major daily newspapers in Taiwan (such as United Daily News, Economic Daily News, China Times, and The Commercial Times). Related reports and statistical data on ERP in Taiwan mostly begin from 1997 (MIC, 2004). Besides, since the millennium is viewed as a critical point, a search of related information sources from 1997 to 2004 is performed. Time-series adoption data are developed by the year function.

Table 1 shows these data (on 82 firms), and by year, provides the number of firms that adopted the ERP system. Figure 4 illustrates the non-cumulative number of adopters. Figure 5 shows the cumulative number of adopters. It shows a clear "S" curve and the pattern of diffusion process. The pattern shows a typical diffusion process. It also finds that the inflection point of the curve is on Y2K in the figure. That means the increasing rate is different before and after Y2K. The curve also shows the increasing rate is positive before Y2K and negative after Y2K.

Analytical Framework

The Bass model assumes that potential adopters of an innovation are influenced by two means of communication: (1) mass media and (2) word of mouth. This further assumes that the adopters of an innovation comprise two groups: (1) those influenced by mass media communication, an external influence; and (2) those influenced by interpersonal communication, an internal influence (Mahajan et al., 1990). Mahajan et al. (1988) studied the adoption for the M-form organization structure and used linear regression analogue equation (ordinary least square: OLS estimation) to test different models. Based on the Bass model and Mahajan et al. (1988) analysis methods, the analysis method of this study adopted the OLS method.

Research Procedures

The Null Hypothesis

A stringent null hypothesis assumes that the diffusion pattern follows a white-noise or a random walk process (Majahan et al., 1988; Loh & Venkatraman, 1992). The white-noise process clarifies the difference between the numbers of adopters at t and $(t\text{-}1)$ is random. That is, in time-series data, the rate of diffusion will be driven by the error term only when:

$$x(t) - x(t-1) = \varepsilon(t) \text{ or } x(t) = x(t-1) + \varepsilon(t) \qquad (4)$$

where $x(t)$ is the number of adopters at time t, and the residuals $\varepsilon(t)$ have a zero mean that is uncorrelated with $\varepsilon(t-k)$ for all nonzero k. The model indicated that in the adoption of time-series, progression occurs via a sequence of unconnected steps, starting each time from the previous value of the adoption time-series.

Table 1. Adoption data (non-cumulative)

Year	1997	1998	1999	2000	2001	2002	2003	2004
Number of adopters	1	1	11	24	15	13	11	6

Figure 4. Non-cumulative adoption

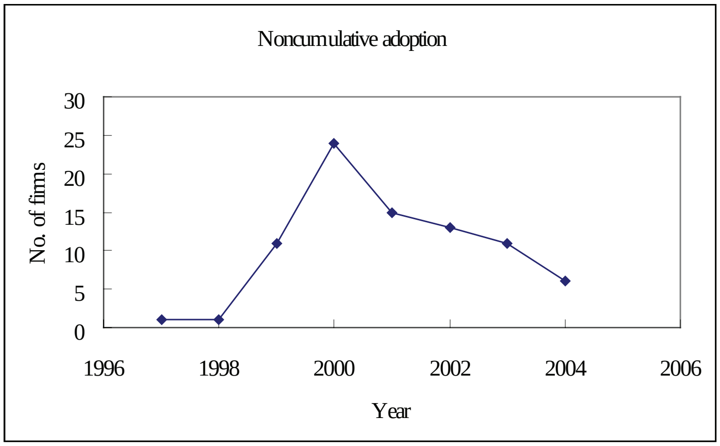
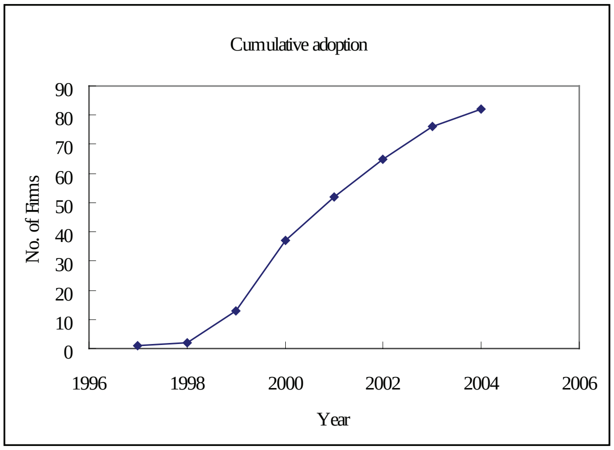


Figure 5. Cumulative adoption



The External-Influence Model

The regression analogue of the external-influence model, equation (2), for describing a time-series adoption pattern, can be stated as (Mahajan et al., 1988):

$$x(t) = \beta_2 x(t\text{-}1) + \varepsilon(t) \qquad (5)$$

where $x(t) = N(t)\text{-}N(t\text{-}1)$ is the number of adopters at time t, $N(.)$ is the cumulative number of adopters, $\beta_2 = (1\text{-}p)$ and $\beta_2 < 1$, and the residuals, $\varepsilon(t)$, have zero mean, and $\varepsilon(t)$ is uncorrelated with $\varepsilon(t\text{-}k)$ for $k \neq 0$. Besides, if β_2=1, equation (5) is reduced to the white noise model.

The Mixed-Influence Model

Two popular innovation diffusion models that generate the S-shape adoption pattern and, in particular, capture the imitation behavior, are those suggested by Mansfield (1961) and Bass (1969). The Bass model can be stated as:

$$\frac{dN(t)}{dt} = p(m - N(t)) + \frac{q}{m}(m - N(t))N(t) \qquad (6)$$

where the second term in equation (6) represents the "contact" between adopter and non-adopters and reflects the imitation behavior. Consequently, the non-negative constant q is usually defined as the coefficient internal influence. Note when q=0 and $\beta_2 < 1$, as in equation (6), it yields the Coleman model (external-influence), equation (3).

One possible regression analogue of both imitational (mix and internal) models can be derived as:

$$x(t) = \beta_2 x(t-1) + \beta_3 N^*(t-1) + \varepsilon(t) \qquad (7)$$

where $\beta_2 = 1+q-p$ for the Bass (mixed-influence) model and $\beta_2 = 1+q$ for Mansfield (internal-influence) model and $\beta_2 > 1$, $\beta_3 < 0$, and $N^*(t-1) = N^2(t-1) - N^2(t-2)$ (Mahajan et al., 1988).

The Internal-influence Model. In the mixed-influenced equation (7), $\beta_2 = 1+q-p$ for the Bass (mixed-influence) model and $\beta_2 = 1+q$ for the Mansfield (internal-influence) model and $\beta_2 > 1$, $\beta_3 < 0$. In the external-influenced equation (5), $\beta_2 = (1-p)$ and $\beta_2 < 1$. So, it is derived that internal-influenced β_2 is 1+ (mixed-influenced β_2) - (external-influenced β_2).

$$x(t) = \beta_2 x(t-1) + \beta_3 N^*(t-1) + \varepsilon(t) \qquad (8)$$

where $\beta_2 = 1 + (1+q-p) - (1-p)$ and $\beta_2 > 1$, $\beta_3 < 0$. Table 2 summarizes the model specification and parameter values.

Evaluating the Two Research Questions

The first research question, based on the analytical framework, is employed to test the entire diffusion regime, to assess the relative adequacy of an influence model against the white-noise model with the three influence models. The second research question is appraised in the two regimes. According to Loh and Venkatraman (1992), the approach used is in accordance with the standard econometric technique of testing structural change by breaking up a full-time series into separate regimes, using some conceptually conceived cutoff points. The research question is to be evaluated by comparing the separate analysis results within each of the regimes, and to interpret the results in terms of the dominant type of influence in the two regimes.

RESULTS

Research question 1: Influence sources in the diffusion of ERP

Table 3 summarizes the parameter estimates and the fit statistics (R^2 and significance values) for the three alternative models and white noise model. The white noise's R^2 value is smaller than those of other models. Three alternative models are significant. Main influence sources are mixed influence sources. It may be thought that external influence has more influence if it is considered that mixed sources are combined with internal and external influence sources; however, there is no significant difference compared with internal and external models.

Table 2. Summary of hypothesized model specifications

Hypothesis	Model name	Model Specification	Parameter Values - - β_2 β_3
Null	White-noise	$x(t) = x(t-1) + \varepsilon(t)$	- - =1 -
Alternative	External mixed Internal	$x(t) = \beta_2 x(t-1) + \varepsilon(t)$ $x(t) = \beta_2 x(t-1) + \beta_3 N^*(t-1) + \varepsilon(t)$ $x(t) = \beta_2 x(t-1) + \beta_3 N^*(t-1) + \varepsilon(t)$	- - <1 - - - >1 <0 - - >1 <0

Table 3. Parameter estimation of ERP diffusion

Model	Coefficients				
	β_2	β_3	R^2	F	*Sig.*
White-noise	1.00	−	0.649	15.768	0.063*
external	0.857	−	0.672	17.369	**0.004*****
mixed	1.270	-0.006	**0.675**	9.326	**0.014****
internal	1.413	−0.007	0.670	9.120	**0.015****

** p<0.1; ** p<0.05; *** p<0.01*

Table 4. Parameter estimation of ERP diffusion before the millennium

Model	Coefficients				
	β_2	β_3	R^2	F	*Sig.*
White-noise	1.00	−	0.485	1.589	0.297
external	1.00	−	0.485	1.589	0.297
mixed	6.119	-0.262	**0.838**	11.364	0.081*
internal	6.119	-0.262	**0.838**	11.464	0.081*

** p<0.1; ** p<0.05; *** p<0.01*

Research question 2: What source of influence best characterizes the diffusion of ERP before and after the millennium?

Table 4 summarizes the parameter estimates and fit statistics for the three alternatives model and the white-noise model before the millennium (included 2000). The results show that white-noise and external models are not significant, while mixed and internal models are significant (significance level 0.1). Mixed and internal models have the same influence (equal R^2 value), explaining the quite high variance (about 84%). From the analysis, the main influence sources are internal channels before the millennium.

Table 5 summarizes the parameter estimates and the fit statistics for the three alternatives model and the white noise model after the millennium. Only the external model is significant with 5% significance level (mixed model is significant with 10% significance level). The results show that the main influence sources are the external channels. It explains the 96.1% variance. Table 4 and Table 5

Table 5. Parameter estimation of ERP diffusion after the millennium

Model	Coefficients				
	β_2	β_3	R^2	F	*Sig.*
White-noise	1.000	−	0.724	3.833	0.145
external	0.700	−	**0.961**	33.438	**0.010****
mixed	1.000	-0.003	0.855	12.830	**0.072***
internal	1.300	-0.006	0.669	4.861	0.171

*p<0.1; ** p<0.05; *** p<0.01*

show the main influence sources differing before and after the millennium. These results confirm that the millennium is a critical point.

DISCUSSION AND CONCLUSION

An innovation is an idea, practice, or object perceived as new by an individual or other unit of adoption (Rogers, 2003). In this study ERP is viewed as administrative innovation and the unit of adoption is an organization. The influence sources of the adoption of ERP were explored and the Y2K effect in Taiwan was also examined by different diffusion models. The results show that the mixed model is a better fit for the total period. More specifically, external communication channels showed more influence. Perhaps mass media reports about the Y2K effect and the benefits of ERP created effective innovation knowledge and change attitudes toward ERP adoption. Considering the Y2K effect, before the millennium, the mixed model and internal model showed the same power of explanation (R^2 = 83.8%). While the internal communication channels were important influences behind ERP adoption before the millennium, interpersonal channels were more effective in forming and changing opinions concerning the adoption of ERP. However, after the millennium, the external influence sources became the main influences (R^2 =96.1%). That suggests that mass media and other external channels (such as consulting firms) are major influences for ERP adoption in this period.

After Y2K, the ERP concept and ERP market reached maturity. The Y2K effect was not an important factor any more for ERP adoption. Enterprises focused on business strategy planning, critical process reengineering, and organization change management for adopting ERP. External channels, such as reports about ERP in the mass media, promotion of ERP providers, and consulting firms were the major influence sources. The external diffusion model showed an exponential distribution, but also showed slow growth at a later stage. The sample data also shows this trend, and this finding is in accord with the MIC annual report about software industry development (MIC, 2006). The report also indicates that most large-sized companies have already implemented ERP systems.

This study expanded the application of the diffusion model to ERP adoption. The research results indicate when the Y2K is the critical point and that can significantly differentiate the pattern of influences in the diffusion of ERP. They also reveal that the market of ERP is decreasing in Taiwan. In particular, large firms turned their software system demands to other systems, such as customer relationship management, business intelligence, and so forth. Comparatively, medium and small-size firms have still been demanding ERP systems recently (MIC, 2006). For practitioners, because of the slow growth of the ERP market, ERP providers should provide multiple services and continue to maintain original customers. Moreover, because of the lower demand of large firms, they could exploit ERP applications for small and medium-size firms.

There are some limitations to this study. The sample is collected from the TTS Web server, perhaps inducing some biases in terms in that almost large companies reported in these sample sources. Some medium or small companies could have been missed. Nevertheless, due to their lower visibility, it could be believed that smaller companies are not a critical impetus underlying imitative behavior in ERP diffusion. This study does not consider several dimensions, such as incorporating the effects of social structure and organizational characteristics. Future researchers could expand the scope of the constructs considered.

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Chapter 4.11

Enterprise Resource Planning (ERP):

A Postimplementation Cross-Case Analysis

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ABSTRACT

In today's intensely competitive marketplace, companies can benefit strategically and tactically from enterprise resource planning (ERP) systems, if implemented correctly. However, with failure rates estimated to be as high as 50% of all ERP implementations, companies can be negatively impacted by a poorly performing ERP system. The research on ERP has focused on events leading to the selection, evaluation, and implementation of the ERP system. The intent of this research is to identify new or lightly researched theories regarding the difficulties of ERP implementations that can help practitioners successfully manage ERP implementations by performing a post-ERP implementation examination of eight corporations. We examine operations management (OM) literature rather than information systems (IS) literature in order to provide IS readers with an alternative yet valuable analysis. Further, we purposely avoid well-established findings by performing a large literature review. This article is based on a qualitative research design using case-study methodology. The propositions derived from the case studies form solid insight into the considerations that may influence the success of an ERP system.

INTRODUCTION

In today's highly competitive manufacturing environment, firms are implementing enterprise resource planning systems to address the problem of fragmentation of information or "islands of information" in business organizations. ERP systems promise to computerize an entire business with a suite of software modules covering activities in all areas of the business. Furthermore, ERP is now being promoted as a critical link for integration between all functional areas within a firm's supply chain, and has shown to be a significant contributor to a corporation's success, if implemented correctly. ERP systems improve efficiency within the four walls of an enterprise by integrating and streamlining internal processes (Anderson, 2000; Koch, 1999). Kalling (2004) has also speculated that ERP may be a source of competitive advantage.

The ERP implementation efforts of many manufacturing companies have resulted in partial failure and, in some cases, total abandonment. Trunick (1999) reports that 40% of all ERP installations only achieve partial implementation, and nearly 20% are scrapped as total failures. Some of the failures have been shown to be user related in that new technology is not always acceptable (Nah, Tan, & Teh, 2004). An American Production and Inventory Control Society (APICS) Conference Board report issued in June 2001 stated that 40% of participants failed to achieve their business case after having implemented ERP for at least 12 months (Salopek, 2001). Other authors have suggested that the failure rate may be higher than 50% (Escalle, Cotteleer, & Austin, 1999). In a recent survey by Deloitte Consulting LLC, 25% of the 64 Fortune 500 companies surveyed said they suffered a drop in performance when their ERP systems went live (Evangelista, 1998). This is after believing that they had successfully installed the system. A recent study conducted by Professors Austin and Nolan of the Harvard Business School reveals that a remarkable 65% of executives believe ERP systems have at least a moderate chance of hurting their business because of implementation problems (Cliffe, 1999). At present, ERP is a new phenomenon and the research relating to ERP implementations is very limited (Al-Mashari, 2000; Dong, 2001; Nah, Lau, & Kuang, 2001; Parr, Shanks, & Drake, 1999). Most of the research to date focuses on preimplementation activities and provides some answers to a successful "path forward" for firms wanting to implement an ERP system. Research shows that some firms have successfully implemented ERP systems with some excellent performance improvement (Anderson, 2000; Melnyk & Stewart, 2002). However, since many ERP systems fail to meet their objectives after going live (Cliffe, 1999; Salopek, 2001), it is logical to conclude that there must be postimplementation improvements being performed by firms committed to using ERP as a successful business tool. This research seeks to uncover new information about the successful implementation and management of ERP systems by analyzing eight firms who have multiple years' experience, with varying degrees of success, with ERP systems.

The intent of this research is to identify new or lightly researched theories regarding the difficulties of ERP implementations that can help practitioners successfully manage ERP implementations by performing a post-ERP implementation examination of eight corporations. Our findings are formed into propositions. We examine operations management literature rather than information systems literature in order to provide IS readers with an alternative, yet valuable analysis. Further, we purposely avoid well-established findings by performing a large OM literature review.

LITERATURE REVIEW

OM ERP implementation literature can be segmented into five major areas, with each addressing several subtopics. These areas include strategic considerations, costs, training, project management, and the implementation process. Since our goal is to provide new ideas and theories, we reviewed the existing OM literature to gain insight into established theory on why ERP

Table 1. ERP implementation literature review

Research Area	Application	Literature Support
Strategic		
Strategic Assessment of ERP and Management Support	ERP adoption should be seen as a business decision rather than a pure technology decision. Top level managers must understand and appreciate the strategic value of ERP and be willing to provide unswerving support for the project.	Anderson, 2000; Brakely, 1999; Davenport, 2000; Griffith et al., 1999; Ng and Ip, 1998; Shulman, 1998; Vasilash, 1997; Volkoff et al., 1997.
ERP Package and Module Selection and Subsequent Technical (Information Technology) Issues	If the firm decides to implement an ERP, the information gathered in the needs assessment will provide a ready checklist for configuring an ERP system with all the necessary modules and their associated subsystems. If the expertise is not located internally it should be solicited from a third party.	Booker, 1999; Davenport, 2000; Holland and Light, 1999; Koch, 1999; Lail, 1999, Nah, et al, 2001; Shulman, 1998; Travis, 1999, Trepper, 1999.
Economic/Financial and Strategic Goals of ERP	Many ERP projects proceed without a formal analysis of costs and benefits. Major strategic benefits such as improved response to customer demands, improved and streamlined internal and external communication, and improved customer-supplier relationships should be factored into the expected benefits.	Davenport, 1998; Herr, 1994; Koch 1999; Maxwell, 1999; Melnyk and Stewart, 2002, Schaeffer, 1999; Vasilash, 1997.
Top Management Support	Top management commitment is much more than a CEO giving his or her blessing to the ERP system and then moving on to other projects. Management commitment should look beyond the technical aspects of the project to the organizational requirements for a successful implementation.	Cotteller et al., 1999; Dong, 2001, Herr, 1999; Maxwell, 1999. Oliver, 1998; Rausch, 1994.
Cost Considerations		
Economic and Strategic Justification of ERP	Economic and strategic justification for an ERP project, prior to installation, is necessary because of the enormous investment and risk involved. Moreover, the justification process helps identify all the potential costs as well as the strategic and economic benefits that can accrue from the ERP implementation.	Cliffe, 1999; Cotteler et al., 1998; Herr, 1994; Koch, 1999; Schaeffer, 1999; Vasilash, 1997.
ERP Implementation Costs	Many firms budget for these systems without adequate appreciation for the full costs of an implementation. Systems integration costs are often more difficult to predict. Often training and education costs are grossly underestimated.	Bradley et al., 1999; Koch, 1999; The Meta Group;
Training		
Training and Education	Extensive training and education are considered to be critical for the success of an ERP implementation. Training of both management and employees is required.	Al-Mashari, 2000, Appleton, 1997; Capron and Kuiper, 1998; Griffin, 1998; Griffith et al., 1999; Schaaf, 1999; Trunick, 1999.
ERP Skill Assessment and Training Needs	Formal assessment of the knowledge and understanding of ERP principles for all levels of employees is required to evaluate the amount of training required. It is also critical in establishing who has the ability to learn and change and if they can survive in the new organization.	Cliffe, 1999; Herr, 1994; Koch, 1999; Kropp, 1994; Muscatello 2002.

Table 1. ERP implementation literature review (cont.)

Research Area	Application	Literature Support
Project Management		
ERP Project Scope	"Scope creep" can create a project that never ends. The functional departments and processes that will be affected by the ERP installation should be selected at the beginning of the project and jealously guarded against additions.	Delaney and Mabary, 1994; Herr, 1994; Holland and Light, 1999; Lewis, 1993; Trepper, 1999
ERP Project Management and Team Structure	A project management structure that includes an executive steering team, a full-time project manager, a project management team and process teams is recommended.	Cotteller et al., 1999; Dong, 2001, Herr, 1994; Koch, 1999; Lewis, 1993; Nah, et al, 2001; Trepper, 1999; Vasilash, 1997, Volkoff et al., 1999; Welti, 1999.
Project Management Tools	The implementation of an ERP package is a complex task requiring specific project management skills and knowledge. As with every project, timely reports and updates are needed to evaluate ERP project progress in terms of time, cost targets and achieved benefits.	Lewis, 1993; Trepper, 1999; Wight, 1993; Welti, 1999.
Managing an ERP project Time Line	Implementing an ERP system in phases allows the executive management team to evaluate the current project phase's success or failure. This allows them to make business decisions without jeopardizing the full project cost.	Cliffe, 1999; Ferman, 1999; Frank, 2000; Holland and Light, 1999
Implementation		
Quality Assurance Methods for an ERP Implementation	Developing a "day in the life of" business case for key functions such as order entry, billing, shipping, etc. and piloting them in a conference room can drive out problems before the module is fully activated.	Benjamin and Levinson, 1993; Herr, 1999; Holland and Light, 1999; Lewis, 1993.
Process Reengineering	Companies need to integrate their core processes, combine related activities and eliminate those activities that do not add value prior to adopting the any new manufacturing or information technology.	Al-Mashari, 2000; Chalmers, 1999; Davenport, 1993; Dickey, 1999; Hammer and Champy, 1993; Hammer and Stanton, 1999; Jenson and Johnson, 1999; Nah, et al, 2001; Muscatello, 2002; 1999; Smith, 1999.

Table 1. ERP implementation literature review (cont.)

Research Area	Application	Literature Support
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ERP Project Management and Team Structure	A project management structure that includes an executive steering team, a full-time project manager, a project management team and process teams is recommended.	Cotteller et al., 1999; Dong, 2001, Herr, 1994; Koch, 1999; Lewis, 1993; Nah, et al, 2001; Trepper, 1999; Vasilash, 1997, Volkoff et al., 1999; Welti, 1999.
Top Management Support	Top management commitment is much more than a CEO giving his or her blessing to the ERP system and then moving on to other projects. Management commitment should look beyond the technical aspects of the project to the organizational requirements for a successful implementation.	Cotteller et al., 1999; Dong, 2001, Herr, 1999; Maxwell, 1999. Oliver, 1998; Rausch, 1994.
Training and Education	Extensive training and education are considered to be critical for the success of an ERP implementation. Training of both management and employees is required.	Al-Mashari, 2000, Appleton, 1997; Capron and Kuiper, 1998; Griffin, 1998; Griffith et al., 1999; Schaaf, 1999; Trunick, 1999.
Project Management Tools	The implementation of an ERP package is a complex task requiring specific project management skills and knowledge. As with every project, timely reports and updates are needed to evaluate ERP project progress in terms of time, cost targets and achieved benefits.	Lewis, 1993; Trepper, 1999; Wight, 1993; Welti, 1999.
Managing an ERP project Time Line	Implementing an ERP system in phases allows the executive management team to evaluate the current project phase's success or failure. This allows them to make business decisions without jeopardizing the full project cost.	Cliffe, 1999; Ferman, 1999; Frank, 2000; Holland and Light, 1999
Quality Assurance Methods for an ERP Implementation	Developing a "day in the life of" business case for key functions such as order entry, billing, shipping, etc. and piloting them in a conference room can drive out problems before the module is fully activated.	Benjamin and Levinson, 1993; Herr, 1999; Holland and Light, 1999; Lewis, 1993.

implementations are so difficult and often fail. This analysis allowed us to refrain from publishing heavily researched areas that may not make much of a contribution. Table 1 provides a summary of an extensive and critical review of the OM literature.

ERP adoption must be seen as a business decision (See for example: Anderson, 2000; Brakely, 1999; Ng & Ip, 1999) and not as a technology decision. This viewpoint will be helped along in the organization if strategic benefits are identified initially (i.e. response to customer demands, improved communications within and outside the firm, and improved customer and supplier relationships (See for example: Davenport, 2000; Herr, 1994). Top management support is not only necessary but critical in a project of the scope of an ERP system (See for example: Cliffe, 1999; Cotteller, Austin, & Nolan, 1998). Management commitment is essential not only in providing the financial support, but in providing the organizational processes that will ensure the success of the implementation. Package selection and identification of the features and functionality required is a tedious and resource-consuming task. Providing resources initially for the preparation of the needs assessment also requires top management support (See for example: Booker, 1999; Travis, 1999).

The second area of cost consideration is also shown in Table 1. Economic and strategic justification must be detailed and accurate in a project of the scale of ERP. Costs and benefits are critical, and must include contingencies and timing of both costs and benefits. While costs may be estimated, there are two categories of costs that are commonly underestimated. These include systems integration and training (See for example: Bradley, Thomas, Gooley, & Cooke, 1999).

Training and education are critical for the success of ERP (See for example Al- Mashari, 2000; Griffith, Zammuto, & Aiman-Smith, 1999). Skills and needs assessment must be done for all levels in the organization. Several authors identify the need to assess an employee's readiness for organizational change (See for example Cliffe, 1999; Muscatello, 2002).

Project management skills and abilities are also important in a high-profile project such as an ERP implementation. These include project structure (See for example Dong, 2001; Koch, 1999), managing scope (See for example Delaney & Mabary, 1994), managing the project time line (See for example Ferman, 1999), and overall project communication (See for example Welti, 1999).

Finally, process reengineering (See for example Chalmers, 1999; Smith, 1999) and quality assurance (See for example Holland & Light, 1999) are but two of the implementation issues that require attention in an ERP implementation.

The gap that exists in current research has to do with the postimplementation ERP effects on a business. What processes, programs, or duties changed post-ERP implementation? What interdisciplinary effects were observed? What are the observed ongoing effects? This research extends the theories on ERP implementation by exploring the selected case studies, both pre- and postimplementation.

METHODOLOGY

Case-study research methodology has been highly recommended by many researchers as an ideal tool for improving conceptual and descriptive understanding of complex phenomena (Flynn, Sakakibara, Schroeder, & Bates, 1990; McCutcheon & Meredith, 1993; Meredith, 2002; Stuart, 2002; Yin, 1994). The case-study method also offers many benefits, such as the ability to directly observe causality, and combine evidence and logic to build, develop, or support theories that are not available using other research methods (Maffei & Meredith, 1995). In contrast to survey research formats, it allows for more meaningful follow-up questions to be asked and answered, and can result in more extensive findings and insights that are valid, generalizable, and rigorous (Meredith, 1998).

ERP implementation is an expensive and extensive undertaking involving all activities related to planning, justification, installation, and commissioning of the installed system. An ERP system extends across the entire organization and beyond to cover integral partners in the supply chain. Furthermore, ERP projects can take two, three, or more years to fully implement (Parker, 1999). All of the above factors contribute to the complexity of ERP installations, and make snap-shot/cross-sectional approaches unsuitable for investigating the entire ERP implementation process. We adopt a case-study methodology to create propositions based on a longitudinal analysis of postimplementation factors that contribute to the successful installation and management of an ERP system. However, unlike the majority of studies in this area that focus on single case studies or survey information based on a specific ERP process or implementation plan, we develop propositions based on ERP implementations at eight diverse manufacturing facilities.

Selection of organizations is a very important aspect of building theory from case studies. While the cases may be chosen randomly, random selection is neither necessary, nor even preferable. Given the limited number of cases that can be studied, it has been suggested that researchers choose extreme situations and polar types in which the process of interest is transparently observable (Eisenhardt, 1989). Of the eight ERP implementation projects included in this study, four were successful, two are partially completed with low to moderate success, and two were eventually abandoned with very little gain. It was difficult to assess whether the abandoned projects should be included in a postimplementation study since obviously, their postimplementation was a failure. However, after reviewing the supporting documents and conducting preliminary interviews we decided to include them since they believed they had implemented the ERP system and abandoned it after the project team was disbanded. The author of this study served as a team member on six of the eight projects, with different roles on each project. His roles included Executive Sponsor, Project Manager, Subject-matter Expert, and Project Team Member. On the other two studies, the author had follow-up access to the project charter, plan, reengineering records, scope, quality plan, meeting minutes, consultants, project manager, team members, and executive sponsors.

Multiple methods were used to generate the data including the principle author's observations and constant interactions with ERP project team members during and after implementation. As an integral member of the pre- and postimplementation project team for six projects, and as a postimplementation advisor to the remaining two businesses, the principle author had unlimited access to historical documents and other records, financial data, and operations statistics. Open-ended interviews were also held with corporate officers, divisional managers, project leaders, super-users, and various project team members. A minimum of 10 interviews was held for each case study. These interviews included opening statements by the interviewer, open-ended questions, and nonsolicited interviewee statements. These interview techniques permitted the project participants to identify and frame the important issues and factors that affect ERP implementation success, as also suggested in Maffei and Meredith (1995). This approach is consistent with the recommendation that, in an area where theory is relatively undeveloped, researchers should use an inductive approach to the process of identifying issues for inclusion in the study (Flynn, Schroeder, & Sakakibara, 1994; Hensley, 1999; Spector, 1992). The written records, project plans, interview findings, and financial data were sorted for relevancy and completeness, and placed into tables that are referenced later in this paper. Sorting data into well-defined components in order to perform cross-case analysis follows the case-study analysis recommendations of Maffei and Meredith (1995).

COMPANY BACKGROUND AND DATA

Four of the companies covered by this study were divisions of larger companies. Four were stand-alone companies. They represented a range of firm sizes, products, types of manufacturing (continuous process, batch, and job shop) markets, and organizational arrangements, as shown in Table 2. The companies also had different prior experiences with manufacturing and information technology. The financial performances of seven of the eight companies were below the expectations of their corporate headquarters. Company G had average profits compared to the industry. Four companies (A, B, E, and F) were recording consistently declining profits. Company C was just breaking even in a growing market, and companies D and H were losing money. In addition, they were all experiencing problems with excessively highinventory levels and low inventory turnover rates. Only companies D and H had on-time delivery performances better than the industry average, while the remaining six were below average. Corporate and divisional management for all the companies recognized the need for immediate strategic and operational responses to these problems.

All eight of the companies entered their ERP decision process under directives from corporate headquarters or the company's executive management team. Companies A and G had been threatened with widespread divisional management changes if the decline in profitability was not reversed. Company B's corporate management had stated that it would close down the division and transfer the work to a foreign division of the company. Executive management of company C had threatened to find an external source for this division's products, and the corporate management of companies D and H indicated that they were going to close the division/company if the losses continued. Company E's management required improvements or underperforming divisions would be closed or sold. Executives at company F required improvement or the acquisition plan would be scuttled, leaving fewer opportunities for middle management. Corporate management of four of these companies had recent encouraging experiences with enterprise system (ES) installations at their headquarters or in other divisions; they were favorably disposed to ES solutions for streamlining divisional operations. Experienced internal managers and consultants, vendors, board members, or other professionals who had an understanding of ERP systems influenced the companies who were not divisions or subsidiaries. Corporate management at all firms viewed integrated enterprise systems as a means of improving efficiencies and communications across all their divisions, and between the divisions and corporate headquarters. Corporate management was also the primary selector of the project sponsor and senior project team members.

A detailed business profile and the findings of each case study are shown in Table 2. To maintain anonymity, the names of the corporations have been removed. The intent of this case analysis is to infer relationships between project interdependencies and project performance. Therefore, each case is akin to a laboratory or complete survey experiment (Meredith, 1998).

PROPOSITIONS AND THEORETICAL FRAMEWORK

The author derived eight propositions based on the eight case studies. Each proposition will be presented at the end of the discussion. Propositions were developed based upon the analysis of the grouped company profile data, the supporting case-study documents, financial records, project plan and meeting notes, interviewer findings and,

Table 2. Company profiles and analysis

Company	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Type of Business	Chemicals	Inorganic coatings	Electronics assembly	Centrifugal and static foundry	Specialty paint and coatings	Specialty heat resistant steels. Metals.	Health and safety products	Steel products, fasteners & specialty construction materials
Operation type	Manufacturing	Manufacturing	Manufacturing/ Distribution	Manufacturing	Manufacturing	Foundry & fabrication Also reseller	Manufacturing/ Distribution	Manufacturing
Category	Fortune 500 division	Fortune 500 division	Fortune 500 division	Division of $300MM corporation	Fortune 500	Small Private Company	Fortune 500	Large Private Company
Annual Sales (millions)	$90	$75	$200	$55	$3,500	$60	$2,200	$800
Market Share	30%	65%	30%	15%	15%	28%	14%	4%
Primary Markets (B2B, B2C)	B2B	B2B	B2B B2C	B2B	B2B B2C	B2B	B2B	B2B
Type of Manufacturing	Continuous process	Batch/repetitive	Batch/repetitive	Job-shop	Batch/repetitive	Job shop	Batch/repetitive	Job-shop, batch/ repetitive
Number of Employees	87	131	145	106	1,228	311	944	512
Finished goods	High	High	High	Low	High	Average	High	Low
WIP	Low	High	Low	Low	High	High	Average	High
Raw Mat'l	High	High	High	High	High	High	High	High
Inventory Turnover Rates	Low compared to industry	Low compared to other divisions in company and Industry	Slightly below industry	Low compared to industry	Low compared to industry	Low compared to other divisions in company and Industry	Slightly below industry	Low compared to industry
On-time (in full) Delivery Performance	60%	78%	62%	76%	85%	62%	90%	83%

Table 2. Company profiles and analysis (cont.)

Company	**A**	**B**	**C**	**D**	**E**	**F**	**G**	H
Industry on-time delivery performance	85%	70%	85%	60%	98%	90%	99%	80%
Impetus for Process Change	Declining profits (40% over a 3 year period)	Declining profits & below corporation targets.	Just breaking even in a growing market.	Losing money	Declining profits, loss of market share.	Declining profits & below corporation targets.	Moderate profits compared to industry.	Losing money. Old plant & ideas. Unionized
Corporate Stance	Improvement or wholesale management changes	Improvement or closure of the division with transfer of work to another country	Improvements or will consider outsourcing	Improvements or closure	Improvement or sell or close under performing divisions	Improvement or no acquisitions	Improvements and growth or wholesale management changes and/or outsourcing	Improvements or closure
Estimated ERP cost (millions)	$1.00	$1.20	$3.00	$0.70	$57	$0.55	$90	$22
Year of ERP Implementation	1998	1994	1997	1998	1998	1998	1997	1999
Estimated Implementation time	1 year	1 year	1.5 years	1 year	2 years	1 year	3 years	1.5 years
Actual Implementation time (years)	2	2.5	3	Abandoned	3	Ongoing	3	Ongoing
Budgeted Investment (millions)	$1.00	$1.20	$3.00	$0.70	$57	$0.55	$90	$22
Expected savings (millions/year)	$1.00	$1.25	Not Available	Not Available	$12.50	$0.30	$17.50	$6.00
-Inventory	$400,000	$500,000	Decrease	Decrease	$5.50	$0.20	$10.00	$3.00
-AP DPO	$150,000	-	-	-	-	-	-	-
-Mfg Efficiency	$250,000	-	Decrease	-	$3.00	-	-	-
-Direct Labor	$100,000	$500,000	Decrease	Decrease	$4.00	$0.10	$5.00	$2.00
-Overhead	$100,000	$250,000	Decrease	-	-	-	$2.50	$1.00
-Customer Service increase	To 95%	-	To 95%	-	To 95%	-	-	-
-Mkt Share	-	-	-	-	-	-	Increase	-

Table 2. Company profiles and analysis (cont.)

Company	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Modules/Sub-Systems								
General Ledger (GL)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Accounts Payable (AP)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Accounts Receivable (AR)			Yes	Yes		Yes	Yes	
Budgeting	Yes				Yes		Yes	
Sales Order Processing	Yes				Yes	Yes	Yes	
Master Production Schedule	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Material Req. Planning	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inventory	Yes	Yes			Yes	Yes	Yes	Yes
Capacity Req. Planning	Yes	Yes		Yes	Yes	Yes	Yes	Yes
Shop Flow Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Statistical Process Control			Yes		Yes		Yes	
JIT/Kanban	Yes		Yes		Yes		Yes	Yes
Order Entry/Billing	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Demand Management			Yes		Yes		Yes	
Distribution			Yes		Yes		Yes	Yes
Advanced Planning		Yes			Yes		Yes	Yes
Warehousing		Yes					Yes	
Forecasting		Yes	Yes		Yes		Yes	

Table 2. Company profiles and analysis (cont.)

Company	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Existing Process Systems	MRP	MRP II	MRP, SFC	None	MRPII	Manuel	MRPII, SPC	MRPII, Legacy Accounting/OE
ERP Skills Assessment	Internal	Internal	None	None	External	None	External	External
No. of division employees	87	131	145	106	1,228	311	944	512
No. (%) of employees involved in the ERP implementation	14 (16.1%)	12 (9.2%)	14 (9.7%)	9 (8.5%)	96 (7.8%)	25 (8.0%)	77(8.2%)	26 (5.1%)
Estimated project cost (millions)	$1.00	$1.20	$3.00	$0.70	$57	$0.55	$90	$22
Actual project cost (millions)	$1.22	$2.10	$3.00	$0.70	$67	$0.75	$87.50	$23
Actual/Estimated	122%	175%	100%	100%	118%	136%	97%	105%
New Hardware requirements	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Interface with legacy systems	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Cost & Efficiency Improvements (millions/yr)	$1.195	$1.925	$0.10	Not Applicable	$9.30	$0.50	$14.70	$1.30
Inventory savings	$.70 (50%)	$.38 (40%)	-	-	$4.3 (20%)	-	$7.70 (22%)	$1.30
Mfg Efficiency	Reject rate reduced by 25%	Eliminate 2 warehouses	-	-	$3.30	-	-	-
Direct Labor	$0.36	$1.00	-	-	$1.70	$0.05	$3.90	-
Overhead	$0.14	$0.25	$0.10	-	-	-	$3.10	-
Market share before ERP	30%	65%	30%	15%	15%	28%	14%	4%
Market share after ERP	35%	70%	Not available	Not applicable	16%	28%	16%	3.5%

Table 2. Company profiles and analysis (cont.)

Current status of Firm	Company A is still in business and has increased market share and profits faster than their competition. They are expanding into TQM and Lean Manufacturing principles	Company B is the largest producer in a market that is replaced by plastics. They feel their ERP system has allowed them to remain competitive	Company C lags the market in both sales and revenue. Only the accounting modules of the ERP system are implemented	Company D closed its doors in 1999. Fortunately for the researchers, we were able to locate several of the senior managers and ERP implementers
	Company E enjoys and increased reputation in the market for both low price and high service	Company F has declined in profitability and has now implemented plans to use off-shore manufacturing	Company G has a strong financial statement and enjoys profits higher than the industry average. They have also implemented Six-Sigma improvement practices	Company H is losing money and closed a division in 2000.

if any, relevant OM literature. The supporting statements made before each proposition are an accumulation of ideas/statements formed into a single like-minded expression. The development of generalities is acceptable for developing propositions when a rigorous case-study analysis has been carried out. (Maffei and Meredith (1995). The companies who contributed to each statement are noted after each statement.

Participants were very vocal about the need to assess the skill and training level of the existing employees after the implementation. There was a general dismay at the lack of ERP and business knowledge residing in companies that implemented ERP systems. One participant stated: “People don’t understand how the whole company operates, just their little corner of the world. They need to understand that an ERP system requires timely and accurate data in order to perform the planning functions. They view transactions as an afterthought and not ‘real work’ like production. This mentality is killing our ERP system.”

Three companies (C, D, and F) performed no formal review of their existing employees’ skill levels until after the implementation. Companies A and B did the skill review with in-house senior managers who had successfully transformed other divisions, and two managers with multiple ERP systems installations. Three companies (E, G, and H) used outside consultants to assess the current skill level, ability to grow, and amount of education and training necessary to grow. The assumption from most management is that after implementation, a person is fully trained. This reasoning is misguided because it assumes that once an employee has gone through an ERP training program, they now understand the business philosophy behind an ERP system. This analysis found that in all eight firms, process and job functions changed so radically in the areas of customer service, production scheduling, purchasing, inventory, and logistics that some employees who were deemed adequate or better performers before the implementation were not able to satisfactorily grasp the new procedures. Human-resource administrators in all eight companies stated they had significantly changed the job descriptions, requirements, and interview procedures after implementing ERP. All of the firms felt they had grossly overestimated the abilities and current job knowledge of at least a few of their employees. Thus,

Proposition 1: Firms who implement ERP systems will significantly change the education, training, and experience requirements for future hires.

Also, after the "go live" date, five firms (A, B, C, E, and G) reported that they implemented more functionality of their ERP systems than planned, and had to conduct further training and education of their employees. Some of the postimplementation functionality implemented included advanced planning systems (APS), distribution requirements planning (DRP), desktop report writers, online costing systems, Internet integration, engineering configurators, and bolt-on software such as timekeeping systems, amongst others. This caused a further gap in the abilities of current employees, and lead to management having to go through the painful process of re-evaluating employees again. However, six firms (A, B, C, E, F, and G) all stated that without the continuous upgrade in employee skills through hire/fire, training and education, or outsourcing, their ERP implementation would have failed, been less successful, or taken longer and been more expensive. So, we propose,

Proposition 2: Firms who address the gap in employees' abilities and performance after the ERP implementation, through an ongoing analysis, will have a greater likelihood of successfully implementing ERP than those who do not.

All eight of the companies performed "needs" assessments. However, there were some differences in their approaches. Company D used an in-house team and examined software packages from various vendors. The remaining companies used independent, third-party consultants to assist in their assessments, and used the results of their reengineering efforts to develop the configuration for their ERP packages. They performed a checklist assessment provided by the consultants to determine the best-fitting software. Company B used a similar checklist and was aided by an outside consultant on their selection of a package. Since they had not yet performed their process reengineering, they selected a package based only on an evaluation of their current processes. After company B's reengineering efforts, changes had to be made to the chosen ERP system to incorporate the requirements of expected future processes. The checklists used by all three companies included questions on

(1) Current IT systems (including hardware)
(2) Type of business (continuous, repetitive, batch, job shop)
(3) Market analysis (demand management, forecasting, customer relationship management, etc.)
(4) Scheduling (MPS, MRP, and BOM requirements; shop floor scheduling, etc.)
(5) Logistics (warehousing, transportation scheduling, etc.)
(6) Purchasing (EDI, Internet, integration to inventory, and MRP, etc.)
(7) Inventory (transactions, bar codes, package types, analysis, etc.)
(8) Performance measurements (types of measurements)
(9) Financial and accounting (GL, AP, AR, credit, online banking, depreciation, aged inventory, budget control, costing, etc.)
(10) Other

All companies came to the conclusion that they needed to install modern information systems, and that this was at least part of the answer to their problem. This conclusion was reached after examining current trends in the marketplace, and after careful consideration of IT needs for their current or reengineered processes, their current IT systems (including hardware), and available IT solutions. The firms all reached several common conclusions about their existing systems that suggested a need for the implementation of new information technologies and ERP systems. We list some of these conclusions drawn by our study participants, as well as supporting research for each conclusion:

- The existing systems required multiple points of input and there was significant duplication, with the same data being entered at multiple points in the system (Davenport, 1998).
- The organization's information and manufacturing technology needs were not adequately being met by the existing systems (Chalmers, 1999; Cliffe, 1999).
- Maintenance and support for the existing systems required significant effort both in terms of time and human resources (Capron & Kuiper, 1998; Griffith et al., 1999).
- The enterprise had islands of information, and many of these systems were incompatible (Muscatello, Chen, & Small, 2003).
- Too much information was stored informally, and “fire fighting” and “expediting” had become the norm (Davenport, 1998; Dickey, 1999).
- In too many instances, employees were unable to respond easily and quickly to questions or information requested by key customers or suppliers (Escalle et al., 1999; Jenson & Johnson, 1999).

The companies expected the ERP systems to provide the required crucial links between factory floor operations and information requirements across all the support functions of the business. The fact that these systems could also be extended to cover partners in the supply chain was also appealing to these companies. The decision to implement ERP was also due, in large part, to the influence exerted by corporate management.

Although all eight companies felt that their ”needs assessment” efforts helped them to configure and select ERP systems that would provide a good fit with their operations, it is clear from the postimplementation respondents that ”needs assessment is ongoing in an ERP project.” The six firms who had some success with their ERP implementation added additional hardware and/or software after the project ”go–live” date. In two instances, the main information systems had to be upgraded due to an unforeseen increase in the usage of the system. Also, five firms (A, B, C, E, and G) decided to install additional modules and/or peripheral devices such as radio frequency (RF) controllers, advanced planning modules, payroll systems, electronic data interchange (EDI), and Internet electronic commerce capabilities. These additional tools were deemed unnecessary or too costly at the beginning of the project. However, after implementation, the value of these technologies was uncovered, and they were subsequently added to the business system.

Proposition 3: A firm's ability to successfully implement an ERP solution requires an ongoing assessment and implementation of technical and functional capabilities beyond the initial scope of the ERP project.

In all eight cases, the manufacturing-marketing interface became much more scrutinized after the implementation of ERP. Current research shows this to be an issue in many organizations (Calantone, Droge, & Vickery, 2002; Parker, 1999). Our study found that the implementation of an ERP system magnifies the diverse perspectives and motivations of manufacturing and sales.

The causes for this increase in potential conflict arise from a variety of factors. First, there is an increased scrutiny of inventory investment since it is one of the leading cost-reduction areas used to justify the implementation. Second, salespeople are rewarded for increasing volume, and this was a project justification factor for all but firm C. In six firms (B, C, D, F, G, and H), manufacturing and sales did not have common performance measurements or goals. Manufacturing was judged on labor cost models, leading to a big run size, lowchangeover philosophy. The sales function was judged on total sales dollars and gross margins, leading to a high stocking philosophy. It was also observed that in five firms (A, C, D, F, and H), there was no formal notification system of changes to the sales plan such as incentive programs, advertisement, and so forth. This led to inventory spikes and stock-outs due to the manufacturing's mandate to lower inventory.

Our study found that postimplementation issues between manufacturing and sales were resolved in several ways. First, five firms (A, B, C, E, and G) created joint performance objectives for all levels of management in the areas of manufacturing and sales. The manufacturing managers had a review component consisting of total sales dollars, gross margins, lost sales, and customer complaints related to customer-service delivery issues. The sales managers had a review component consisting of total inventory dollar investment, schedule changes after freezing the master scheduling, and activity-based product costing. As one executive from firm E described it, both manufacturing and sales had "skin in the game." The same five firms (A, B, C, E, and G) all felt that after they implemented joint performance measurements, manufacturing and sales worked in greater harmony and morale increased in both groups.

Proposition 4: Firms that use ERP functionality to improve performance objectives shared by manufacturing and sales will strengthen the manufacturing-sales interface.

Firms (A, B, C, E, and G) who relied on product forecasts took an integrated role to forecasting. The sales managers were given a forecast variance, plus or minus, that they were expected to adhere to. Manufacturing managers were required to meet the forecast, plus or minus variance, without raising product costs. This created a measurement system that both manufacturing and sales had input into, and the consequences were established. This performance objective helped minimize the after-the-fact arguments between manufacturing and sales.

Proposition 5: Firms that use ERP functionality to create relevant performance objectives for sales forecasting will strengthen the manufacturing-marketing interface.

In summary, the extended theory of ERP implementations reveals that the processes changes forced by an ERP implementation, if acted upon, will strengthen key interfaces and improve the general communication between manufacturing and sales.

Proposition 6: ERP functionality will strengthen the manufacturing-sales interface and increase morale in both areas.

Six firms (A, B, C, E, F, and G) found that the implementation of an ERP system had a dramatic impact on purchasing's role in the corporation, regardless of whether the firm had a centralized or decentralized purchasing function. Five firms (A, B, C, E, and G) reported that the increased pressure to reduce total inventory dollar investments and total product costs caused a greater role for purchasing. In six firms (A, B, C, E, F, and G), purchasing went from a quasiclerical function to a highly skilled professional function because of the emphasis placed on material requirement plans, just-in-time deliveries, and the increased cost of material shortages due to the minimization of raw and component inventory.

Six firms (A, B, C, E, F, and G) agreed that purchasing's role became more strategic after the implementation of the ERP system because of the overall impact to the effective management of the supply chain, and the direct impact to product costing, financial performance measures (inventory turns, etc.), and shop-floor disruption costs.

Proposition 7: Purchasing's strategic and tactical value increases with the implementation of an ERP system

Interestingly, those same six firms (A, B, C, E, F, and G) showed an increase in the amount of time purchasing managers were involved in marketing, financial-, and operations-planning meetings. This also corresponded with an increase in participation from nonpurchasing managers in purchasing meetings, creating more formal integrated purchasing teams. This is interpreted as further proof that purchasing's strategic and tactical value increases with the implementation of an ERP system.

Proposition 8: The Use of Integrated Purchasing Teams Increases with the Implementation of an ERP System

CONCLUSIONS, IMPLICATIONS AND FUTURE RESEARCH

Many researchers have argued that firms implementing ERP systems would benefit from a better understanding of how to implement an ERP system and how will it change their business. This paper conducted an intensive review of OM current literature, academic and practitioner, to determine what theories have been established, and to create groundwork for managing the case studies. We purposely stayed away from areas that have been researched in an attempt to provide new insight into the transforming that takes place with an ERP implementation.

While this study is exploratory in nature, the results provide a number of insights that contribute to ERP strategy research and practice. Current ERP theories showed a strong link between the amount and level of ERP training and implementation success. Our findings conclude that training and education cannot be shorted even after the ”go live” date of an ERP implementation. Also, firms implementing ERP systems must realize that future employees will have to have a significantly greater skill set than previous employees, and that human resources must react to the change. Second, the study demonstrates that there is no single, proven path that a firm can take regarding hardware, software, and other functional capabilities. Each firm has to remain flexible after the ”go live” date, and tune the technical and functional capabilities of the system. Also, a firm should remain flexible and be willing to revisit current processes to establish a better fit between business processes and the hardware and software technology. This point builds upon the findings in OM literature that strong project management skill sets are required for success.

The third conclusion is the suggestion that an ERP system will increase the harmony between manufacturing and marketing. To receive business benefits from an ERP system, manufacturing and marketing need to understand that they both strongly influence the likelihood of success. While this perspective is advanced in the emerging manufacturing strategy literature, it is not found to be uniformly prevalent in practice (Hausman, Montgomery, & Roth, 2002). Hence, firms should strive to increase the harmony between manufacturing and marketing, by integrating performance metrics, to achieve the benefits of ERP.

Fourth, this study highlights the increasing strategic and tactical role purchasing is responsible for in the new supply-chain models. The implementation of an ERP system should increase the visibility and authority of current purchasing managers and their processes, and elevate the need for cross-functional purchasing teams. This is a solid contribution to the emerging practice of strategic purchasing.

Despite the merits of this study, it has certain limitations that should be recognized. First, the study is exploratory and introduces new concepts that need to be verified by further research. Second, we examined only eight companies, and it limits our responses. This research should spawn studies that examine different contextual factors such as SIC codes, firm size, and international firms, amongst others, which may find different results.

Clearly, the effects of an ERP system need to be studied further, especially in light of its pervasive system of choice among operation and service organizations. In summary, this study calls for the extension of current research, and identifies new areas of interest for both researchers and practitioners interested in ERP.

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Chapter 4.12

Information Technology Adoption and the Role of Organizational Readiness:

The Case of an Indian Bank

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EXECUTIVE SUMMARY

This case describes the evolution of the use of information technology (IT) at National Banking Services, one of the oldest banks in India. It describes the bank's response to economic liberalization and the resulting initiatives for IT adoption. It highlights the influence of organizational readiness on IT adoption. In particular, it describes the negative influence on IT adoption of conditions such as the lack of top management support, skeptical end-user attitudes about the benefits of IT, and resistance from employee unions. The case ends with a description of the changing role of IT in the banking industry in India and the challenges confronting the bank.

ORGANIZATIONAL BACKGROUND—PRIOR TO 1985

Many countries around the world have undergone economic liberalization in the last two decades. As a result, organizations in these nations have been faced with changing industry structures, new policy directives, and greater competition. These changes have resulted in significantly higher levels of information technology (IT) adoption, prompted by requirements for greater process efficiency and better operational and management control. For instance, firms in China have experienced higher levels of IT investment as a result of increased competition (Kunnathur & Shi, 2001). Similarly, Montealegre (1998) describes a case of increased IT adoption in a Guatemalan organization, influenced by changes in the economic environment. Similar findings have been reported from other countries as well (Saxena & Sahay, 2000; Wolcott & Goodman, 2003).

However, all organizations have not adopted IT to the same extent, even in similar industries. While some firms have used IT to achieve significant competitive advantage, others have implemented IT only to the extent required, often only in compliance with regulations (Tarafdar & Vaidya, 2004). This is because there are significant challenges in firms in these countries, in terms of required organizational support, availability of information systems (IS) related to technical and human resources, and appropriate management of change that needs to accompany the transition to higher levels of IT adoption. For instance, studies have shown that it is difficult to acquire and manage IS-related resources because of inadequate physical and information infrastructure as well as social and cultural diversity (Montealegre 1998). There is also a paucity of adequate IS personnel and support (Jain 1997; Ranganathan & Kannabiran, 2004). Moreover, cultural and organizational issues, such as resistance to IT adoption and use and the existence of employee unions, have been challenges, as has been the frequent absence of top management support for the acquisition of IT (Dasgupta, Agarawal, Ioannidis, & Gopalakrishnan, 1999; Kanungo, Sadavarti, & Srinivas, 2001).

A number of studies (see Chwelos, Benbasat, & Dexter, 2001; Iacovou, Benbasat, & Dexter, 1995; Kuan & Chau, 2001; Mehrtens, Cragg, & Mills, 2001) have analyzed IT adoption using a framework that takes into account three antecedent factors: perceived benefits from IT adoption, organizational readiness for IT adoption, and external pressure for IT adoption. Perceived benefits describe advantages that organizations perceive from the adoption of IT, such as increased process efficiency and lower cycle times. Organizational readiness refers to the availability of adequate organizational resources as well as the presence of appropriate supporting conditions (such as top management support and a proactive approach, for instance) required for IT adoption. External pressure refers to influences outside the organization (such as, competitive pressures and government regulation) that lead to IT adoption. Using this framework, this case highlights challenges and issues in IT adoption in one of the largest public banks in India.

National Banking Services (NBS) was one of the largest public banks in India. The company was founded in 1906 and had its corporate headquarters in Mumbai. It had more than 2,500 branches in India and 19 foreign branches in 10 other countries. It employed more than 50,000 employees. The mission statement of the bank was:

…to provide superior, proactive banking services to niche markets globally, while providing cost-effective, responsive services to others in our role as a development bank, and in so doing, meet the requirements of our stakeholders.

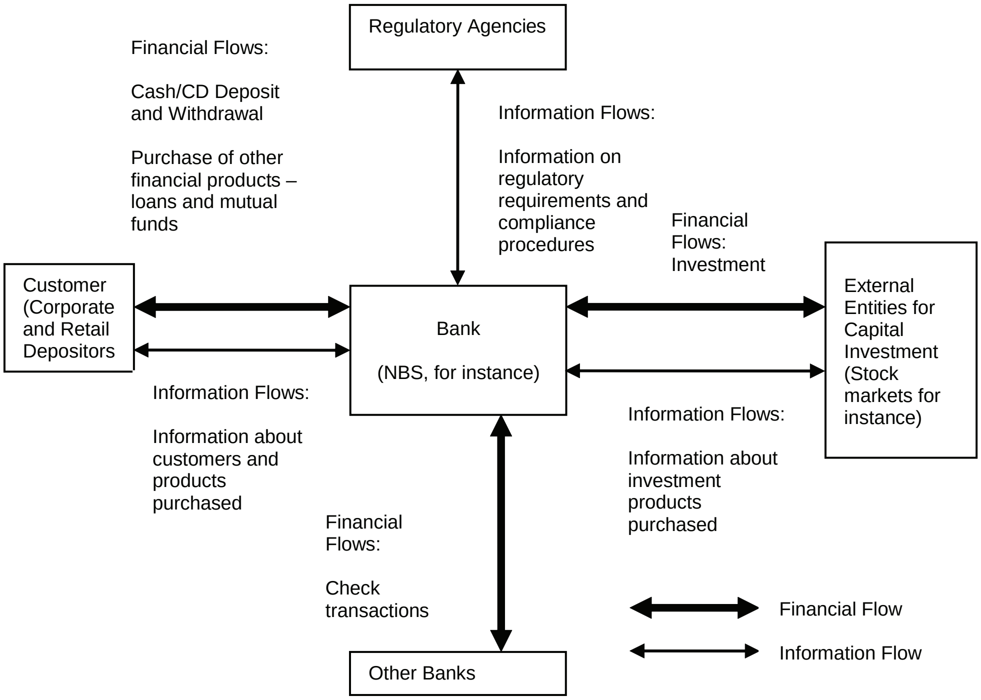
The Indian banking sector was divided into three categories. There were 27 "public sector," or government controlled, banks, 31 private banks owned by Indian companies, and 29 banks owned by foreign companies. The larger ones, usually public banks, operated on a large, nationwide scale. They had on an average, more than 2,000 branches, more than 50,000 employees, and assets of more than 50,00,00 million INR. The smaller banks had, in general, less than 1,500 branches, and assets less than 15,00,00 million INR. Some of the smaller private banks had less than 100 branches, assets less than 70,000 million INR, and less than 700 employees. The public banks were under the jurisdiction of the Reserve Bank of India (RBI), which determined broad strategic directions and formulated policy decisions. All banks operated under broad financial and economic policies specified by RBI and the Ministry of Finance (MOF).

Products and Processes

NBS served two kinds of markets: corporate and retail. Corporate banking products included corporate loans and advances, current account facilities, bill discounting, opening of letters of credit, and overdraft facilities. Retail banking products included savings accounts, current accounts, fixed deposits, and long-term advances as well as loans for houses, automotive vehicles (cars, trucks, and tractors), farm machinery, and white goods. Many of its customers, especially in the rural segment, were small farmers and owners of small-scale business units. Hence, the bank had 70% of its branches in rural areas, so that farmers could have access to capital when required and could also have an avenue to save money. These branches made credit for development and other business opportunities available in the economically backward areas. Along with its commercial objectives, therefore, there had historically been a strong social motive to the bank's operations.

The value chain of a typical bank is described in Figure 1. Important flows relate to the *financial* inflows and outflows of the bank, as well as the flow of *information* to and from external entities, such as other banks and regulatory agencies. NBS interacted with four entities: customers, other banks, investment institutions, and regulatory agencies. First, two-way financial flows with corporate and retail customers included deposits and withdrawal of cash and disbursement of loans. Two-way information flows included customer and product information. Second, NBS had two-way financial flows with other banks, when it cashed a check from another bank or another bank received and honored a check drawn on NBS. Third, NBS had two-way financial and information flows with investment institutions, such as the stock markets. Financial flows were related to capital investment activities, and information flows included

Figure 1. Value chain of NBS



information about investment products that NBS purchased from these institutions. Finally, there were two-way information flows with regulatory agencies, such as the RBI and the MOF, regarding regulatory policy directives and compliance procedures and activities.

The processes at NBS were by and large routine and standardized, with well-defined work procedures. Decision making and policy formulation were centralized. Top management provided clear operating instructions to middle and junior management. Branches worked within well-defined parameters and did not have much scope for making independent decisions. Official communication was written and extensively archived. At the same time, however, information was not stored in a systematic manner, and it was not possible to quickly retrieve information required for task performance. According to a counter clerk at one of the larger branches, "Before branch computerization, information was missing about 70% of the time. We were often not able to trace the account number, or else the account balance was not correct ... some problems were always there."

This was reflective of the general nature of operations of banks during the 1970s and most of the 1980s. At the end of the 1970s, public banks in India had more than 10 million customers. Each day, an estimated 3 million intrabranch transactions and 1 million interbranch transactions took place. This generated acute requirements for complex information processing systems for housekeeping, internal control, and auditing and macrolevel information for policy formulation and control by the government. Throughout this period, information processing techniques in the banking sector remained manual. Consequently, services degenerated and there were delays in settling transactions. The banking control system was suboptimal, leading to possibilities for forgery, fraud, and malpractice. Indeed, the only element of automation that was introduced before 1985 was the introduction of magnetic ink character reader (MICR) checks, to assist in speedier clearance of checks.

Organization Structure

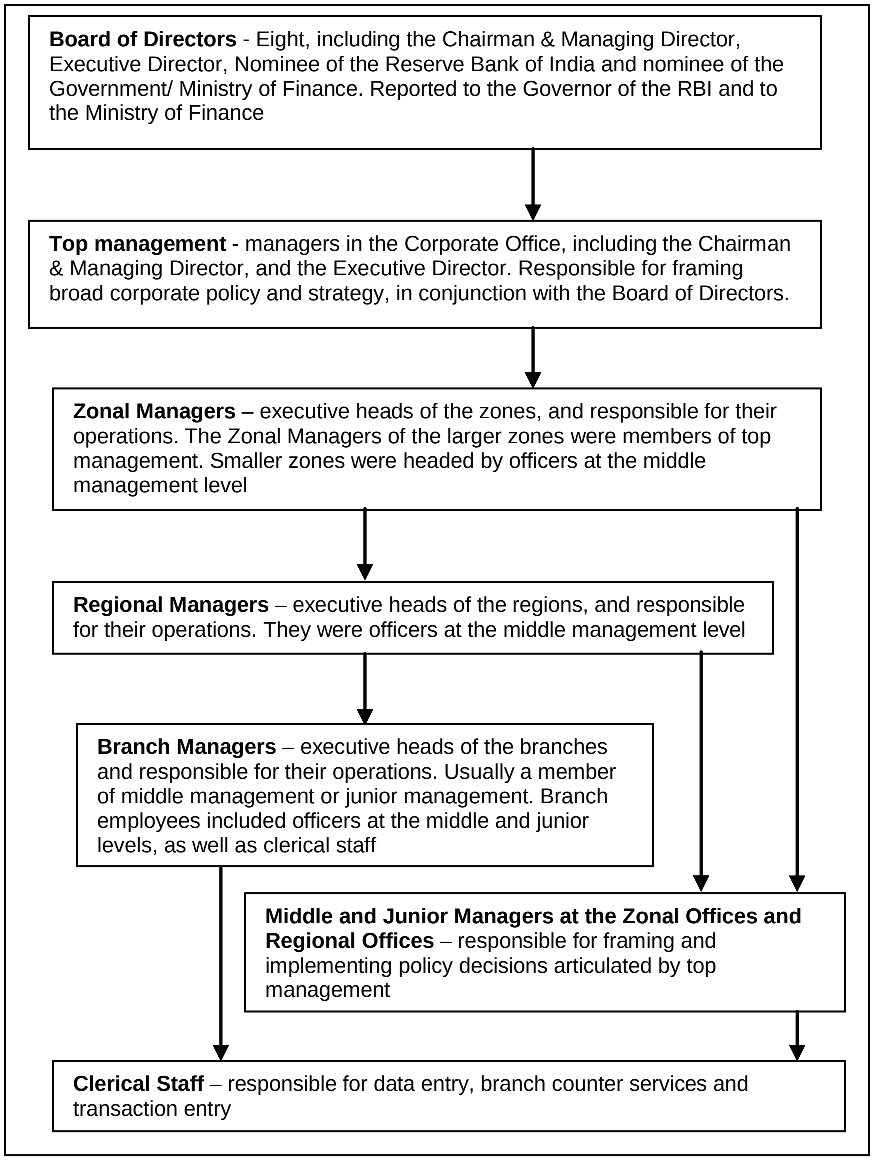
NBS was a headed by a senior government employee, who was the chairman and managing director. He was a professionally qualified bureaucrat or a career banker, specializing in economics and finance, and was appointed by the MOF. The main governing body was the board of directors, which consisted of eight people, including one nominee of the government and another nominee of the RBI. The top management functioned out of the corporate office in Mumbai. The operations were divided into 17 zones and 60 regions. Each zone and region was headed, respectively, by a zonal manager and regional manager. The zonal managers of the larger zonal offices were members of top management, while middle managers headed the smaller zones and regions. Each zone was responsible for three to four regions. At the senior, middle, and junior management levels, the zonal and regional offices were largely staffed by professional bankers, selected competitively from a central pool of applicants. Each region was responsible for a given number of branches. Each branch was headed by a branch manager, who was either a middle or junior manager, depending on the size of the branch.

Zonal managers of the larger zones, along with the corporate top management were responsible for framing overall strategy and policy. Middle and junior managers framed and executed implementation strategies for these policies. Clerical staff was responsible for line operations such as data entry, counter services, and transaction entry. The organization structure is shown in Figure 2.

Regulatory Environment

Traditionally, NBS had functioned in a protected environment. The Indian banking sector, like the rest of the Indian economy, was regulated until

Figure 2. Organizational structure



Board of Directors - Eight, including the Chairman & Managing Director, Executive Director, Nominee of the Reserve Bank of India and nominee of the Government/ Ministry of Finance. Reported to the Governor of the RBI and to the Ministry of Finance

Top management - managers in the Corporate Office, including the Chairman & Managing Director, and the Executive Director. Responsible for framing broad corporate policy and strategy, in conjunction with the Board of Directors.

Zonal Managers – executive heads of the zones, and responsible for their operations. The Zonal Managers of the larger zones were members of top management. Smaller zones were headed by officers at the middle management level

Regional Managers – executive heads of the regions, and responsible for their operations. They were officers at the middle management level

Branch Managers – executive heads of the branches and responsible for their operations. Usually a member of middle management or junior management. Branch employees included officers at the middle and junior levels, as well as clerical staff

Middle and Junior Managers at the Zonal Offices and Regional Offices – responsible for framing and implementing policy decisions articulated by top management

Clerical Staff – responsible for data entry, branch counter services and transaction entry

1991. All banks were governed and administered by the central government, which mandated the nature of activities they could undertake and the financial products and services that they could provide. The government also determined the macro-economic framework within which banks operated. One of the most important aspects of banking policy, historically, had been the concept of "deposit mobilization." As part of this policy, banks were vehicles for generating savings within the economy. One of the measures of their performance, therefore, was the amount of retail "savings" or "deposits" that they were able to generate, especially in the rural sector. Another important parameter was the disbursement of "microcredit," loans for individual entrepreneurs and small businesses that encouraged and generated commerce and economic activity in the rural sector. These objectives were in line with the nation's development goals following political independence in

1947. In addition to their financial and monetary role, therefore, banks were also expected to perform a "service" role. During the 1970s and 1980s, NBS pursued deposit mobilization in the rural areas and provided credit to small-scale sectors, farmers, and agricultural co-operative societies, in keeping with this role.

SETTING THE STAGE—1985-1991

Nature of Information Processing Activities: Perceived Benefits from the Use of IT

The processes of NBS had three characteristics. First, the information processing requirements were quite high. This was because of the sheer size of the bank, which had 2,500 branches, and the volume of transactions handled. The number of branches, total assets, and deposits were among the largest in the country, and almost four times that of the smaller banks. Further, given that products and services were information based, all functions and processes involved the transfer of information (amount of money, interest rates, loan and deposit schemes, account balance, exchange rates) from one point to another. Also, customers had to process significant amounts of information in order to acquire and use the products of the bank. On the whole, therefore, operations of the bank required huge amounts of information to be processed. The adoption and use of transaction processing systems, therefore, would result in significant efficiencies in information processing.

Second, information processing had to be accomplished quickly, especially during counter operations when information regarding bank balance, credit balance, and so forth had to be furnished and retrieved very quickly at the point of service. Operations, such as loan approval and credit appraisal, also had to be completed quickly since customers' decisions depended on the outcome of these activities. The same was true for transactions related to stock exchange services. The use of databases would lead to better access to information and would considerably help speed up these processes.

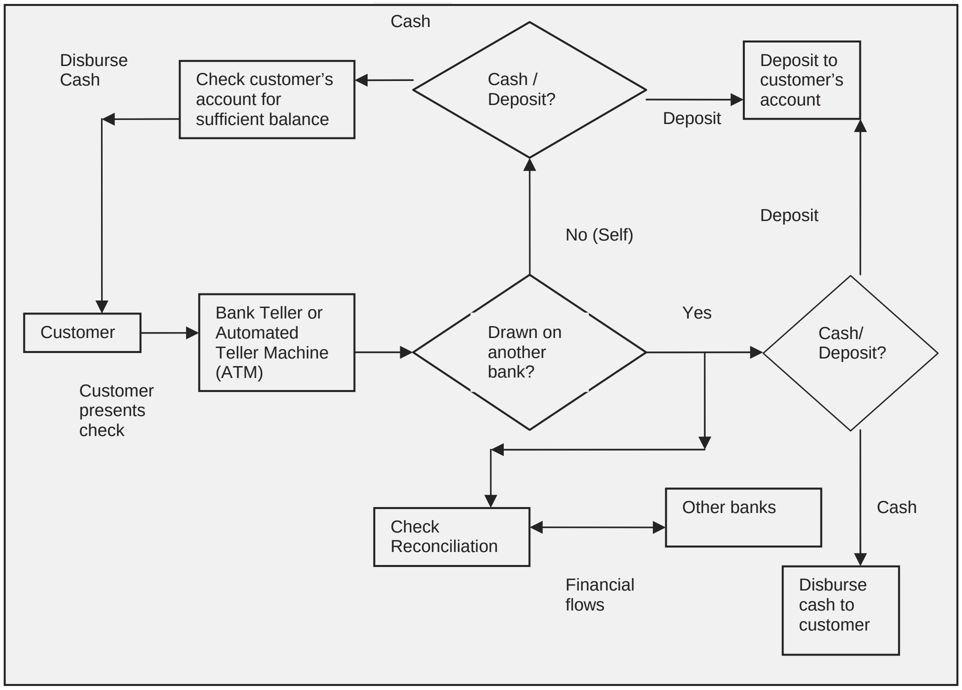
Third, there were significant interdependencies in information processing activities because many of the activities were sequential. For example, Figure 3 shows a typical check processing transaction at NBS. Customers presented their checks at the counters or at the automated teller machines (ATMs). The check was then scrutinized for authenticity, after which an amount of money corresponding to the check was either disbursed as cash (to the customer) or transferred to the customer's account. If the check was drawn on another bank, NBS transferred "reconciliation" information about the check to the bank on which it had been drawn, and received financial flows of the corresponding amount. When other banks honored checks drawn on NBS, they sent in similar information, and received financial flows from NBS of the corresponding amounts. As Figure 3 shows, the speed with which a customer could withdraw money depended on the speed with which the account number was matched and the account balance checked. Similarly, for loan approvals, the time taken to approve a particular loan depended on the speed with which the credit appraisal process was carried out. The use of centralized databases and networked computers would help in this context.

From the above descriptions, it is clear that because of the nature of its processes, the perceived and possible benefits from the adoption of IT at NBS were high, and included better customer services, housekeeping, and control over operations.

IT Deployment During this Period

IT deployment during this period was a result of government directives. In the 1980s the government appointed a committee (Joshi & Joshi, 2002)

Figure 3. Check processing transaction at NBS



to frame guidelines for addressing the information processing requirements of the banking sector. Subsequent to this, and in order to address the major recommendations of the committee, the Indian Banks Association (IBA) reached an agreement with the staff union for introducing electronic ledger posting and accounting machines. These were to be used for updating transactions related to current and savings accounts, general ledger accounts, and cash credit and loan accounts. The process of computerization at NBS and other public banks was initiated against this back drop. A computer department, consisting of senior managers from the administration and internal audit departments, was set up in NBS in 1984.

In 1985-86, automated ledger posting machines (ALPMs) were introduced as part of the computerization efforts in the branches. The RBI coordinated this effort and helped decide on vendors and software. Activities having heavy information processing requirements, such as ledger posting, financial accounting, and payroll processing, were computerized. Initially ALPMs were introduced only in those branches that had greater than 750 transactions in a day. They were located mostly in the larger cities. The ALPMs were stand-alone terminals where transactions were entered at the end of the day to generate the ledger. Data entry was performed offline, and counter clerks were trained in operating the ALPMs. ALPMs were not well received by the employees. Their implementation and adoption were fraught with set backs, mainly because of hardware problems. A teller at one of the branches mentioned: “Initially, we found it frustrating to use ALPMs. They were difficult to operate and would frequently break down. We always kept manual back ups of the data.”

On the whole, during this period, the IS were rudimentary, and used primarily for increasing the speed of existing processes. The total monetary investment in IT deployment during this time was 5 million INR.

Environmental Conditions

Before 1991, given the larger economic perspective of increasing consumer savings, there was a strong thrust for branch expansion in the rural and semi-urban areas and on rural credit disbursement. As a result, branches were opened even in those places where there was little possibility of generating profit. The government provided financial support to offset losses from these branches. About half of the loans given to the agricultural sector were bad debts because of calamities, poor supervision, and willful defaults. The social objectives of the bank took precedence. There was no flexibility in lending, and borrowing rates were fixed. The performance of the bank was judged by the extent to which it had been successful in mobilizing savings. Therefore, "total deposits," rather than "profit," was the primary indicator of the company's performance. Deposits grew by 15 times from 1970 to 1990.

Moreover, the bank did not make any attempts to market its products and services. According to the branch manager of one of the largest branches in the country,

> *We regarded ourselves as a bank as well as a kind of social institution. There was no concept of marketing in this bank. The idea was that we would open shop, customers would come, and we would disburse credit or deposit their money.*

There was no competition from the private sector, since only the nationalized banks could offer loans, take in deposits, and carry out foreign exchange transactions. Additionally, entry barriers were high because of government regulations, so new banks did not emerge. The capital market as an alternative source of savings was perceived to be speculative and unsafe. Alternatives in the rural areas were the post office, money lenders, and unorganized depositors. For the large middle and lower-middle class population of the country, therefore, NBS and other similar banks provided the only organized, regulated, and secure channels through which they could manage their personal finances. Given all this, NBS had an assured customer base and almost no competition. External competitive pressures, therefore, were low.

Impending Changes—Economic Liberalization

In 1991, the government of India started the process of economic liberalization. A number of significant changes ensued in the banking and financial services sectors. Interest rates were liberalized, and the government loosened its control over the operations of banks. Private investment in banking and financial services was allowed. Norms for foreign investment also were eased. At a broad level, this resulted in the entry of new competition in the form of private and foreign banks. At a more specific level, the increased competition forced NBS to re-examine its key products and operations. There was a need for improving efficiencies and lowering costs through automation and modernization, and this had implications for considerably increased use of IT.

CASE DESCRIPTION—1992-2003

Changes in the Industry: External Pressures

NBS faced a number of changes after liberalization. First, regulations changed. The interest rate was partially deregulated. International prudential norms for income recognition, asset classification, delinquent loan provisioning, and capital adequacy were introduced. Whereas earlier, the most important performance criterion had been the *quantum* of deposits; after 1991, the *quality* of deposits, as well as profits, became measures of performance. Interest rate subsidy on rural credit was lowered, and categories for required directed credit were rationalized and reduced.

NBS was required to classify its assets into separate categories, depending on the probability of recovery. The maximum allowable percentage of nonperforming assets (NPAs or loans which had a low probability of being recovered) also was fixed. The government reduced its control over the bank's operations and significantly lowered its financial support. The bank also was allowed to raise equity from capital markets, and offloaded 26% of its shares to retail and institutional investors in the mid 1990s.

Second, competition emerged as entry of private banks, investment banks, and nonbanking financial companies (NBFCs) were allowed by the government. These companies not only offered products and services traditionally offered by public banks like NBS, but they also presented new ones of their own. NBS faced competition from private banks, mutual fund companies, NBFCs, and investment banks for saving accounts, current accounts, and certificates of deposit. For asset lending, NBS faced competition from venture capital funds, investment banks, and housing finance companies. Mutual funds and capital markets emerged as substitute avenues for retail investments.

Third, the power of retail customers increased and their demographics changed. There emerged a section of consumers who were urban, upwardly mobile, young, and educated, and had large disposable incomes. They expected innovative loan and deposit schemes, convenient, single-window services for short and long term investment requirements, and superior customer service from banks. Moreover, they had alternative banks from which to choose. Corporate customers wanted more personalized and differentiated offerings. The new banks had modern technology, efficient processes, and lower operating costs. They provided differentiated products and better customer service. They were smaller and had lower overheads. They, therefore, were well positioned to serve the increasingly sophisticated requirements of the new-age urban customers as well as the small and medium corporate customers.

For NBS, access to cheap funds and protection from competition had resulted in considerable operational and managerial inefficiencies. Its profitability had declined over the years, as shown in Table 1. It was now faced with the prospect of having to reduce costs, increase the quality of its assets, improve customer service, and develop more innovative products and services.

The head of one the zonal offices said that:

Earlier we were not a commercial organization, and it was not required of us to show profit. Now, for our own survival, we have to compete with other private banks and foreign banks. We have been forced to change. Moreover, ours being a big organization, it is difficult for us to change quickly. Senior managers are under pressure to expedite the change process. Indeed, after liberalization, pressures have increased tremendously.

Table 1. Financial performance of NBS

NBS	**2001-2002**	**2000-2001**	**1999-2000**	**1998-1999**	**1997-1998**	**1996-1997**	**1995-1996**	**1994-1995**	**1993-1994**	**1992-1993**	**1991-1992**
Revenues (Rs. 10 million)	6,178	5,535	5,164	4,590	3,935	31,513	2,890	2,338	2,318	2,657	1,885
Profit (Rs. 10 million)	252	173	202	201	364	360	276	50	-3,311	56	22
No. of employees	52,500, as of 2001-2002										
No. of branches	2,515, as of 2001-2002										

From a mobilizer of rural savings, we have had to become a competitive and commercial, profit oriented business enterprise.

As these descriptions show, external pressures increased significantly during this period, due to competitive and government policy changes. Competitive pressures have widely been seen to be one of the most immediate and important reasons for IT adoption. Organizations respond to the demands of the business environment and adopt IT-related and other innovations (Subramanium & Nilakanta, 1996), and increased competition leads to IT adoption (Caldeira & Ward, 2002; Iacovou et al., 1995; Premkumar & Roberts, 1999; Thong 1999,). IT adoption at NBS during this period was primarily due to competitive pressures and the consequent need for increasing operational efficiency. In addition, in the later part of the 1980s and early part of the 1990s, there was a nationwide government policy initiated to modernize the functioning of nationalized banks. Existing studies (see, for example, Mustonen-Ollila & Lyytinen, 2003) mention that changes in government regulation serve as important external impetuses for IT adoption, especially in organizations that are partly or wholly controlled by the government.

IT Deployment in NBS During this Period

The Saraff Committee was set up by the MOF and RBI in the early 1990s, to look into various aspects of computerization of the public banks. It recommended in 1994 the use of IT in activities related to fund transfer, check clearing, and the payment of interests, dividend, pensions, and bills.

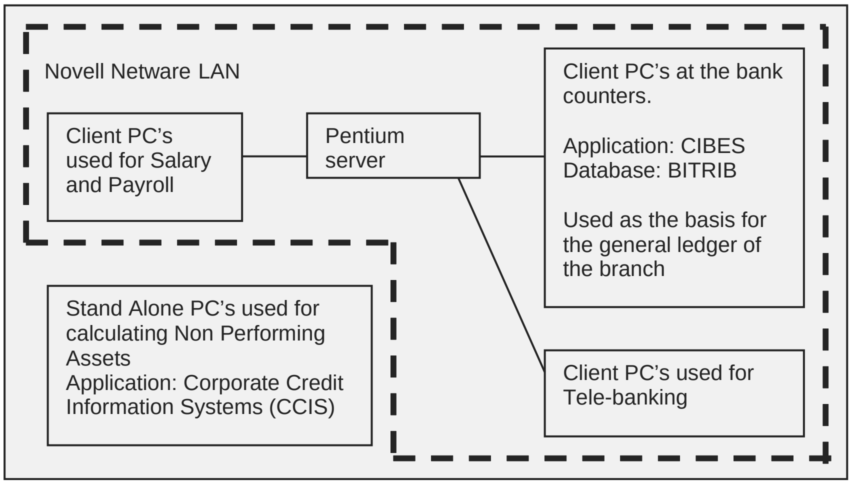
Consequent to these recommendations, and in preparation for imminent computerization, changes were introduced in the IT department. A new position, designated as the general manager (IT) was created to head the department, which reported to the chief general manager (finance). There were about 150 employees in the IS department at the corporate office. About 30% of them were assigned to technical jobs, like software development and hardware maintenance. These employees were recruited in the technical cadre and had IT and software diplomas. The rest of the employees from other administrative departments were transferred and retrained, and were assigned to semitechnical jobs, like report generation, simple maintenance jobs, and vendor management. A team of senior managers were responsible for overall IS planning, hardware acquisition, software development, maintenance, and training. Each zone had an electronic data processing (EDP) department that was staffed largely by junior managers. They maintained existing hardware and software, liaised with vendors and third party maintenance contractors, provided end-user technical support, analyzed data from regions and branches, generated reports, conducted training programs, and looked after the overall functioning of IS within the zone. All computerized branches had one system administrator and one back-up system administrator. Their functions were to maintain hardware and software, liaise with vendors, communicate branch requirements to the regional or zonal offices, and provide training and technical assistance to end users.

The IT investment during this period was 100 million INR, and there was considerable deployment of IT. First, in 1991-92, automation of back office and offline operations, like payroll and general ledger posting, was introduced in the branches. Initially, stand-alone terminals were set up at the service counters. These terminals housed proprietary banking software and entries were made online. The data from the terminals was transferred into the back office servers through floppy disks. Server computations were then performed offline, that is, there was no physical connection between the front office and back office computers. Simultaneously, minicomputers running SCO Unix were installed at each of the zonal offices, for compilation of the data from branches and regional offices within each zone. Reports showing total deposits, total advances, and so forth were created for each zone and sent to the corporate office in floppies and on paper.

Second, in 1996-97, total branch mechanization (TBM) was introduced in branches that had deposits ranging from 500 million INR to 1 billion INR. As part of this, local area networks (LANs) were installed to facilitate real-time transaction processing and integration between the front and back ends at the branches. A number of standardized applications also were developed. First, the *computerized integrated banking executive system* (CIBES) was the primary COBOL-based transaction processing system. The counter personnel used it to post transactions related to savings and current and corporate accounts. The database used was BITRIB. CIBES formed the basis of the general ledger of the bank. Second, the *corporate credit information system* (CCIS), introduced in 1998, was another COBOL application used for recording NPAs. Third, corporate customers used *telebanking software* to obtain and request information about their accounts. It was linked to CIBES. Fourth, the *Equifax* software was used to store transactions related to credit cards payments. This was a stand-alone application. Finally, salary and payroll processing was done through an application developed in FoxBASE. The IT deployed in a typical branch has been described in Figure 4. There were typically two to four Pentium servers and a Novell NetWare LAN, having around 20 diskless nodes and four personal computers (PCs). The diskless nodes were used for counter operations. The use of IT was limited to transaction processing, and there were no operations relating to decision support or other higher level functions. Further, although individual branches were computerized, there was no connectivity among different branches or from the branches to the corporate office.

At around the same time, IS were introduced in the corporate, zonal, and regional offices. The basic infrastructure in the regional and zonal offices was a Novell NetWare based LAN. The regional offices usually had one server and about 10 Pentium II PCs. The zonal offices had two servers and between 15 and 30 PCs. The servers housed SYBASE databases that stored records of branch, region, and zone operations. There were two kinds of applications. Functional applications such as payroll and accounting were written in house in FoxBASE. They operated on stand-alone machines and were standardized across offices. MicroSoft (MS) Office was used for productivity operations, such as word process-

Figure 4. TBM—IT deployed at a typical NBS branch



ing and spreadsheet analysis. The regional and zonal offices compiled MIS reports and sent them to the corporate office. These reports included consolidated information from the branches about customers, loans, deposits, and other financial information, as well as payroll and human resource information.

Third, interconnectivity among branches was introduced in 1999-2000. NBS installed a very small aperture terminal (VSAT) network. The network had 38 antennas or nodes, which connected through satellite some of the regional offices, the zonal offices, and the corporate office. As Figure 6 shows how the branches compiled their bank statements and sent printouts to the regional offices. The regional offices compiled reports for all branches under them and sent them to the zonal offices, either on floppies or on paper print outs. The zones combined and analyzed the data from the regions in specific formats suggested by the corporate office and sent the reports through electronic transfer. At the time of the study, about 520 branches, which accounted for 66% of the bank's business, had been computerized.

With the introduction of TBM and online transaction processing, the dependence of NBS on computers increased sharply. The computerized branches were completely operationally dependent on IT and could not carry out their operations without it. According to the IT manager of one of the first branches that was computerized, "After the branch was computerized, everyone would leave the office by 5 o'clock, whereas earlier they would stay 'til 10 in the night. Computers became the medium through which we carried out our work."

IT Applications Used by Competitors

Even though there was significant IT deployment at NBS during this period, the outcome of IT implementation was only to achieve a desired level of efficiency and parity with other banks. NBS did not obtain competitive advantage from its IS. This is because many of the private-sector banks that had been set up after economic liberalization were much more sophisticated users of IT, both in terms of infrastructure and manner of use. To give an example, the IS used by one of NBS's private-sector competitors. As shown in Figure 7, each branch had a server that had front-to-back integrated banking software, to which tellers' and other employees' terminals were connected. Another server was connected to ATM terminals. Both servers had real-time connectivity to central database servers at the corporate office through a third server at the branch.

At the corporate office, a central server housed real-time account and transaction data. This was connected to a "hot" standby server for disaster recovery as well as with external stock exchanges for stock trading and depository services. All

Figure 5. IS in regional and zonal offices

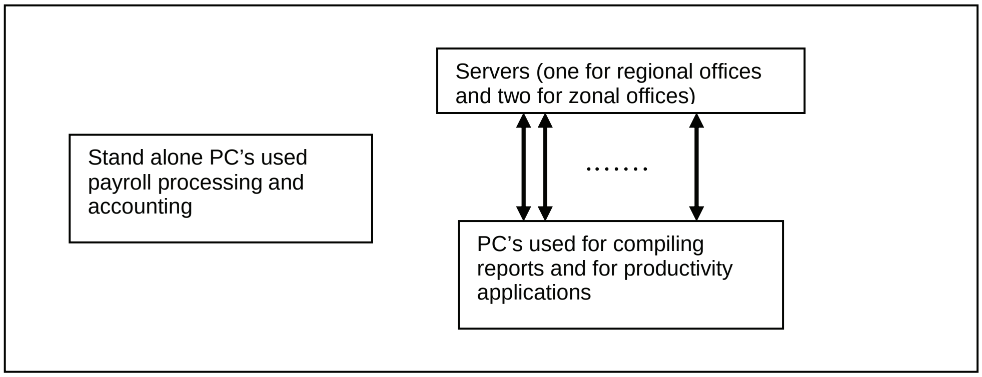


Figure 6. Interoffice connectivity and information flow

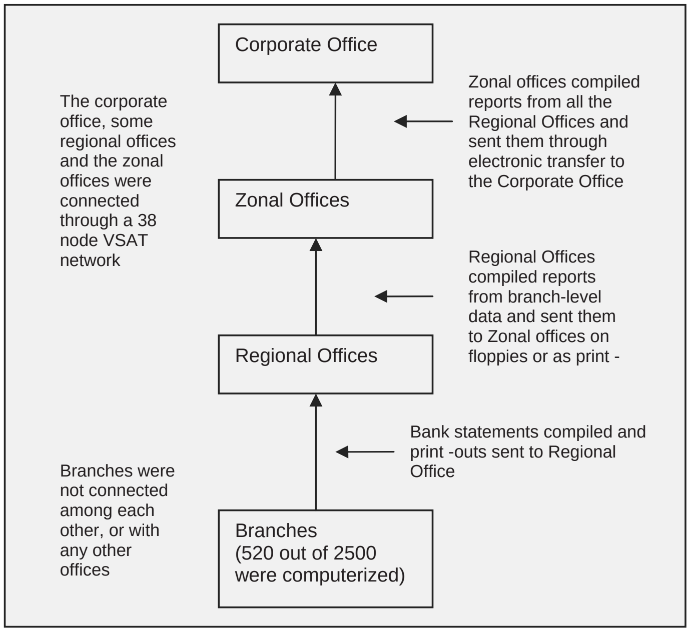
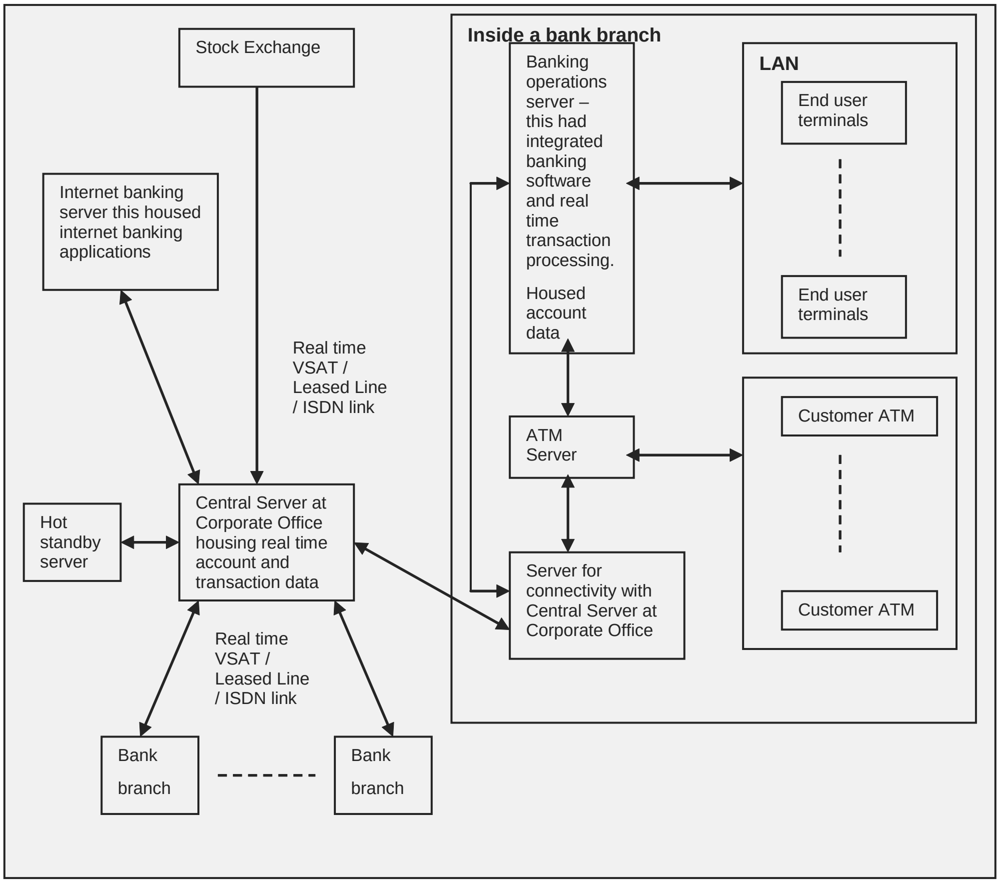


Figure 7. IT infrastructure for a typical private-sector bank



branches and ATMs were connected to the central server in real-time, through VSAT, leased line, and ISDN links. As a result, the bank could provide "anywhere" banking for retail customers and countrywide cash management services for corporate customers. There was separate infrastructure for banking over the Internet. As of 2001, the bank's Web site had information about the organization, its products, branches and ATMs, online banking facilities, annual reports, and news.

Clearly, NBS lagged behind many other organizations in the industry in its use of IT, and, in spite of its considerable capital outlay for modernization and automation, did not derive any competitive advantage from IT. In the next section, we explore possible reasons for this.

Organizational Readiness for IT Adoption

Factors that determine organizational readiness include the availability of technical and managerial IS resources (Iacovou et al., 1995). The former relates to the level of technical expertise and knowledge regarding IT, and the latter describes the level of management understanding and support for the use of IT for competitive advantage (Chwelos et al., 2001). We describe below, three aspects that contribute to the readiness for IT adoption: top management support, organization culture, and characteristics of IS professionals.

Top Management

First, top management support is an important aspect of organizational readiness and leads to higher IT adoption (Lauren & Igbaria, 2001; Nambisan & Wang, 2000; Premkumar & Roberts 1999; Thong, 1999,). Top management support is essential for defining the role of IT in the organization. It also is required for IT planning and in making sure that resources for IT projects are available (Payton, 2000; Premkumar & Ramamurthy, 1995). In this context, senior managers and policy makers at NBS were professional administrators, bureaucrats, and finance professionals. Their average age was more than 45. They were indifferent to computerization and did not show any enthusiasm for it. They had no knowledge about the worldwide use of computers in the industry. Their initiatives towards computerization were driven only by regulatory requirements. The tendency was more for achieving the target in terms of a given number of branches computerized, rather than for proactive changes towards process redesign. One of the branch mangers mentioned, "Many senior managers do not use computers themselves. They delegate computer-related jobs to staff and secretarial personnel."

Another manager, at the middle management level, remarked,

> *We were very focused on the targets given to us in terms of the number of banks to be computerized in a given time period. We did not plan to do anything beyond what was required. We did not, for instance, plan for IT human resource requirements.*

Organization's Culture

Second, elements of the organization's culture influence the organizational readiness to adopt IT. End users' prior exposure to IT increases their inclination to use different IT applications (Lin & Lee, 2005; Mehrtens et al., 2001). Also some organization's cultures offer strong support for the expression and discussion of new and innovative ideas related to IT. This has a positive influence on the ability and inclination of managers to develop and adopt applications with new technology (Hoffman & Klepper, 2000). Organizational support for risk taking and experimentation, and incentives for new ideas hastens the process of adoption of new IT, as observed by Moon and Norris (2005) and Scarbrough and Lannon (1988). The existence of technology champions

(Beath, 1991; Sutcliffe, 1999) is also important for articulating the positive impact of IT (Howell & Higgins, 1990) and for playing the role of opinion leaders in facilitating the choice and evaluation of new technologies. A proactive business strategy also leads organizations to explore different options with respect to innovative and new uses of IT, positively influencing IT adoption (Teo & Ranganathan, 2004).

At NBS, decisions regarding the overall adoption of IT were based on the directives from RBI and the MOF. The specifics of the IT deployment strategy were planned by top management, and the implementation was accomplished by middle and junior management. NBS did not have any innate drive for business excellence and innovation. Of the 50,000 employees in the organization, more than 75% were unionized and performed low skilled and clerical tasks. They perceived computers to be the cause of retrenchment and unemployment. The bank unions were strongly against the use of computers and were determined to block the introduction of any form of computerization. They signed an agreement with NBS, allowing automation and computerization only within certain strict limitations. The agreement emphasized that no ALPM machines would be used at rural branches, and TBM would not be introduced at semi-urban centers. Even so, the unionized staff bitterly opposed the introduction and use of computers. The junior and middle-level managers were apathetic towards it. A counter clerk at one of the branches said, “I am not personally interested in working with computers. However, since it has been mandated by the government, I have to use them. I don’t have a choice.”

Moreover, there were no technology champions to facilitate and expedite the spread of use of IT or encourage innovative uses of IT. The operating-level employees did only what they were asked to. In many branches, benefits in terms of reduced cycle time and improved customer service were not significant, because counter operators were deliberately slow in performing their operations, even while using computers.

Characteristics of IS Professionals

Third, the IS department can play a positive role in influencing IT adoption. IS professionals who understand business needs can increase organizational awareness with respect to IT and actively push for new IT applications. They also can encourage organizational use of IT by providing prompt and effective end-user support (Caldeira & Ward, 2002; Chau & Tam, 2000; Swanson 1994).

At NBS, the general manager (IT) was not an IT professional and did not proactively follow technological developments in the field. He did not independently make crucial decisions relating to IT deployment. He mentioned:

IT related decisions pertaining to resources and budgets are taken at the level of the Chief General Managers. The IS department is given broad guidelines in terms of target deliverables such as the number of branches to be computerized, for example. We then have to frame implementation policies. We do not have independent charge of many of our operations.

The general manager (IT) also could not influence the top management enough to be able to change their inclination towards IT. Most IS personnel had earlier worked in other functions and were subsequently trained to take over the responsibilities of the IS function. They had no formal education in computer hardware or software. IS professionals did not actively push for the development of new applications. They were indifferent and just complied with the instructions that were issued to them. Moreover, IS professionals did not proactively interact with end users; they provided technical support and solved end-user problems only when asked for. They did not try to develop a positive attitude towards IT among the unionized employees.

These discussions illustrate that the organizational readiness to deploy IT was low at NBS.

Therefore, in spite of significant increase in external pressure, NBS adopted IT only to comply with government regulations and to achieve uniformity with other public banks, rather than use IT for achieving a competitively superior position.

CURRENT CHALLENGES

Banking Sector in India—Competitive Challenges

The banking sector in India is widely seen to be headed for consolidation. With the Indian financial sector and stock market experiencing one of the most explosive phases of growth ever (Bellman, 2005a,b), interest rates are expected to rise, and gains from treasury and government bonds are likely to fall. Competition for customers and market share is likely to remain intense.

The private-sector banks had introduced new services since 1996. These included depository services for retail customers and clearing bank services for the major stock exchanges, besides Internet banking facilities, such as bank statements, fund transfers, credit card payment, and general account management. Services intended to be introduced in the future included payments for mobile phone services, insurance premiums, and utility bills through the Internet or by telephone. These banks also had used the Internet to introduce niche products. Citibank, for example, had introduced a special "Women's Account," which used the Internet to provide information about personal finance, savings, investments, loans, insurance, mutual funds, deposits, and stock trading and general education on finances and retirement accounts to women. The account also carried special credit cards linked to shopping outlets and grocery stores.

Clearly, for NBS, external pressures, especially competitive pressures, would continue to remain high. How should it use the Internet to develop more innovative products and services? NBS had, in recent years, taken some steps towards this. In 2001-2002, the company started offering depository services to two of the largest stock exchanges in the country. In 2003, it introduced Internet banking for customers of the networked branches.

Moreover, the operating profit per employee of the bank was 48,000 INR, whereas that of one of the larger private Indian banks, for example, was 1 million INR. How should NBS use the Internet to reduce costs? Build cheaper and more efficient online delivery points and distribution processes? At the time of writing, customers could use the Internet to get statements and account balances and to order checkbooks. NBS also planned to introduce "Any Branch Banking" for its retail customers, cash management services for its corporate customers, and fund transfers for both. NBS had entered a joint venture with five other public banks, to set up and operate a shared ATM network, whereby customers of any of these banks could access ATMs of other member banks. This was called the "Cash Tree" initiative and was expected to include 1,200 ATMs.

Given the high information intensity of the banking sector, the perceived benefits to adopting IT were high. However, based on policy guidelines laid down by the RBI and the MOF, all banks in India had computerized transaction processing, electronic funds transfer, automation of generic banking processes, and local and wide area networking. These applications were "factory" systems (McFarlan, McKenney, & Pyburn, 1983); they were for achieving competitive parity and did not provide any competitive edge. To get competitive advantage out of IT, NBS would need to develop distinctive and proprietary applications that could be used for differentiation in customer service, developing decision support models for market research and financial research, and market development. These applications would enable the development of new products. For setting up Web-based banking systems, the branches and the corporate treasury offices would have to be connected to a single data center through a centralized banking system, using the VSAT network. Real-time connectivity to external stock exchanges was required, as was Web-based infrastructure for linking the Web site to back-end databases. IT management would need to be that of the "strategic" sector (McFarlan et al., 1983), where IT planning would need to be aligned with business planning.

Organizational Challenges

What then were the organizational challenges that NBS faced for developing and implementing "strategic" IT applications? Of the three antecedents to IT adoption, external pressures and perceived benefits were high. However, organizational readiness for IT adoption was low. An important challenge before NBS was, therefore, to increase organizational readiness. There were a number of aspects important in this context.

First, top management had an indifferent attitude towards IT adoption. Senior managers were either appointed by the RBI or consisted of officers who had risen through the ranks. Given the long history of the bank, its historical resistance to change, its formalization, and its bureaucracy, the attitude of top management towards IT could be difficult to change. Second, there was a need to bring about appropriate changes in the overall organizational climate and attitude with respect to IT. There was a need to increase the level of knowledge and awareness about IT and to encourage IT-related innovation that would generate and develop ideas for new and strategic applications in areas such as customer service and the market. The power of unions also would have to be addressed. A lot of new technology implementation and the related learning mechanisms in large, bureaucratic organizations take place through "programs" or well-publicized organization wide procedures (Earl, 1989). In this context, institutional support mechanisms, such as creating an understanding of the business role of IT, encouraging learning, training, and the use of consultants, can increase end users' awareness of IT and help create more opportunities for its use. Finally, the IS function would need to be given greater prominence and say in business decisions. One of the ways of accomplishing this could be to include the general manager (IT) in the top management team, with increased autonomy in IT-related decision making. Moreover, given the role of IT as a service department, effective interaction would be required between IS professionals and top management, as well as between IS professionals and end users. Most IS personnel at NBS were employees from other departments who had been retrained and redeployed; they were not career IS professionals and did not know how to effectively deal with end-user problems or interact with top management. They would have to be re-oriented towards greater end-user or "customer" satisfaction, through training and exposure to best practices of other IS departments in comparable organizations.

WHAT NEXT?

NBS had faced a number of environmental changes in the last 15 years. These included changed regulations and increased competition that has led to imperatives for increased product innovation and process efficiency. So far, in its use of IT, NBS has achieved uniformity and standardization compared to most other banks. However, in order to achieve differentiation and competitive advantages from the use of IT, it faces a number of challenges. How should it use the Internet to develop new products and increase market share? How would banking processes need to be redesigned for reducing costs? How would the required organizational changes be implemented? These are the options that face the executive leadership of the company.

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Chapter 4.13

Building Enterprise Network Infrastructure for a Supermarket Store Chain

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EXECUTIVE SUMMARY

Enterprise network infrastructure has served as a vehicle on which data and information can be transferred between functional units regardless of their location. Creating the network infrastructure that enables firms and organizations to adapt to rapidly changing business needs has never been more important than now. Building the enterprise network infrastructure requires careful planning, effective design, and appropriate strategies for successful implementation. The current case study examines how a regional supermarket store chain in the retail food industry develops its enterprise network infrastructure to outperform its larger competitors. A detailed description of the evolution of the company's enterprise network infrastructure is presented to show how the strategy of network infrastructure development has aligned with the organization's growth strategy for the past two decades. The current case study highlights critical success factors for firms to build an effective enterprise network infrastructure that include IS planning firmly tied to critical business goals, strategic collaboration with technology vendors, and careful evaluation and selection of network services and technical details.

ORGANIZATIONAL BACKGROUND

The retail food industry can be broadly defined as businesses that cover diverse aspects of grocery productions and sales, ranging from making, processing, packaging, distribution, to retailing and catering food. In 2004, the retail food industry in the United States took nearly 10% of its Gross Domestic Product. It consists of businesses that include conventional supermarkets, superstores, convenience stores, membership clubs, independent food stores, and dot-coms. While the retail food industry relies on government regulations and administration for establishing an efficient consumer market, it has heavily utilized continuous innovation in the areas of technology, transportation, and logistics for an efficient flow of products and related information (Kahn & McAlister, 1997; Li, Lin, Wang & Yan, 2007; Walsh, 1993). The competition in the industry is extremely high and so typically the management is under constant pressure for sales growth and market share while dealing with competitive challenges.

ABC[1] Corporation is one of the successful privately owned, regional supermarket store chains in the retail food industry in the United States. Headquartered in one of the cities in Northern California, ABC employs more than 16,600 employees and owns 139 grocery stores and one distribution center in several West Coast States of the United States. Its store chains sell groceries including bakery, dairy, deli, frozen foods, general grocery, meat, liquor, natural foods, pharmacy, produce, seafood, snacks, and so forth. In the fiscal year of 2006-07, the estimated sales of the company were $3.4 billion with its annual growth rate of 2.1%, thus placing the company in the upper 50% of the "Top 75 North American Food Retailers" (Supermarket News, January 2006). ABC Corporation is currently under the management team of two owners, a president as CEO, and a CFO. The mission of the company is to be "the place where customers love to shop and employees love to work". The company values "excellence in business practices" such as leadership, accountability, respect, teamwork, excellence, responsibility, learning, and integrity.

As part of a growth strategy, ABC Corporation has made some serious acquisitions in its history that led the company to be one of the leading supermarket store chains in the region. In 1956, the company operated just nine grocery store sites with around $8 million in annual revenues. In 1973, after acquiring ten drug stores put up for sale in the region, the company began to deal with both the grocery and drug items in the same store. The company boosted its annual sales volume up to nearly $1.8 billion after the acquisition of another store chain with 17 grocery store sites, which had developed a reputation for their superb product quality and excellent customer service throughout a West Coast state. By the mid-1990's, the company grew up to operate 81 stores, thus making it one of the giant supermarket chains. In 1998, the company acquired an up scale grocery chain with 27 stores. Again in 1999, the company purchased additional 27 stores from two grocery store chains so that it could compete against larger chains such as Safeway, Albertson, and Lucky.

ABC Corporation has operated under centralized control from its headquarters, which aims at making its operations efficient and cost effective. When a customer buys a specific item from a particular store and pays for the item at the cash register, this information is immediately passed on to the headquarters. At the headquarters, the system reduces the inventory stock level for the purchased item at that particular store by a quantity of one (or whatever quantity is sold) in the central database. By this way, the company can keep a real-time inventory amount of every product item in every store. The ABC's real-time inventory accounting system allows the company to restock the store shelves in an efficient and effective manner. When a reorder quantity reaches an optimum level, the company can immediately place a reorder request to the vendor and receive the merchandise at its warehouse locations. The warehouses can then break up the shipment and distribute the product to the individual store sites that are running low on the shelf inventory. Each store also uploads daily transaction data to the headquarters so that each day, customer buying data can be compiled and analyzed in order to determine buying behavior of the customer to develop marketing schemes or to produce efficient centralized bulk buying.

To support its organizational strategies, ABC Corporation has been active in adopting information systems and communications technologies. According to the management of ABC Corporation, while most grocery chains, on average, spend 1 to 2% of revenues on information technology investment, ABC typically allocates just 0.5% of total revenue to its information technology investment. Yet, the management claims that ABC's enterprise network reportedly has better overall performance and provides lower operational costs than the networks of their larger competitors.

SETTING THE STAGE

Businesses in the retail food industry have actively utilized information and communication technologies to improve its operational efficiency (Barua, Konana, Whinston & Yin, 2004; Kinsey, 2000; Rai, Patnayakuni & Patnayakuni, 1997). Starting from the scanning technology to electronic cash register to computer systems and electronic data interchange (EDI), different combinations of information technology (IT) has helped grocery store chains increase productivity of retail food operations (Chen, Motiwalla & Khan, 2004; Kinsey & Ashman, 2000).

The establishment of reliable network infrastructure has been one of the critical success factors for the ABC Corporation's everyday business operations. Even a small amount of system downtime could lead to lost sales, inaccurate inventory counts, and failure to restock store shelves adequately. To support the communication between the headquarters and the store sites, ABC Corporation has invested in developing enterprise network infrastructure since 1980's. More recent rapid growth of the company in the late 1990's required a more efficient and effective network infrastructure for timely information sharing and dissemination. Building the enterprise network infrastructure however requires careful planning, effective design, and appropriate strategies for successful implementation.

Enterprise Network Planning

Enterprise network planning is a process aimed at meeting the needs of network users in large organizations. It is a critical process that involves not only network technology planning, but also business planning. Creating a business-driven IT infrastructure requires that executives and management thoroughly understand their organization's current and future needs and environment. Drawing on more over 200 on-site interviews with senior business and IT executives, Broadbent and Weill (1997) formulated an IT infrastructure planning methodology, which helps identify the IT infrastructure service needed and its specific design criteria. The framework consists of four components: strategic context, business maxims, IT maxims, and IT infrastructure. It begins with consideration for the organization's strategic context. Searching the answer for the question of "how will the organization achieve the strategic synergy among the business subunits to maximize the effectiveness for the entire organization as a whole?" is the first and most essential task when formulating strategic context. The current and long-term strategies of the entire organization including each business unit can then be translated into what is called business maxims. The purpose is for business and IT managers to articulate an agreed-on position in a form that executives can readily understand and act on.

IT maxims are identified from the business maxims. IT maxims describe clearly and concisely how a firm will meet business maxims through the use of IT, or more specifically how a firm will connect, share, and structure information and deploy IT across the firm (Haeckel & Nolan, 1993). IT maxims must specify the firm's approach regarding the role of IT and levels of investment relative to competitors, transaction processing (standardization, common interfaces, or local tailoring), and access and use of different types of data (e.g., financial, product, or consumer (Broadbent & Weill, 1997, p. 82-83).

Also, an organization should determine how IT infrastructure is used; there are four views of firmwide IT infrastructure: none, utility, dependent, or enabling (Weill, 1993) (Table 1). One of these four views is typically taken with individual firms. No particular view is best for all firms, but typically one view is more appropriate for a business according to their business and IT maxims. There are two different approaches in enterprise IT infrastructure planning: maxim route and deals making route. The maxim route assumes that both business and IT management look at the company as a whole. The deal making route focuses on a more immediate need of a business. In the deal-making route, typically there are only three views: none, utility, or dependent.

Enterprise Network Design

A typical enterprise network design involves a three-step cycle: needs analysis, technology design, and cost assessment (FitzGerald & Dennis, 1999). The cycle is repeated as necessary to complete the design. After the firm-wide infrastructure planning is conducted, the project team starts with a needs analysis of the overall goals of IT maxims. Needs analysis is typically concerned about factors such as geographic scope, application systems to be served using the network, number and types of network users, a rough assessment and classification of the network capacity needs, and so forth.

Technology design builds on the network diagrams created in the needs analysis phase. At this phase, the network diagrams include information on the type and quantity of all users' computers and network servers, network circuits and devices (e.g., hubs, routers, switches), the fundamental technology and protocols (e.g., Ethernet or token ring, TCP/IP or SNA), and the capacity of each circuit (e.g., 64 kbps, 10Mbps, 1Gbps). Network capacity planning is required for the assessment of circuit loading. Circuit loading is the amount of data transmitted on a circuit. Analysis can focus on average or peak circuit traffic. If an existing network is in place, network monitors usually can provide such information.

Table 1. Four views of firm-wide IT infrastructure

View	Description	Note
None	• No firm-wide IT infrastructure	• No synergetic effect
Utility	• Firm-wide IT infrastructure provides a necessary, unavoidable service that incurs administrative expenses.	• Spending on IT in this view is only a way to reduce costs through economies of scale and sharing. • Maximizing return on assets while minimizing costs is a high-priority.
Dependent	• Firm-wide IT infrastructure investment is a response to a specific current strategy.	• IT infrastructure investments are derived directly from business strategies that specify IT needs. An example is the need for an e-business to have Web application servers.
Enabling	• Firm-wide IT infrastructure expands a dependent infrastructure beyond the current requirements of the business.	• The purpose is to achieve the firm's long-term goals. • Executive officers must justify enabling infrastructure spending as a core competence that provides competitive advantage. • Typically enabling technologies are highly centralized.

Finally, the team moves on to the costing of a network project, which typically includes hardware, software, and circuit connections. Businesses rarely have the resources to develop and implement their own large-scale network so outside vendors are often called to complete the project. In many cases, network designers will compose a request for proposal (RFP) that incorporates all desired specifications of the network being built.

Enterprise Network Implementation

Rapid technological advances on many fronts have made it less feasible for firms and organizations to internally maintain all the technological expertise. As a result, firms increasingly seek the use of outside suppliers for IT related services which were previously supplied internally. An effective supplier management strategy has become critical to maximize the business value of purchased IT products and services (Heckman, 1999). Heckman further states that this has created a "gamut of possible supplier relationships" ranging from "purely transactional, price-based interactions to highly interdependent partnerships and alliances" (1999, p. 142). The "purely transactional, price-based interactions" view posits that the process of IT supplier management requires discipline, structure, and that successful buyer-seller relationships are based on semi-distant, rigorously negotiated contractual understandings. In this regard, contracted IT products and services should result from rigorous and professional contract management, usually involving multi-skilled contract management teams (Lacity, Willcocks & Feeny, 1995, 1996). On the other hand, the "highly interdependent partnerships and alliances" view posits that buyer-seller relationships are more effective when based on less formal notions such as commitment, trust, and partnership. Heckman (1999) argues that because the complexity of any large IT vendor/outsourcing arrangement makes it extremely difficult to specify in advance all the possible future contingencies, customer and supplier alike are best served when they enter into such relationships expecting to live by the spirit rather than the letter of the contract (Sabherwal, 1999; Sawhney, 2002).

CASE DESCRIPTION

The central information processing system at the ABC's headquarters consists primarily of two mainframes run by Unix and two communications controllers. Unix provides the high reliability required for mission-critical applications and the high functionality needed for complex server situations. The mainframes are used to process transactional data. The first mainframe is used to process all transactions that occur at the regular checkout line. This mainframe processes transactions on general merchandise and other food items. It accesses, processes, and stores the database that tracks real-time inventory of every shelf item in every store. The database keeps detailed records of sales from individual stores. The data stored are used for statistical analysis in order to determine buying behavior and develop marketing schemes to better promote a wider range of products.

The second mainframe is used by the pharmacy. This mainframe houses transactional data from pharmacy purchases and provides real-time inventory of all pharmaceuticals in every store. This data are used to produce efficient buying and restocking of pharmaceuticals. This mainframe is also used to house a database of customer information, which is used to keep track of prescription refill orders, additional drug sales, and medical reasons used by the pharmacists. Two communications controllers conduct front-end processing that operates in tandem to provide redundancy for the mission critical connections to store sites. Communications controllers are located between the mainframes and cluster controllers in store sites. They manage communications with cluster controllers, thus freeing up the mainframe to focus on file and database processing.

In the late 1980's and early 1990's ABC Corporation used dial-up network to connect the data communication devices. Systems network architecture (SNA) protocol was used to provide high reliability and centralized control for real-time terminal-host interactions. ABC's each store site dialed in directly to ABC's headquarters. The maximum upload data speed for this dial-up connection was 33.6 kbps and maximum download speed was 56 kbps. Long distance charges were applied to each dial-up connection from a store site to ABC's headquarters. All voice connections between the store sites and headquarters were held at an additional expense to the network connection. ABC's dial-up was very advanced compared to other supermarket networks at that time but still was not on the leading edge of technology. In 1993, ABC decided to do away with the dial-up connections and build their own private frame relay network, which was called ABC's Net I.

ABC's Net I Period (1993-1997):

In the mid 1990's ABC Corporation grew up to operate 81 stores. It became obvious that ABC's dial-up network could not support the company's rapidly growing business operation. Net I project was initiated to create a firm-wide enterprise network infrastructure that connects all store sites to the headquarters utilizing the mainframe computers. The primary goal of Net I was to provide faster, integrated communications services that allow voice-over-data transmission services. ABC took the total responsibility for the entire project; its project team conducted a range of activities including network planning, analysis, design, and implementation of the enterprise network infrastructure utilizing leased lines and its own network equipments.

Net I - Wide Area Network (WAN)

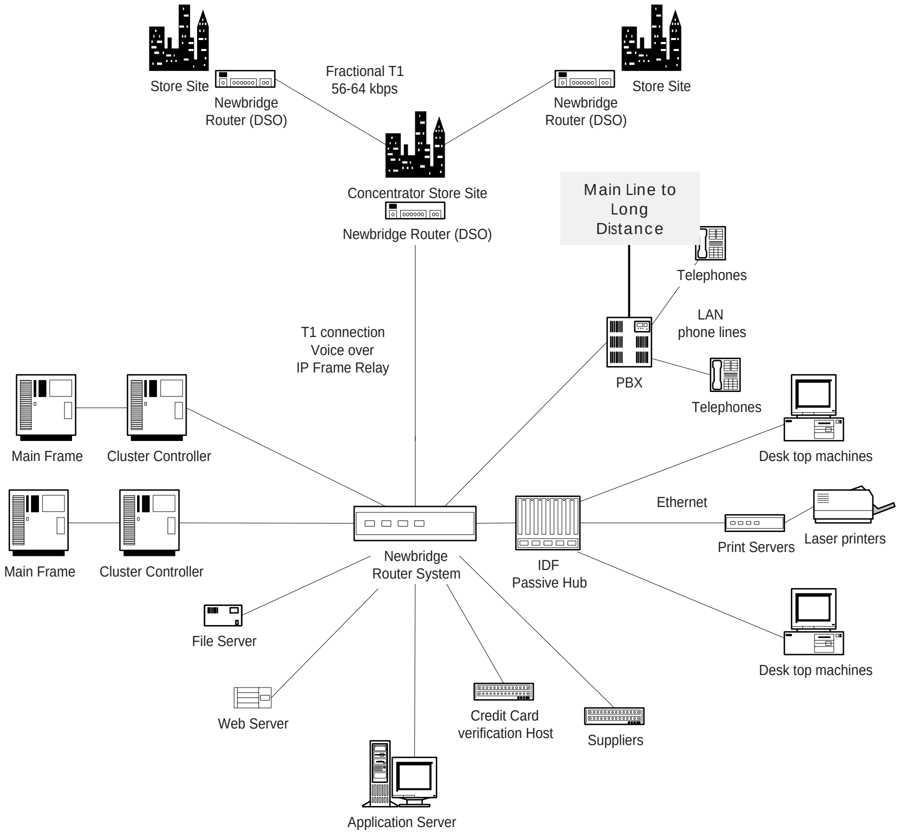
Network connections between all store sites and headquarters formed the WAN of ABC's Net I. The team decided to construct a private frame relay network along with IP protocol as its WAN solution. Compared to other communication technologies such as X.25 packet switching network, frame relay was more appropriate technology than other alternatives to meet the needs of the company for faster data communication between store sites and headquarters. The team designed the frame relay network configuration in which groups of individual store sites were linked to a central store in the region called a concentrator site, which was then connected to the headquarters. The connections between store sites and a concentrator site were established by fractional T1 leased lines with 56 kbps data transmission rate whereas each concentrator site was connected to the headquarters by a full T1 leased line. All the network components of ABC's Net I were owned or leased by ABC, which include routers, leased lines, and other communication devices. Figure 1 illustrates a schematic view of ABC's Net I. Note that in actuality, more than two stores were connected to a concentrator site, and more concentrator sites, desktop machines, and phones were present than are depicted in this diagram.

ABC's Net I also provided the capability of transmitting voice traffic over the frame relay network in order to meet the needs of the company. Telephone services between any store sites and headquarters or between any two store sites could be provided at no additional charge. This gave ABC the capability to route all long distance calls through one central connection to a long distance carrier, thus allowing a sizable cost savings of telephone communication payment.

Net I - Local Area Network (LAN)

The local area network at that time consisted of client stations located on three floors of the

Figure 1. ABC's Net I network diagram (simplified version)



headquarters. Each client station was connected to one of two hubs located on each floor. ABC's Net I LAN used Ethernet protocol by which data traffic was broadcasted to every desktop machine at the headquarters.

Net I – Challenges and Issues

ABC's Net I was an improvement over its dial-up network because it had the potential to deliver faster data as well as voice-over-data communications. These improvements were recognized when Net I was operational. However, ABC's Net I WAN was not extremely reliable. For example, if a router was down at a concentrator site, the whole group of stores connected to that concentrator site could have been down. Also, since ABC's Net I operated using leased lines, the company was totally responsible for maintaining all site-to-site connections. Leased lines were expensive and difficult to maintain because the lessee must perform all the labor required to make the leased lines available. Voice connections over the network were less than satisfactory. Many staff bypassed the network all together and simply dialed nine to reach an outside line to complete the call over the conventional public switched telephone network, which defeated the purpose of placing voice over data and lowering long distance telephone costs.

ABC's Net I LAN was not extremely reliable either. The hub technology with Ethernet broadcasting protocol frequently caused network congestion which brought LAN communications to a near stand still at times. Moreover, ABC's Net I was using multiple protocols which further caused network congestion. Some of the protocols were characterized as "chatty" that produced multiple data exchanges between hosts.

In the late 1990's, the amount of downtime of Net I was determined to be unacceptable. In 1998, ABC initiated a major overhaul to its LAN and WAN and initiated a new project called Net II. ABC's Net II is currently operational and has many advantages over its Net I.

ABC's Net II Period (1998-Present):

By late 1990's, the ABC's mainframes were upgraded using the latest version of mainframe operating systems, which were then supported by the backbone of a gigabit fiber optic connection, thus creating what is called the data center. With additional processing power, all the functions of the mainframe computers, such as database processing for all inventories, transaction data, and the pharmacy database, could be performed more effectively and efficiently. While the company depended on ABC's Net I to run its daily routine business, it became increasingly challenging to operate ABC's Net I with regards to its reliability, quality, and the cost of maintenance, which posed a great threat to the company to grow through rapid expansion.

In 1998, a network development team led by ABC's chief information officer (CIO) initiated a major overhaul to its enterprise network infrastructure, thus initiating ABC's Net II project. The team consisted of members from WAN Support, Voice Support, LAN Support, and Technical Advisory Committee. The team started off with defining the goals for Net II: (1) reducing network operational costs, (2) decreasing network downtime, (3) cutting down network latency, and (4) providing usable voice connections through network. Given the goals, the team made detailed tactical decisions on design criteria such as network protocol to be used, bandwidth, services provided, equipment, and deployment method. The CIO made sure to keep the decision making process open. "Where all participants sought a limited number of relevant alternatives that provide a satisfactory solution," the CIO recalled, "the team selected a satisficing solution that was more ethically and rationally relevant to ABC that either maximization or optimization could deliver".

The ABC's team was very knowledgeable and did well on needs analysis to understand basic network requirements without being experts on the engineering issues related to technical network design. The team discussed a variety of network technology alternatives in terms of their capabilities, expected costs, and the expected fitness with the needs of the company. For example, the team seriously considered using satellite technology as a WAN solution. But because the bandwidth was shared and some of ABC's data traffic was bursty with large payloads, satellite was only considered for disaster recovery. Asynchronous Transfer Mode (ATM) technology, a special type of packet switching network that delivers small fixed-size data packet across a network, was also considered, but was not considered appropriate due to various reasons. For instance, ATM works well with live video and audio due to its low latency and very high quality of service. However, ATM technology has largely been implemented by large carriers for their wide area network cores, thus making this technology less feasible both technologically and economically.

The team however was not as knowledgeable about design specific details of the technologies required for network implementation. The CIO and the team decided to partner with a technology vendor to create the technology design for the network upgrade. The team ended up focusing on the identification and development of business and IT requirements of the company, as well as the development of basic design for network upgrade, and handed these off to technology vendors to complete the technical design. Interviews were conducted with various network technology suppliers to assess their capabilities. The team ultimately selected Cisco as its partner not only because Cisco was a well established and internationally known telecommunication products manufacturing company, but also because it was very cooperative and willing to collaborate in efforts to evaluate the capabilities of router, switch and other network technology required for Net II implementation. The ABC's team and its implementation partner Cisco together went over the network analysis and design. Following a top down network design approach (Oppenheimer, 1999), they started with analyzing company's goal and customer's needs and conducted logical/physical network design, testing, optimizing, and documentation. This collaboration helped determine specific features, functions, and networking hardware early on to optimize the network. This enabled ABC to successfully implement enhanced network features shown below unavailable to the company's competitors, in addition to rendering a large amount of cost savings.

- Single protocol technology TCP/IP
- 100% Switched network, no hubs
- Reliable and functional Voice over IP
- Frame relay connections to store sites (no more leased lines)
- ISDN Backup

The team's decision to seek advice from a competent technology vendor as early as possible and having a rapport relationship with the vendor laid the foundation for successful implementation of the network. The CIO recognized the importance of this action, saying "without question (Cisco was) key to the success of the project." The CIO and the team attributed a considerable portion of the successful planning and development of the network to the close relationship established and maintained with the router vendor. The CIO said "Cisco played a large role in the functional assessments, and ultimately was selected as the implementation partner because of their collaborative efforts."

Net II - Wide Area Network

ABC removed the leased T1 lines and went to subcontracted frame relay service from MCI. Subcontracted frame relay is a special type of public switched data network (PSDN). PSDNs are typically portrayed as clouds on network diagrams because the user does not have to know what is going on inside the PSDN. The PSDN service provider handles all switching, management, and maintenance tasks. Overall, PSDNs are easier to use than leased lines, and because of price competition, PSDNs tend to be less expensive than a comparable mesh of leased lines. ABC's Net II used Cisco routers to switch data frames over the frame relay PSDN. The Cisco routers on ABC's Net II followed the frame relay protocol which routes data according to layer two or the data link layer protocol. Once the frame is in the PSDN, it is MCI's responsibility to deliver the frame at the other end of the cloud to the proper Cisco router of ABC's Net II.

Individual store sites have to provide a router and a single leased line to the frame relay network's point of presence (POP) which is a connection location to the PSDN. ABC's Net II frame relay connections are 128 kbps; the cost of each store connection is approximately $400 per month. ABC negotiated this competitive rate by tying the connection of all stores into one large service contract.

The frame relay connections include voice over data frame capability. Cisco 7204 routes voice frames directly to PBX. Net II used integrated Voice over Internet Protocol (VoIP) to provide completely meshed, 4 digit dialing from store to store, as well as the headquarters to store and vice versa. Unlike Net I, ABC's Net II actually provides clear usable telephone connections. The CIO recalled, "That was huge and we were the first retail chain in the world to do it".

Because the network connections to ABC's stores are mission critical, ABC's Net II has included a back-up network connection to each store. The back-up connection is an integrated services digital network (ISDN). ISDN differs from PSDN in that it is based on circuit switching, which is expensive for data transmission because it creates and holds an open circuit between hosts. Users must pay to keep this ISDN circuit open, even if no data traffic enters the circuit. The maximum connection speed of ISDN is 128 kbps and the cost for each store's ISDN connection ranges from $1,100 to $3,000 per month depending on the store location.

ABC's Net II has been an overwhelming success. According to the CIO, the cost of the setting up the network was about $1 million, but this cost was recovered one year after ABC's Net II implementation in the form of reduced long distance charges, reduced network connection fees, and most importantly, reduced system downtime. Damages from system downtime could be quite substantial not only because of lost revenues resulting from downtime, but also because of potential changes in future buying behavior of customers who were alienated from system downtime.

Net II - Local Area Network

The MCI frame relay network is connected to ABC's headquarters by two Cisco 7204 routers. Each ABC's store is connected to the headquarters by a Cisco 2610 router. There are no more concentrator sites with ABC's Net II—each store is directly connected to the headquarters through the cloud. In this regard, this is a star shaped connection. The Cisco 7204's route data frames to the switch which replaced the hubs on ABC's Net I.

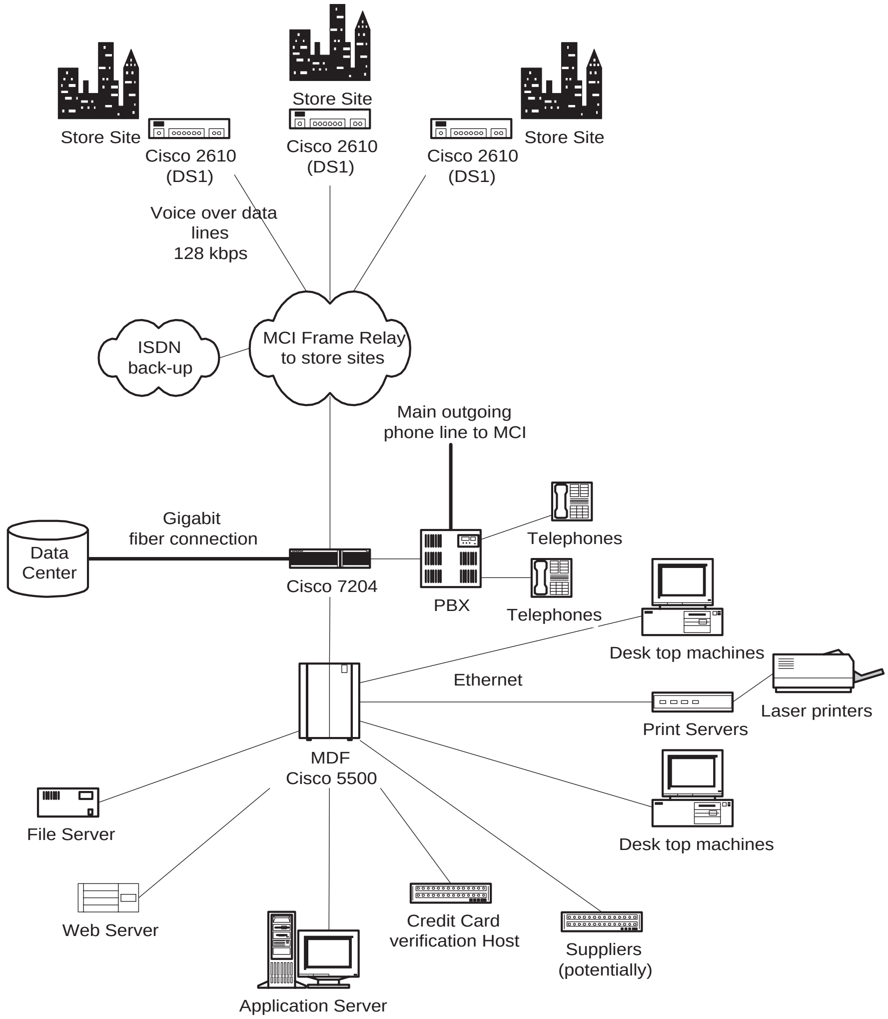
The team removed all non-IP protocols on the ABC's Net II LAN. It was determined that the mixing of various protocols on the LAN turned out to be a major cause of network congestion. Switching to all IP protocol substantially reduced network congestion and decreased latency but unfortunately was very difficult to install. The system had issues with legacy applications and data sources that were not IP compatible. Substantial work had to be done to convert these applications and data sources to IP, and, in some cases, new software had to be installed to convert these applications.

Figure 2 illustrates a schematic view of ABC's Net II. Note that in actuality there are more than three stores connected to the frame relay network, that there are two Cisco 7204 routers, and that there are more applications, applications servers, desktop machines, and phones than depicted in the diagram.

CURRENT CHALLENGES/ PROBLEMS FACING THE ORGANIZATION

ABC's current Net II has started facing with challenges in providing enterprise IT network infrastructure services for the company. As the company continues to grow, the needs and requirements from network users, including business subunits and partners, are constantly evolving. For example, ABC's Net II network infrastructure has had difficulties in providing the quality of service demanded by end-users and voice and data applications. Prioritizing network traffic is almost impossible using the current frame relay network, which tends to become increasingly expensive as compared to other emerging communications technologies. Moreover, ABC Corporation has started seeing some potential in deploying supply chain technology with partners in the retail food industry and attempts to capitalize on it when its suppliers are ready. The supply chain network links businesses with their suppliers, customers, or other businesses that share data and applications. Typically extranets connections are deployed over the Internet connecting personnel and applications from different organizations. It is a collaborative network, extending a company's internal network out onto the Internet, which

Figure 2. ABC's Net II network diagram (simplified version)



requires careful planning that should be made by a group of concerned stakeholders and supported by appropriate network infrastructure.

As part of the strategy to address the problems, ABC Corporation started considering another network upgrade to the Multiprotocol Label Switching (MPLS) technology using ATT. MPLS is a networking technology similar to the concept of the frame relay technology, but uses packet labels to prioritize network traffic to optimize network performance, thus enabling the company to meet the business needs. The primary difference is that user organizations like ABC Corporation can purchase quality of service (QoS) for applications across the MPLS network. Some of the expected benefits for ABC Corporation include reduced costs, improved manageability, and enhanced performance of its wide area networks, as well as better alignment with current and future business needs. While the benefits from migrating to MPLS are quite attractive, there is a caveat that the user may lose visibility into the MPLS cloud, which will challenge IT professionals in ABC Corporation.

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ENDNOTE

[1] Name of the company has been replaced by pseudonym to ensure confidentiality.

GLOSSARY

ATM: Asynchronous Transfer Mode (ATM) is a special type of packet switching network that delivers small fixed-size data packet across a network. It works well with live video and audio due to its low latency and very high quality of service.

EDI: Electronic Data Interchange (EDI) is an international standard format for exchanging business data. It is a set of standards for structuring information that is to be electronically exchanged between and within businesses and other organizational entities.

Ethernet: Ethernet is another name for the IEEE 802.3 protocol. This network protocol operates at Layers 1 (physical layer) and 2 (data link layer) of the TCP/IP architecture.

Frame Relay: Frame relay is a telecommunication service designed for cost-efficient data transmission over a wide area network (WAN). It is effective for intermittent traffic between local area networks (LANs) across a WAN.

Fractional T1: Fractional T-1 refers to any data transmission rate between 56 Kbps and 1.544 Mbps in the North American T-carrier system. It is typically provided by a carrier in lieu of a full T-1 connection and is leased to a customer for a point-to-point connection arrangement.

ISDN: Integrated Services Digital Network (ISDN) is a set of standards for digital transmission over ordinary telephone line as well as over other media. ISDN allows home and business users to transmit data at up to 128 Kbps. ISDN service is generally available from phone companies in most urban areas.

MPLS: Multiprotocol Label Switching (MPLS) is a data-carrying mechanism that belongs to the family of packet-switched networks. MPLS speeds up network traffic flow and makes it easier to manage. MPLS saves the time needed for a router to look up the address by setting up a specific path for a given sequence of packets identified by a label put in each packet.

PSDN: Public Switch Data Network (PSDN) is a publicly available network based on packet switching technology. Packet switched networks do not establish physical communication channels between communicating devices. In packet-switched networks, data packets from different sources going to different destinations can share common data pathways.

QoS: QoS is an acronym for Quality of Service. It is a networking term that specifies a guaranteed throughput level. QoS is the ability to provide different priority to different applications, users, or data flows.

SNA: Systems Network Architecture (SNA) is a proprietary networking architecture designed in 1974 for IBM's mainframe computers. It is a set of network protocols for interconnecting IBM computers and their resources.

Switch: A switch is a special-purpose computer that receives and transmits data across a network.

T1: T1 is a part of T-carrier system. It is the most commonly used digital transmission service for businesses to connect to an Internet access provider or other entities. T1 allows the data transmission speed of up to 1.544 million bits per second (Mbps).

TCP/IP: Transmission Control Protocol/Internet Protocol (TCP/IP) is a protocol architecture used as part of the TCP/IP architecture. This is used on the Internet.

Token ring: A Token Ring network is a type of local area networks (LANs) in which all computers are connected in a ring topology. A token-passing scheme is used in order to control the flow of data between computers.

Unix: Unix is an operating system developed at Bell Labs. It has been used for the scientific and engineering communities since 1970's. It has evolved over time with many extensions provided in a variety of versions of Unix. The Unix environment and the client/server model were important elements in the development of the Internet.

VoIP: Voice over Internet Protocol (VoIP) is a protocol optimized for providing voice communication service through the Internet or other packet switched networks. VoIP enables people to use the Internet as the transmission medium for telephone calls.

X.25: 25 is a widely-installed commercial wide area network protocol based on packet switching technology. A packet switching network describes the type of network in which relatively small units of data called packets are routed through a network based on the destination address contained within each packet.

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Chapter 4.14

Managing the Implementation of Business Intelligence Systems:

A Critical Success Factors Framework

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ABSTRACT

The implementation of a BI system is a complex undertaking requiring considerable resources. Yet there is a limited authoritative set of CSFs for management reference. This article represents a first step of filling in the research gap. The authors utilized the Delphi method to conduct three rounds of studies with 15 BI system experts in the domain of engineering asset management organizations. The study develops a CSFs framework that consists of seven factors and associated contextual elements crucial for BI systems implementation. The CSFs are committed management support and sponsorship, business user-oriented change management, clear business vision and well-established case, business-driven methodology and project management, business-centric championship and balanced project team composition, strategic and extensible technical framework, and sustainable data quality and governance framework. This CSFs framework allows BI stakeholders to holistically understand the critical factors that influence implementation success of BI systems.

BACKGROUND

Engineering asset management organizations (EAMOs), such as utilities and transportation enterprises, store vast amounts of asset-oriented data (Lin et al., 2007). However, the data and information environments in these organizations are typically fragmented and characterized by disparate operational, transactional and legacy systems spread across multiple platforms and diverse structures (Haider & Koronios, 2003). An ever-increasing amount of such data is often collected for immediate use in assessing the operational health of an asset, and then it is either archived or deleted. This lack of vertical integration of information systems, together with the pools of data spread across the enterprise, make it extremely difficult for management to facilitate better learning and make well-informed decisions thus resulting in suboptimal management performance. Yet large volumes of disperse transactional data lead to increased difficulties in analyzing, summarizing and extracting reliable information (Ponniah, 2001). Meanwhile, increased regulatory compliance and governance requirements have demanded greater accountability for decision making within such organizations (Logan & Buytendijk, 2003; Mathew, 2003). In response to these problems, many EAMOs are compelled to improve their business execution and management decision support through the implementation of a BI system.

According to Negash (2004), “BI systems combine data gathering, data storage, and knowledge management with analytical tools to present complex and competitive information to planners and decision makers.” Implicit in this definition, the primary objective of BI systems is to improve the timeliness and quality of the input to the decision making process (Negash, 2004). Data is treated as a corporate resource, and transformed from *quantity* to *quality* (Gangadharan & Swami, 2004). Hence, actionable information could be delivered at the right time, at the right location, and in the right form (Negash, 2004) to assist individual decision makers, groups, departments, divisions or even larger units (Jagielska et al., 2003). Fisher et al. (2006) further posited that a BI system is primarily composed of a set of three complementary data management technologies, namely data warehousing, online analytical processing (OLAP), and data mining tools.

A successful implementation[1] of BI system provides these organizations with a new and unified insight across its entire engineering asset management functions. The resulting unified layer, in reporting, business analysis, and forecasting assures consistency and flexibility (Gangadharan & Swami, 2004). Critical information from many different sources of an asset management enterprise can be integrated into a coherent body for strategic planning and effective allocation of assets and resources. Hence, the various business functions and activities are analyzed collectively to generate more comprehensive information in support of management’s decision-making process.

BI systems come as standardized software packages from such vendors as Business Objects, Cognos, SAS Institute, Microstrategy, Oracle, Microsoft and Actuate, and they allow customers to adapt them to their specific requirements. In recent years, the BI market has experienced extremely high growth as vendors continue to report substantial profits (Gartner, 2006a; IDC, 2007). Forrester’s recent survey indicated that for most CIOs, BI was the most important application to be purchased (Brunelli, 2006). The results of the latest Merrill Lynch survey into CIO spending similarly found that the area with the top spending priority was BI (White, 2006). These findings are echoed by Gartner’s CIOs priorities surveys in 2006 which revealed that BI ranked highest in technology priority (Gartner, 2006b). In the most recent survey of 1400 CIOs, Gartner likewise found that BI leads the list of the top ten technology priorities (Gartner, 2007).

INTRODUCTION AND RESEARCH MOTIVATION

While BI market appears vibrant, nevertheless the implementation of a BI system is a financially large and complex undertaking (Watson et al., 2004). The implementation of an enterprise-wide information system (such as a BI system) is a major event and is likely to cause organizational perturbations (Ang & Teo, 2000). This is even more so in the case of a BI system because the implementation of a BI system is significantly different from a traditional operational system. It is an infrastructure project, which is defined as a set of shared, tangible IT resources that provide a foundation to enable present and future business applications (Duncan, 1995). It entails a complex array of software and hardware components with highly specialized capabilities (Watson & Haley, 1998).

BI project team need to address issues foreign to the operational systems implementation, including cross-functional needs, poor data quality derived from source systems that can often go unnoticed until cross-systems analysis is conducted; technical complexities such as multidimensional data modeling; organizational politics, and broader enterprise integration and consistency challenges (Shin, 2003). Consequently, it requires considerable resources and involves various stakeholders over several months to initially develop and possibly years to become fully enterprise-wide (Watson & Haley, 1997). Typical expenditure on these systems, includes all BI infrastructure, packaged software, licenses, training and entire implementation costs, may demand a seven-digit expenditure (Watson & Haley, 1997). The complexity of BI systems is exemplified by Gartner's recent study that predicted more than half of systems that had been implemented will be facing only limited acceptance (Friedman, 2005).

Much IS literature suggests that various factors play pivotal roles in the implementation of an information system. However, despite the increasing interest in, and importance of, BI systems, there has been little empirical research about the critical success factors (CSFs) impacting the implementation of such systems. The gap in the literature is reflected in the low level of contributions to international conferences and journals. Although there has been a plethora of BI system studies from the IT industry, nonetheless, most rely on anecdotal reports or quotations based on hearsay (Jagielska et al., 2003). This is because the study of BI systems is a relatively new area that has primarily been driven by the IT industry and vendors, and thus there is limited rigorous and systematic research into identifying the CSFs of BI system implementation. Therefore, the increased rate of adoption of BI systems, the complexities of implementing a BI system, and their far-reaching business implications justify a more focused look at the distinctive CSFs required for implementing BI systems.

Research Objective

Given the background and motivation of this research, the authors used Delphi method to:

- explore and identify the CSFs, and their associated contextual elements that influence implementation of BI systems
- consolidate a CSFs framework for BI system implementation

Essentially, the authors argue that there is a set of factors influencing the implementation of BI systems and such antecedents (i.e., CSFs) are necessary. In alignment with Sum et al.'s (1997) argument, this research also recognizes that the associated contextual elements that make up each factor provide more specific, useful and meaningful guidelines for BI systems implementation. As asserted by Sum et al. (1997),

> Top management support has often been cited as a CSF, but what exactly constitutes top management support is not really known. Good performance of the CSFs requires that their elements (or constituents) be known so that management can formulate appropriate policies and strategies to ensure that the elements are constantly and carefully being managed and monitored. Lack of clear definitions of the CSFs may result in misdirected efforts and resources.

Furthermore, the CSFs identified can be consolidated into a framework to provide a comprehensive picture for BI stakeholders, and hence allowing them to optimize their resources and efforts on those critical factors that are most likely to have an impact on the system implementation. Thereby ensuring that the initiatives result in optimal business benefits as well as maintaining effective uptake.

The remainder of this article has been structured as follows. The following section describes the research methodology, before elaborating on the CSFs finding. The next section then presents the CSFs framework and detail of each CSF. In the last section the authors state the conclusion, research contribution and future study.

RESEARCH METHODOLOGY

In the absence of much useful literature on BI system, this study seeks to explore and identify a set of CSFs that are jointly agreed by a group of BI system experts who possess substantial experience in EAMOs. The Delphi method was deemed to be the most appropriate method for this study because it allows the gathering of subjective judgments which are moderated through group consensus (Linstone & Turoff, 1975; 2002; Helmer, 1977). Moreover, this research assumes that expert opinion can be of significant value in situations where knowledge or theory is incomplete, as in the case of BI systems implementation in EAMOs (Linstone & Turoff, 2002). Unlike focus group method, this Delphi method is particularly suitable for this research situation where personal contact among participants and thus possible dominance of opinion-leaders is not desirable because of concerns about the difficulty of ensuring democratic participation.

For this study, a Delphi panel composed of fifteen BI systems experts in EAMOs was established. Ziglio (1996) asserts that useful results can be obtained from small group of 10-15 experts. Beyond this number, further increases in understandings are small and not worth the cost or the time spent in additional interviewing (Carson et al., 2001). Thus, the size of such a Delphi panel is deemed suitably representative. As shown in Table 1, the Delphi participants have all been substantially involved in the implementation of BI systems within EAMOs in Australia and the United States.

In addition, the range of engineering asset management organizations represented by these experts was diverse and included public utilities (such as electricity, gas, water, and waste management) and infrastructure-intensive enterprises such as telecommunications and rail companies. It should be noted that some of the large organizations in which the participants have been involved have implemented BI projects in a series of phases. Most of the EAMOs are very large companies with engineering assets worth hundreds millions of dollars and have committed immense expenditure to BI projects. So the expertise of the Delphi participants represents ‘state of the art’ knowledge of BI systems implementation in a broad range of engineering asset-intensive industries.

The Delphi study comprised three rounds. During the first round the authors conducted face-to-face interviews with each participant (and phone interviews in some cases due to geographical constraints), and these varied in duration from one to one and half hours. Rather than having an open-ended question, the authors adopted a different approach from traditional Delphi methods by beginning with a list of factors derived from data warehousing literature, which is the core component of a BI system. Having a prior theory has advantages such as allowing the opening and probe questions to be more direct and effective, and helping the researcher recognize when something important has been said (Carson et al., 2001). However, the existing literature is not comprehensive in regard to CSFs for an entire BI system, but mainly focuses on data warehousing. Therefore, those factors were mainly used to start each discussion. When the mention of particular factors elicited relevant responses then further

Table 1. Delphi participants and their BI systems experience in EAMOs

Current Position	Organization Type	BI System	EAMOs' Industry Sector
Principal consultant, Committee, Author, Speaker	BI Consultancy, TDWI Committee	Business Objects, Information Builder, Cognos, Oracle	Electricity, gas, water & waste utilities, oil & gas production, defense, public transportation
Principal consultant, Committee	BI Consultancy, DWAA Committee	Cognos, Business Objects, Actuate	Telecommunications, airlines, municipal utility
Principal consultant, Author, Speaker	BI Consultancy, TDWI Summit	Cognos, Business Objects, Hyperion, Oracle, SAS	Energy utilities, transportation, mining industries
Principal consultant, Committee	BI Consultancy, DWAA Committee	Actuate, Microstrategy, Business Objects	Transportation & municipal utility, logistics
Principal consultant, Author, Speaker	BI Consultancy, TDWI Summit	Hyperion, Informatica, Oracle, Actuate, Business Objects	Electricity, gas, water utilities, telecommunications
Principal consultant	BI Consultancy	Business Objects, Cognos, Oracle	Electricity, gas, water & waste utilities
Principal consultant	BI Consultancy	SAS, Business Objects, Cognos, Microsoft, Oracle, Informatica	Rail infrastructure and fleets, public transportation, mining industries
Principal consultant	BI Consultancy	Oracle, IBM, Hyperion, Informatica, Cognos, Microsoft	Telecommunications, electricity, gas, water utilities,
Executive VP (global consulting), Speaker	BI Consultancy, Conferences	Hyperion, Informatica, Oracle	Utilities, telecommunications, public transportation
Principal consultant	BI Consultancy	Oracle, Business objects	Energy utilities, logistic transportation company
Principal consultant	BI Consultancy	Informatica, Oracle, Hyperion	Rail infrastructure and fleets
Principal consultant	BI Consultancy	Cognos, SPF Plus	Energy utilities
Principal consultant	BI Consultancy	Business Objects, SAS, Oracle	Utilities & logistics
Academic, Consultant, Author, Speaker	Academia, BI Consultancy	Oracle, Business Objects, Hyperion Microstrategy	Utilities, telecommunications & manufacturing
Principal consultant	BI Consultancy	Oracle, IBM	Municipal utilities

probing questions would follow in order to gather more details on those factors. The panelists were indeed encouraged to suggest other factors that they deemed critical.

At the commencement of the interviews, it was explained that the study focused on CSFs that facilitated the implementation success of BI systems in terms of infrastructure performance and process performance. The infrastructure performance consists of three major IS success dimensions proposed by Delone and McLean (1992; 2003), namely system quality, information quality, and system use, whereas process performance is composed of meeting time-schedule and budgetary constraints (Ariyachandra & Watson, 2006). After the interview, further clarifications (if any) were made by follow-up phone calls and e-mail communications. Subsequently, the data gathered from the first round of interviews were analyzed thoroughly by content analysis technique, a constant comparison ('grounded') technique, to identify major themes (Glaser & Strauss, 1967). This technique encourages the emergence of a finding from the data set by constantly comparing incidents of codes with each other and then abstracting related codes to a higher conceptual level (Glaser, 1992; 1998). In other words, the qualitative data were examined thematically and emergent themes were ranked by their frequency and later categorized. The objective of the present research was to identify the CSFs that influence the implementation of BI systems. Hence, it is considered to be very important to determine what emerges from the data regarding interpretations of the CSFs for implementing BI systems.

In the subsequent round, the suggested factors of all the participants were consolidated into a single list. The list was then distributed among the participants to facilitate comparison of the expert's perceptual differences. However, none of them nominated any additional factors of their own. Also, based on feedback from participants, some further minor changes were incorporated. In addition, the participants confirmed that the classification of factors and their associated contextual elements is appropriate. For instance, several elements are grouped together because of the closed interrelationship. During the third round, the list of candidate CSFs was surveyed by the Delphi participants using a structured questionnaire survey approach. Specifically, a 5-point Likert scale was applied to rate the importance of the candidate CSFs in the process of seeking statistical consensus from the BI experts. The purpose of using a 5-point scale from 1 to 5 (where 1 meant 'not important,' 2 of 'little importance,' 3 'important,' 4 'very important,' to 5 'critically important') was to distinguish important factors from critical success factors. From the survey feedback, only those factors with average rating of 3.5 and above were shortlisted as CSFs (as shown in Table 2). These CSFs ratings are considered legitimate because the participants were directly drawing on their hands-on experience in EAMOs' BI system implementations. The details of the results are discussed below.

CSFS FINDING AND DISCUSSION

Table 2 depicts the average rating results for the respective CSFs in descending order of importance. It contains the consensus outcomes and shows that the Delphi study captured the importance of the seven critical factors, namely committed management support and sponsorship, business user-oriented change management, clear business vision and well-established case, business-driven methodology and project management, business-centric championship and balanced project team composition, strategic and extensible technical framework, sustainable data quality and governance framework.

Notably, data and technical-related factors did not appear to be the most critical in relation to

Table 2. Ratings of critical success factors by Delphi participants

Critical Success Factors	Mean	Std. Dev
• Committed management support and sponsorship	4.16	0.99
• Business user-oriented change management	4.10	1.00
• Clear business vision and well-established case	4.09	0.90
• Business-driven methodology and project management	4.08	0.88
• Business-centric championship and balanced project team composition	3.94	0.89
• Strategic and extensible technical framework	3.90	0.89
• Sustainable data quality and governance framework	3.82	0.91

other organizational factors. According to most interviewees, technological difficulties can be solved by technical solutions. However, it was found that achieving management and organizational commitment for a BI initiative poses the greatest challenge, because the BI teams considered them to be outside their direct control. The organizational support is reflected in the attitudes of the various business stakeholders; that is, their attitudes to change, time, cost, technology, and project scope. Based on a large-scale survey result, Watson and Haley (1997) pointed out that the most critical factors for successful implementations were organizational in nature. Committed management support and adequate resources were found to determine the implementation success, because these factors worked to overcome socio-political resistance, address change-management issues, and increase organizational buy-in. This finding was also converging with Gartner's recent observation that "overcoming complex organizational dynamics will become the most significant challenge to the success of business intelligence initiatives and implementations" (Burton et al., 2006).

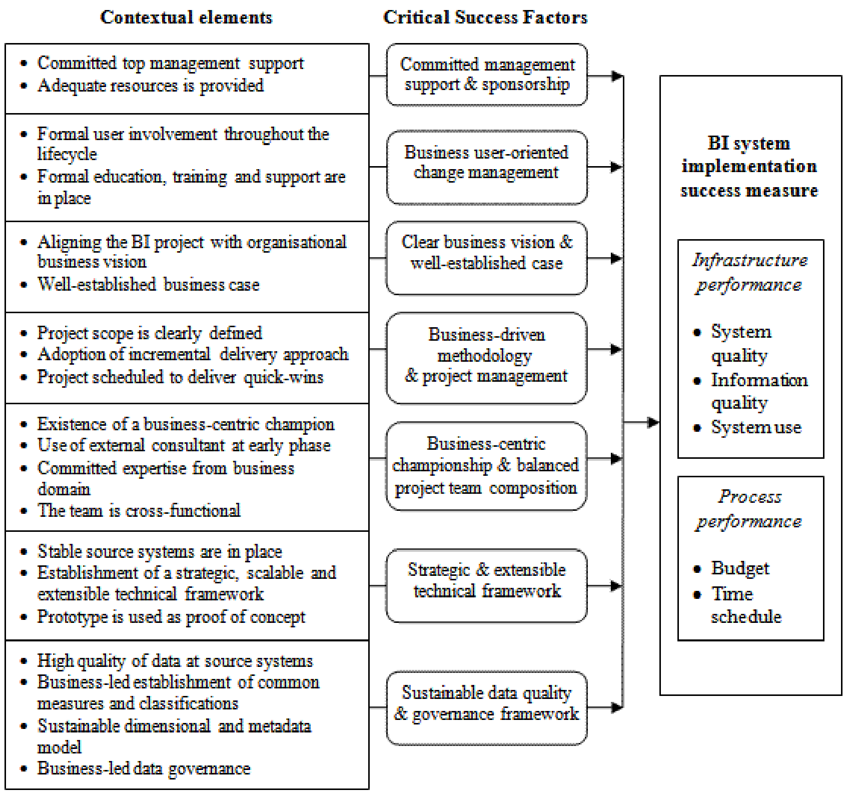
In fact, the effort of implementing BI systems is highly regarded by the Delphi participants as a business-driven program as opposed to a technological one. The fulcrum of BI program success is thus dependent on the business personnel, whereas technical people are expected to support the analytical requirements via technologies and tools. The definition of strategic BI framework, project scoping and data quality initiatives were considered within the realm of business personnel. That is, this new understanding emphasizes the priority of business aspects, not the technological ones, in implementing BI systems.

While the specific CSFs may seem to vary slightly between BI systems and general IS studies, the actual contextual elements of these CSFs are substantially different from the implementation effort required for conventional operational systems. Unlike those transactional systems, business stakeholders need to be involved interactively in order to meet their dynamic reporting and ever-changing analytical needs. Owing to the evolutionary information requirements, the BI team has to provide continual support not only on tools application, but also at broader data modeling and system scalability issues. This is in line with the adoption of an incremental delivery approach for implementing an adaptive decision support system, such as a BI system (Arnott & Pervan, 2005). Moreover, organizational and business commitment to a BI system implementation is critical to solve the complex organizational issues, especially in the democratization process of data ownership, selection of funding model, change of business process, definition of the scoping study, data stewardship and quality control, and the provision of domain expertise and championship. The following section presents the CSFs framework consolidated from these CSFs findings.

DEVELOPMENT OF A CRITICAL SUCCESS FACTORS FRAMEWORK

Based on the research finding, these seven critical factors were integrated with the implementation success measures to provide a comprehensive CSFs framework for implementing BI systems. As illustrated in v below, this CSF framework outlines how a set of factors contribute to the success of a BI system implementation. It postulates that there is a set of CSFs influencing the implementation success that takes into account two key measures: infrastructure performance and process performance. The infrastructure performance has parallels with the three major IS success variables described by (Delone & McLean, 1992; 2003), namely system quality, information quality, and system use, whereas process performance can be assessed in terms of time-schedule and budgetary considerations. Specifically, system quality is

Figure 1. A critical success factors framework for the implementation of business intelligence systems



concerned with the performance characteristics of the information processing system itself, which includes ease-of-use, functionality, reliability, flexibility, integration, and response time (Delone & McLean, 1992; Rai et al., 2002). Information quality refers to accuracy, timeliness, completeness, relevance, consistency, and usefulness of information generated by the system (Delone & McLean, 1992; Fisher et al., 2006). System use is defined as "recipient consumption of the output of an information system" (Delone & McLean, 1992). These success criteria serve as the operationalizations of this study's dependent variables (i.e., the critical success factors).

In brief, this framework treats the CSFs identified as necessary factors for implementation success, whereas the absence of the CSFs would lead to failure of the system (Rockart, 1979). Within the framework, each of the CSFs identified by the Delphi study is described as follows.

Committed Management Support and Sponsorship

Committed management support and sponsorship has been widely acknowledged as the most important factor for BI system implementation. All Delphi participants agreed that consistent support and sponsorship from business executives make it easier to secure the necessary operating resources such as funding, human skills, and other requirements throughout the implementation process (Watson et al., 2001). This observation is reasonable and expected because the whole BI system implementation effort is a costly, time-consuming, resource-intensive process (Watson et al., 2004).

Moreover, the Delphi experts further argued that BI system implementation is a continual information improvement program to leverage decision support. They believed that the typical application-based funding for implementation of transactional systems does not apply to BI systems that are adaptive in nature. That is, a BI system evolves through an iterative process of systems development in accordance to dynamic business requirements (Arnott & Pervan, 2005). Therefore the BI initiative, especially for the enterprise-wide scale, requires consistent resource allocation and top-management support to overcome organizational issues. These organizational challenges arise during the course of the cross-functional implementation, as it often uncovers many issues in such areas as business process, data ownership, data quality and stewardship, and organizational structure. Many functional units tend to focus on tactical gains, ignoring the rippling effects imposed on other business units, and one expert observed that,

The whole BI effort cut across many areas in the organization that's making it very difficult, it hits a lot of political barriers. For instance, for a systems owner, they are only interested in delivering day to day transaction, as long as all that done… that's what they care about.

Also, without dedicated support from top management, the BI project may not receive the proper recognition and hence the support it needs to be successful. This is simply because users tend to conform to the expectations of top management and so are more likely to accept a system backed by their superiors (Lambert, 1995).

Business User-Oriented Change Management

Having an adequate user-oriented change management effort was deemed critical by the Delphi participants. The experts perceive that better user participation in the change effort can lead to better communication of their needs, which in turn can help ensure the system's successful implementation. This is particularly important when the requirements for a system are initially unclear, as is the case with many of the decision-support applications that a BI system is designed to sustain (Wixom & Watson, 2001). Significant numbers of Delphi participants shared the same view that formal user participation can help meet the demands and expectations from various end users. No doubt, the user groups know what they need better than a secluded architect or developer that does not have day to day user experience. Hence, key users must be involved throughout the implementation cycle because they can provide valuable input that the BI team may overlook. The data dimensions, business rules, metadata, and data context that are needed by business users should be considered and incorporated into the system (Wixom & Watson, 2001). Furthermore, users can provide input to the process through review and testing to ensure that it meets the goals that they think it should.

Furthermore, when users are actively involved in the effort, they have a better understanding of the potential benefits and this makes them more likely to accept the system on completion (Hwang et al., 2004). Thus through this 'implicit' education approach, it create a sense of ownership by the users. Most interviewees also agreed that consistent support for, and systematic training of, end users must not be ignored when aiming for successful BI system implementation (Ang & Teo, 2000). Many participants emphasized that training should focus on the technology itself as well as on the associated management and maintenance issues. This training is important to equip users to understand and experience the features and functions, and to learn about the configured environment and business rules of the BI applications.

Clear Business Vision and Well-Established Case

As a BI initiative is driven by business, so a strategic business vision is needed to direct the implementation effort. The Delphi participants indicated that a long-term vision, primarily in strategic and organizational terms, is needed to enable the establishment of BI business case. The business case must be aligned to the corporate vision because it would eventually impact the adoption and outcome of the BI system. Otherwise they will not receive the executive and organizational supports that are required to make them successful. Consequently, the investment return of a BI system implementation should be included in those of the business process as a whole (Liautaud & Hammond, 2000). Majority interviewees indicated that the mindset of 'setting an excellent system there, then people will come to use it' is totally inappropriate. In fact, one interviewee claimed that:

A BI system that is not business-driven is a failed system! BI is a business centric concept. Sending IT off to solve a problem rarely results in a positive outcome. There must be a business problem to solve.

Most participants stressed that a solid business case that was derived from a detailed analysis of business needs would increase the chances of winning support from top management. Thus, a substantial business case should incorporate the proposed strategic benefits, resources, risks, costs and the timeline. Hence, a solid business case would provide justifiable motivations for adopting a BI system to change the existing reporting and analytical practices.

Business-Driven Methodology and Project Management

The next factor to be considered is business-driven methodology and project management. According to the Delphi experts, adequate project scoping and planning allows the BI team to concentrate on the best opportunity for improvement. To be specific, scoping helps to set clear parameters and develops a common understanding as to what is in scope and what is excluded (Ang & Teo, 2000). For instance, a Delphi expert gave insight into his experience:

The success of 90% of our project is determined prior to the first day. This success is based on having a very clear and well-communicated scope, having realistic expectations and timelines, and having the appropriate budget set aside.

Hence, adequate scoping enables the project team to focus on crucial milestones and pertinent issues while shielding them from becoming trapped in unnecessary events. Many experts further indicate that it is advisable to start small and adopt an incremental delivery approach. Large-scale change efforts are always fraught with greater risks given the substantial variables to be managed simultaneously (Ang & Teo, 2000). Moreover, business changes very fast and is always looking to see immediate impact, and such an incremental delivery approach provides the tools for delivery of needed requirements in a short time (Greer & Ruhe, 2004). Also, an incremental delivery approach allows for building a long-term solution as opposed to a short term one, as is the case for an evolutionary BI system development (Arnott & Pervan, 2005).

Besides that, some interviewees commented that a BI program that starts off on a high-impact area is always valuable to provide tangible evidence for both executive sponsors and key users

(Morris et al., 2002). According to them, adopting this so-called 'low hanging fruits' approach—projects with the greatest visibility and monetary impact— demonstrates to leadership that there is a payback (ROI) for their investment and it shows it in a short timeframe. This will increase leadership support and help the other associated initiatives to be supported readily. One interviewee elaborated that:

You cannot role out the whole BI system at once but people want to see some key areas. You need to do data marts for a couple of key areas and then maybe a small number of other key reports in an attempt to keep all stakeholders happy. Then when the first release is done and you get some feedback, you can work on other data mart areas and enhance existing subject areas over time.

Therefore, a 'low hanging fruits' approach allows an organization to concentrate on crucial issues, so enabling teams to prove that the system implementation is feasible and productive for the enterprise.

Business-Centric Championship and Balanced Project Team Composition

The majority of Delphi experts believed that having the right champion from the business side of the organization is critical for implementation success. According to them, a champion who has excellent business acumen is always important since he/she will be able to foresee the organizational challenges and change course accordingly. More importantly, this business-centric champion would view the BI system primarily in strategic and organizational perspectives, as opposed to one who might over-focus on technical aspects. For example, as noted by an interviewee:

The team needs a champion. By a champion, I do not mean someone who knows the tools. I mean someone who understands the business and the technology and is able to translate the business requirements into a (high-level) BI architecture for the system.

All interviewees also agreed that the composition and skill sets of a BI team have a major influence on the implementation success. The project team should be cross-functional and composed of those personnel who possess technical expertise and those with a strong business background (Burton et al., 2006). As most interviewees stressed, a BI system is a business-driven project to provide enhanced managerial decision support, and so a suitable mix of IT expertise is needed to implement the technical aspects, whereas the reporting and analysis aspects must be under the realm of business personnel.

Furthermore, most experts posited that the BI team must identify and include business domain experts, especially for such activities as data standardization, requirement engineering, data quality analysis, and testing. Many respondents also agreed with the critical role played by external consultants, especially at early phase. They believed that the lack of in-house experience and competencies can be complemented by external consultants who have spent the majority of their time working on similar projects. As well as being a subject matter expert, the interviewees indicated that an external consultant could provide an unbiased view of solution to a problem. This is because the organizational structure of an engineering asset management enterprise is traditionally functional-oriented and culturally fragmented with siloed information systems design (Haider & Koronios, 2003). There may even be situations where the client possesses the expertise to solve a particular problem, but are conflicted on the organizational ground. An external consultant hence can evaluate and propose an unbiased course of action without having fear of political repercussions (Kaarst-Brown, 1999).

Strategic and Extensible Technical Framework

In terms of strategic and extensible technical framework, most experts asserted that stable source/back-end systems are crucial in implementing a BI system. A reliable back-end system is critical to ensure that the updating of data works well for the extraction, transformation and loading (ETL) processes in the staging area (Ponniah, 2001). Hence the data can be transformed to provide a consistent view into quality information for improved decision support. It is therefore crucial for BI team to assess the stability and consistency of source systems before embarking on a BI effort. Otherwise after the system implementation, the cost of changes in terms of time and money can be significant. A BI expert explained the importance of this factor in detail:

It's more important you got a reliable, consistent, stable back-end system, in my experience, I'm working with a mining company now, in their case, they don't have consistent back-end systems, in some departments, they have just large number of spreadsheets, which call production data into their spreadsheets, it is scary. It's a major impediment to BI system, and you got multiple bits over all the places.

Another prime element concerned by the respondents was that the technical framework of a BI system must be able to accommodate scalability and extendibility requirements. Having a strategic view embedded in the system design, this scalable system framework could include additional data sources, attributes, and dimensional areas for fact-based analysis, and it could incorporate external data from suppliers, contractors, regulatory bodies, and industry benchmarks (Watson et al., 2004). It would then allow for building a long-term solution to meet incremental needs of business.

The majority of interviewees also agreed that a prototype is always valuable as proof of a concept. That is, constructing a fairly small BI application for a key area in order to provide tangible evidence for both executive sponsors and general users (Watson et al., 2001). They perceive that a prototype that offers clear forms of communication, and better understanding in an important business area, would convince organizational stakeholders on the usefulness of a BI system implementation. As a result of a successful prototype, senior management and key users would be more likely and more motivated to support larger-scale BI efforts.

Sustainable Data Quality and Governance Framework

The Delphi findings indicate that the quality of data, particularly at the source systems, is crucial if a BI system is to be implemented successfully. According to the interviewees, a primary purpose of the BI system is to integrate 'silos' of data sources within enterprise for advanced analysis so as to improve the decision-making process. Often, much data related issues within the back-end systems are not discovered until that data is populated and queried against in the BI system (Watson et al., 2004). Thus corporate data can only be fully integrated and exploited for greater business value once its quality and integrity are assured.

The management are also urged to initiate data governance and stewardship efforts to improve the quality of the data in back-end systems because unreliable data sources will have a ripple effect on the BI applications and subsequently the decision outcomes (Chengalur-Smith et al., 1999). For instance, an expert expressed his concern:

This is the most underrated and underestimated part of nearly every BI development effort. Much effort is put into getting the data right the first time, but not near enough time is spent *putting in place the data governance processes to ensure the data quality is maintained.*

Some interviewees further argued that a sound data governance initiative is more than ad-hoc data quality projects. Indeed, it should include a governing committee, a set of procedures, and an execution plan. More specifically, the roles of data owners or custodians and data stewards must be clearly defined (Watson et al., 2004). Frontline and field workers should be made responsible for their data source and hence data quality assurance. Meanwhile, a set of policies and audit procedures must be put into place that ensures ongoing compliance with regulatory requirements as most EAMOs like utilities are public-owned company.

Apart from that, the Delphi participants believed that common measures and definitions address the data quality dimension of representational consistency. This allows all stakeholders to know that this term has such definition no matter where it is used across the source systems. Furthermore, it is typical for an EAMO to have hundreds of varying terms with slightly different meanings, because different business units tend to define terms in ways that best serve their purposes. Often accurate data may have been captured at the source level; however, the record cannot be used to link with other data sources due to inconsistent data identifier. This is simply because data values that should uniquely describe entities are varied in different business units. Once an organization collects a large number of reports it becomes harder to re-architect these areas. As a result, a cross-system analysis is important to help profiling a uniform ‘master data set’ which is in compliance with business rules. The development of a master data set on which to base the logical data warehouse construction for BI system will ease terminology problems (Watson et al., 2004).

In order to have consistent measures and classification across subject areas, most interviewees asserted that business-led commitment is pivotal to establish consensus on data measurement and definition. Indeed, a BI system implementation is a business driven initiative to support the reporting and analytical requirements of business. As a result, the BI team would use those common definitions to develop an enterprise-wide dimensional model that is business-orientated. Many participants asserted that a correct dimensional data model is the absolute cornerstone of every BI project. A faulty model will surely lead to failure of the project as it will fail to deliver the right information. As noted by an interviewee:

Not understanding dimensional modeling will cause lots of grief later on and make it difficult to answer some questions. Once you have a large number of reports, it becomes harder to re-architect these areas. Better to get it right the first time with a star schema and well-designed dimensions and fact tables. Good use of aggregates can speed report results and make people happy.

Also, a sustainable metadata model on which to base the logical and physical data warehouse construction for a BI system was deemed critical by many experts. Therefore, the metadata model should be flexible enough to enable the scalability of the BI system while consistently providing integrity on which OLAP and data mining depend (Watson & Haley, 1997).

CONCLUDING REMARKS AND FUTURE RESEARCH

This theory building research presents a CSFs framework derived from a Delphi study with 15 BI systems experts within engineering asset management domain. An analysis of the findings demonstrated that there are a number of CSFs peculiar to successful BI system implementation. More importantly, this study revealed a clear trend towards multi-dimensional factors in implementing BI systems. Organizational factors were perceived to be more important than the technological ones because the BI team considered them to be outside their direct control. Furthermore, the contextual elements of these CSFs appear to be substantially different from the implementation effort of conventional operational systems.

The research is likely to make both theoretical and practical contributions to the field of BI systems implementation. First, this study fills in the research gap by building theory of CSFs, addresses issues of concern to practitioners and supplements the current limited understanding on implementation issues of BI systems. Moreover, this research provides thought-provoking insights into multi-dimensional CSFs that influence the BI systems implementation. The contextual elements identified alongside for each of the critical factors and the consolidated CSFs framework provides a comprehensive and meaningful understanding of CSFs.

Not only does this research contribute to the academic literature but it benefits organizations in several ways as well. Essentially, BI practitioners (both current and potential) will be better able to identify critical factors for successfully implementing BI systems. The findings will enable them to better manage their implementation of BI systems if they understand that such effort involves multiple dimensions of success factors occurring simultaneously and not merely the technical aspects of the system. With the CSFs framework, it could enable BI stakeholders to better identify the necessary factors, and to possess a comprehensive understanding of those CSFs. Such outcomes will help them to improve the effectiveness and efficiency of their implementation activities, by obtaining a better understanding of possible antecedents that lead to successful BI system implementation. For senior management, this research finding can certainly assist them by optimising their scarce resources on those critical factors that are most likely to have an impact on the BI systems implementation. Moreover, the management can concentrate their commitment to monitor, control and support only those key areas of implementation.

In the next stage, it is planned to conduct case study with multiple engineering asset management organizations to further validate the CSFs findings. The multiple case studies will examine whether these critical factors and/or any other alternative factors influence the implementation success of BI systems.

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ENDNOTE

[1] Implementation refers to an on-going process which includes the entire development of an information system from the original suggestions through the feasibility study, system analysis and design, programming, training, conversion, and installation of the system (Lucas, 1978).

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Chapter 4.15

Business Process Management Systems for Supporting Individual and Group Decision Making

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INTRODUCTION

The complexities involved in managing intra-functional as well as interfunctional activities have triggered many organizations to deploy large information technology (IT) systems such as ERP and CRM. While such systems have focused mainly on providing solutions to problems such as enterprise-wide application integration and customer driven revenue management, one of the prime issues of managing coordination among activities in organizational processes has not gained adequate attention and support. Business process management (BPM) systems have emerged as a key technology primarily in the past two decades with a goal of providing process support to organizations and supporting better decision making.

This article focuses on highlighting this role of BPM systems while discussing some of the recent advances and approaches from a decision making standpoint, both for supporting individual and collaborative decision making activities.

BACKGROUND

The original ideas upon which BPM systems are founded upon can be traced back to several different areas of computing and management.

It is worthwhile to glance at the history to better understand the motivating factors for the advancement and role of BPM systems. One such area is that of office information systems. In the 1970s and 1980s, researchers like Holt (1985) focused on modeling routine office procedures with mathematical formalisms such as Petri Nets. These efforts did not gain much momentum due to the functional nature of organizations. Later, in the mid-1990s, management initiatives such as Business Process Re-engineering (BPR) (Hammer, 1990), and Total Quality Management (TQM) (Harrington, 1991) highlighted the importance of process oriented thinking in organizations, which helped in rejuvenating the interest in business process modeling and management.

During mid-1980s and early-1990s, another research stream of organizational decision support system (ODSS) emerged. It built upon Hackathorn and Keen's (1981) key ideas of decision support: individual, group, and organizational. From a decision standpoint, it laid out a foundation for focusing on organizational activities and further decomposing them into a sequence of subactivities performed by various organizational actors. Although process coordination was not the primary focus of ODSS, it supported the notion of coordinating and disseminating decision making across functional areas and hierarchical layers such that decisions are congruent with organization goals and management's shared interpretation of the competitive environment (Watson, 1990). The term ODSS was sometimes also referred to as "distributed decision support system" in the literature.

Also in the early 1990s, document imaging and management systems fostered the notion of automation of document-driven business processes by routing documents from person to person in an organization (Smith, 1993).

BPM AND RELATED TERMINOLOGY

The term BPM is often used by commercial vendors with different connotations. It is therefore essential to present operational definitions of related terms. Firstly, the term *process* itself is very broad. Medina-Mora, Wong, and Flores's (1993) classification of organizational processes into material processes, information processes, and business processes is noteworthy here. Material processes relate human tasks to the physical world (e.g., assembly of machine parts). Information processes relate to automated tasks (i.e., performed by computer programs), and partially automated tasks (i.e., tasks performed by people with the assistance of computer programs). Business processes are a higher level abstraction of organizational activities that are operationalized through material processes and/or information processes (Georgakopoulos, Hornick, & Sheth, 1995). The term process in the BPM context relates to business processes implemented primarily as information processes, and is used in the discussion in this article.

Workflow is a related concept to automating business and information organizational processes. The Workflow Management Coalition (WfMC) defines *workflow* as: "The automation of a business process, in whole or part, during which documents, information, or tasks are passed from one participant to another for action, according to a set of procedural rules" (WfMC, 1999). Also, WfMC defines the term *Workflow Management System* (WFMS) as: "A system that defines, creates and manages the execution of workflows through the use of software, running on one or more workflow engines, which is able to interpret the process definition, interact with workflow participants and, where required, invoke the use of IT tools and applications" (WfMC, 1999). It can be seen that WfMC places strong emphasis on the execution aspect, which is limiting in many ways. While managing execution of workflows is essential, making use of information about workflows to analyze, diagnose, and redesign business processes at a conceptual level is critical to reap benefits from the technology, rather than focusing merely on process design, system configuration, and process enactment. With this realization, the term *BPM* has emerged, which involves "supporting business processes using methods, techniques, and software to design, enact, control, and analyze operational processes involving humans, organizations, applications, documents, and other sources of information" (Weske, van der Aalst, & Verbeek, 2004). Similarly, a *BPM system* can be defined as "a generic software system that is driven by explicit process designs to enact and manage operational business processes" (Weske et al., 2004).

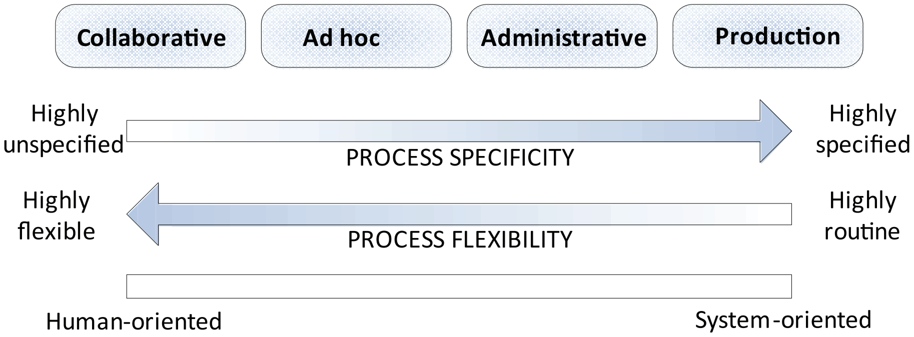
The BPM life cycle can be viewed as the one involving process (re)design, system configuration, process enactment, and diagnosis. Thus, along with a strong workflow management component, BPM systems involve decision-making support for business managers through the diagnosis phase. The diagnosis phase mainly involves *business process analysis* (BPA) and *business activity monitoring* (BAM). In this context, a visionary characterization of workflow management infrastructure provided by Georgakopoulos et al. (1995) fits closely with the current BPM systems characterization. It indicates that workflow management involves a distributed computing infrastructure that is component-oriented (i.e., supports loose coupling between heterogeneous, autonomous, and/or distributed systems), supports workflow applications for accessing organizational information systems, ensures the correctness (in case of concurrency) and reliability (in case of failures and exceptions) of applications, and supports re-engineering business processes through modification of workflows.

WORKFLOW CHARACTERIZATION

Workflows can be classified in several different ways. The most widely accepted classification, one that has been used by the trade press and endorsed by the WfMC, divides workflow in four categories: *production*, *administrative*, *ad hoc*, and *collaborative* (Georgakopoulos et al., 1995; Stohr & Zhao, 2001). Different aspects of these workflows are shown in Figure 1.

Production workflows deal with highly structured and repetitive tasks, providing automation support for which can lead to great improvements in productivity. These workflows are characterized by minimal human intervention in process management (e.g., handling exceptions). From a system support perspective, production

Figure 1. Characterization of workflows. Adapted from Georgakopoulos et al. (1995) and Stohr and Zhao (2001).



workflows are supported as either autonomous workflow engines or as embedded workflow components within enterprise systems such as ERP. Since various decisions in the process are made by the workflow system component, rather than humans, they involve high task complexity in addition to integration and interoperatibility of different enterprise applications. Also, with high transaction volumes, these workflows are mission critical and demand high accuracy, reliability, efficiency, security, and privacy. Typical examples of production workflows are health claims processing and order entry and billing in manufacturing supply chains.

Administrative workflows are characterized by human decision-making and task execution (with the assistance of software applications). They involve simpler task coordination rules as compared to production workflows, thus having relatively less task complexity. Also, the emphasis is on routing and document approval functionalities such as in the case of travel expense reports. Most often, these workflows are nonmission critical from a business value standpoint. Coordination is achieved by prompting users to perform their tasks, most commonly by using electronic mail technology.

Ad hoc workflows are best suited where flexibility in processes is a key requirement. They are often used where spontaneous, user-controlled ordering, and coordination of tasks is needed. A typical example includes a small team of knowledge workers involved in a short term project involving a set of activities. These are most often nonmission critical and do not have high repeatability, thus ruling out the need for an automated task coordination and facilitation system, such as in the case of administrative or production workflows. Electronic mail, group calendaring, and conferencing systems (collectively termed as groupware tools) are commonly used for ad hoc workflows and thus advancements in computer supported cooperative work (CSCW) are relevant for enabling these workflows.

Collaborative workflows are activities which predominantly involve group decision making activities, which are mission critical. Quite differently from ad hoc workflows, collaborative workflows are knowledge intensive with collaborative intellectual problem solving involved, which requires expertise from multiple people. However, they may or may not be repeatable, depending on the process. For example, organizational processes such as strategic planning, engineering design, user requirements gathering, are not repeatable (as compared to production workflows), although they are critical to the business process. Traditionally, these processes have been supported by group decision support systems (GDSS) (Nunamaker, Dennis, Valacich, Vogel, & George, 1991), but deserve a place in the workflow spectrum.

Supporting Decision Making Through Coordination and Control

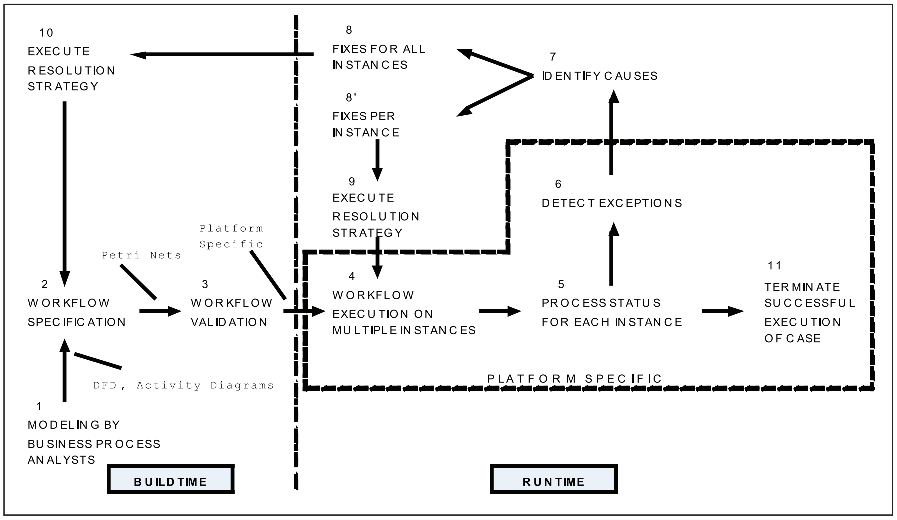
BPM systems can be used for coordinating and controlling interleaved individual and collaborative decision making tasks. With efficient coordination and control of the process, better decision making can be achieved. It is useful to look at a life cycle of a workflow schema to understand this mechanism.

Workflow Management for Coordination and Control of Tasks

The contemporary workflow management approach can be illustrated by considering the lifecycle of a workflow schema (process definition). Figure 2 illustrates the lifecycle of a workflow schema for a business process, through design and deployment, which forms the basis for coordination and control of tasks through workflow management in modern day BPM systems.

The lifecycle begins when business process analysts acquire and structure organizational processes into a workflow (Step 1). Defining a workflow schema involves identifying the differ-

Figure 2. Lifecycle of a workflow schema for a business process



ent tasks that constitute a business process in an organization and then specifying the execution sequences along with the executing agents, control, and data dependencies for the various tasks. The workflow thus defined is verified, tested, and then executed (enacted) in a workflow engine (Steps 2, 3, and 4). A single workflow schema may cater to multiple workflow instances (or cases). Each executing case is monitored and tracked (Steps 5 and 6). Cases may execute normally without any errors or may lead to exceptions of various kinds. These exceptions may have a variety of causes and are handled by manual intervention (Step 7). The failures of the workflow cases are usually caused by underspecified or erroneously defined workflows during the modeling task, as it is usually difficult to acquire comprehensive knowledge to model all possible variations of a business process (which is one of the limitations of the procedural approaches used for workflow management). Further, the workflow implementation environment changes as the business evolves; organizational roles and task assignments change. Repairs may be applied to a single executing instance or organizationally it may be decided to update the initial workflow specification (Step 8, 8'). The process of updating single instances and generic definitions is a highly knowledge intensive task in organizations because of the complexity of the workflows (Steps 9 and 10). The workflow validation/verification step is usually done via simulation/animation.

The lifecycle in Figure 2 also indicates the different process representations that may be used during the various stages of the lifecycle. For example, data flow diagrams (DFDs) and unified modeling language (UML) activity diagrams may be used by business process analysts, which may be then encoded into a specification. Such a specification may be translated into a Petri Net based formalism for analysis. Note that the activities in the Figure 2 are classified into build time (design) and run time (execution) activities. Runtime models are highly dependent on the technology platform used to execute a workflow. Thus, the process of deploying a workflow model into production requires a consistent set of model transformations that need to occur through different stages of the lifecycle.

It can be noted that the contemporary approach presented is fundamentally programmatic or procedural, as the predefined rigid process structures (workflow schemas) rely on the process designer to search the design space (although implicitly) for seeking the right kind of process model to model the business process at hand and achieve the organizational goals. As a result, failure and change management approaches to support adaptive and dynamic processes are largely ad hoc. Once a workflow is deployed, maintenance of the workflow schema (or its instances) is manual and resource intensive. Manual intervention requires knowledge of the business processes as well as the underlying workflow technology. Also, simulation-based validation may not identify all the errors early because of the large number of test cases that need to be checked.

Alternatively, declarative, goal-driven workflow process design approaches have recently been explored for business process management in dynamic settings (Deokar, Madhusudan, Briggs, & Nunamaker, 2004). Instead on deriving generic schemas for business processes, these approaches use instance specific information to generate a customized process model for addressing the business process problem. Automated logic-based algorithms (such as artificial intelligence planning) may be used for these purposes (Myers & Berry, 1999). While these approaches are novel and useful, they involve a knowledge intensive process of encoding task descriptions based on domain knowledge in order for machine to be able to intelligently generate process models.

Individual Decision Making

Administrative workflows are typical examples where individual knowledge workers are involved in decision making in workflows. These decision making tasks are modeled and designed as any other task in a workflow process; however, the execution may be supported with the help of decision support systems (DSS) to aid the individual decision maker. For example, in a loan application process, the manager might have to make decisions based on the applicant's credit history and assets, among other factors. This decision may be facilitated using a DSS that is geared toward this task (Turban, Aronson, Liang, & Sharda, 2007).

Group Decision Making

Collaborative workflows involve group decision making tasks with high process complexity (due to high information unspecificity and flexibility). Systems supporting collaborative workflows are based on GDSS or group support systems (GSS) technology. Traditionally, such systems have been restricted to face-to-face and small group decision making through facilitator guided meeting sessions (e.g., GroupSystems) (Nunamaker et al., 1991). The process structure and support is also not explicated in such systems. To be embedded as a part of a BPM system, such systems need to contain an explicit embedded representation of the underlying group process (Deokar et al., 2004).

Over the past few years, researchers in the area of collaboration technology have been working on finding ways for teams to wield GSS successfully and manage their collaboration tasks for themselves with predictable results. Addressing this challenge is the domain of an emerging field of collaboration engineering. *Collaboration engineering* is an approach for designing, modeling, and deploying repeatable collaboration tasks for recurring high-value collaborative workflows that are executed by practitioners (knowledge workers) without the ongoing intervention of facilitators (de Vreede & Briggs, 2005). *Collaborative workflows* designed through this approach are processes that support a group effort towards a specific goal, mostly within a specific time frame. The workflow is built as a sequence of facilitation interventions that create patterns of collaboration; predictable group behavior with respect to a goal. As can be noted, the research efforts are moving towards making collaborative workflows "process-aware" in the true sense, thus expanding the horizons of typical GDSS systems from face-to-face to virtual collaboration.

The main thrust of the collaboration engineering research is thus on codifying and packaging key facilitation interventions in forms that can be readily and successfully reused by groups in collaborative workflows and that can produce predictable, repeatable interactions among people working toward their goal. These packaged facilitation interventions are termed as *thinkLets* (Briggs, de Vreede, & Nunamaker, 2003). These codified facilitation interventions are based on experiences of professional facilitators in conducting successful collaborative sessions (e.g., Lowry & Nunamaker, 2002). An example of thinkLet is a "LeafHopper" thinkLet, whose purpose is to have a group brainstorm ideas regarding a number of topics simultaneously. The detail description of this thinkLet can be found in Briggs et al. (2003). Each such thinkLet provides a concrete group dynamics intervention, complete with instructions for implementation as part of some group process. Researchers have formally documented approximately 70 such distinct thinkLets to date (Briggs et al., 2003). Field experiences suggest that these 70 thinkLets account for nearly 80% of a given collaboration process design. The other 20% of group interactions need to be designed with customized thinkLets for the group task at hand.

The underlying rationale behind the design of collaborative workflows using thinkLets is that each group task can be represented as a sequence of different collaboration patterns (thinkLets) with the goal of developing a process design (schema), which when executed (possibly repeatedly), can yield a predictable behavior from the group as a whole, while creating the different constituent patterns of collaboration among team members during the execution of a collaborative workflow.

Managerial Decision Support

As noted in earlier discussion, BPM systems involve BPA and BAM as key components for analysis and diagnosis of processes. These components can provide decision support for business managers who can track the performance of the business process from various standpoints such as productivity, and resource allocation. BPA primarily involves simulation of process models to improve the level of understanding of a business process and further assisting in limiting the amount of variation in the business process. BAM can benefit at multiple levels. At the activity level, it can provide the ability to track and monitor individual work requests, while at the process level, it can provide the ability to review resource productivity and work volume analysis.

BPA and BAM collectively can enable (re) engineering and optimization of business processes. Workflow audit history tracked by BAM tools may help in providing feedback on performance issues, which may be further analyzed to indicate bottlenecks in the process. Root causes for bottlenecks (such as ineffective process design and lack of resources) may be determined to reengineer the process.

FUTURE TRENDS

BPM systems are benefiting from advances in related areas of computing and information systems. Services science is one such emerging area where the focus is on provision and consumption of services. Each service is really a wrapper around a set of activities and would involve process-awareness for systems to fulfill and/or consume services.

In the same vein, work system framework, proposed by Alter, situates BPM systems in this broader context of services science. According to Alter, "a work system is a system in which human participants and/or machines perform work using information, technology, and other resources to produce products and services for internal or external customers" (Alter, 2006).

Also, Semantic Web is another area which has implications for BPM systems and decision making. Automated reasoning technologies and ontology-based frameworks founded primarily upon principles of RDF, OWL, and Description Logic, can be useful in improving decision making by associating semantics to process related information. Ongoing research in this area holds promise for the next generation of BPM systems for coordination, control, and decision making in organizations.

CONCLUSION

Recent advances in information technology are delivering decision support tools for enabling a variety of business activities. Hence, effective and efficient coordination and control between these activities is a key requirement of modern day organizations. In this article, we discussed the role of BPM systems in meeting this requirement. The discussion on the lifecycle of a workflow schema illustrates the contemporary workflow management approach. It is noted that facilitating integrated support for individual as well as group decision making involves many challenging issues and remains an open area for further research and development.

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KEY TERMS

Business Process Management (BPM): Supporting business processes using methods, techniques, and software to design, enact, control, and analyze operational processes involving humans, organizations, applications, documents, and other sources of information

Business Process Management Systems (BPMS): A generic software system that is driven by explicit process designs to enact and manage operational business processes.

Collaboration Engineering: An approach for designing, modeling, and deploying repeatable collaboration tasks for recurring high-value collaborative workflows that are executed by practitioners (knowledge workers) without the ongoing intervention of facilitators.

Group Support System (GSS): A software system used for improving team productivity in collaboration tasks.

Group Decision Support Systems (GDSS): A type of GSS geared towards collaborative decision making tasks.

Organizational Decision Support System (ODSS): A decision support system focused on coordinating and disseminating decision making across functional areas and hierarchical layers such that decisions are congruent with organization goals and management's shared interpretation of the competitive environment.

Workflow: The automation of a business process, in whole or part, during which documents, information, or tasks are passed from one participant to another for action, according to a set of procedural rules.

Workflow Management System (WFMS): A software system that defines, creates, and manages the execution of workflows through the use of software, running on one or more process engines, which is able to interpret the process definition, interact with workflow participants, and, where required, invoke the use of IT tools and applications.

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Chapter 4.16

An Application of Multi-Criteria Decision-Making Model for Strategic Outsourcing for Effective Supply-Chain Linkages

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ABSTRACT

An appropriate outsourcing and supply-chain planning strategy needs to be based on compromise and more objective decision-making procedures. Although factors affecting business performance in manufacturing firms have been explored in the past, focuses are on financial performance and measurement, neglecting intangible and nonfinancial factors in the decision-making planning process. This study presents development of an integrated multi-criteria decision-making (MCDM) model. This model aids in allocating outsourcing and supply-chain resources pertinent to strategic planning by providing a satisfying solution. The model was developed based on the data obtained from a business firm producing intelligent home system devices. This developed model will reinforce a firm's ongoing outsourcing strategies to meet defined requirements while positioning the supply-chain system to respond to a new growth and innovation.

INTRODUCTION

In today's global age, business firms are no longer able to manage all supply-chain processes from new product development to retailing. In order to obtain a successful business performance, appropriate outsourcing and supply-chain practices should be identified, established, and implemented within the firm. The growth of business scale and scope forces business decision-makers to resolve many of the challenges confronting business firms. These tasks and activities are often not well-defined and ill-structured. This new paradigm in business practices can deliver unprecedented opportunities to establish the strategic outsourcing and supply-chain planning in business firms (Heikkila, 2002; Li & O'Brien, 2001). Due to the technology and market paradigm shift, strategic outsourcing and supply-chain planning process in business firms may become more tightly coupled with new product research and development, capacity and financial planning, product launching, project management, strategic business alliances, and revenue planning.

Successful linkages of these complicated processes play a critical role affecting business performance in manufacturing settings (Cohen & Lee, 1988; Fisher, 1997; Min & Zhou, 2002; Quinn & Hilmer, 1994). Strategic outsourcing and supply-chain planning is a growing requirement for improving productivity and profitability. Many outsourcing studies have been conducted with supply-chain linkages directly and indirectly as follows: capacity planning (Lee & Hsu, 2004), downsizing (Schniederjans & Hoffman, 1999), dual sourcing (Klotz & Chatterjee, 1995), information system decision (Ngwenyama & Bryson, 1999), line balancing (Liu & Chen, 2002), service selection (Bertolini, Bevilacqua, Braglia, & Frosolini, 2004), transportation mode choice (Vannieuwenhuyse, Gelders, & Pintelon, 2003), and vendor selection (Karpak, Kumcu & Kasuganti, 1999).

In spite of a plethora of outsourcing studies in the existing literature, multi-criteria decision making (MCDM) applications are scarce and seldom identified as the best practice in business areas. Especially, an integrated MCDM model comprising goal programming (GP) and analytic hierarchy process (AHP) is rarely applied to manage an emerging outsourcing and supply-chain concern. This chapter has dual purposes: (1) to develop a decision-making model that aims at designing a strategic outsourcing and supply-chain plan, and (2) to provide the decision-makers with an implication for effectively managing strategic outsourcing and supply-chain planning in business firms and other similar settings.

The chapter is organized in the following manner. The "Introduction" section presents current research issues in both strategic outsourcing and supply-chain planning and MCDM in a business setting. The next section "Multicriteria Decision Making" provides a review of MCDM models. After that, a problem statement of the case study along with description of data collection is described. The model development to a real-world setting and the model results and a sensitivity analysis are provided, followed by concluding remarks.

MULTI-CRITERIA DECISION MAKING

Multi-criteria decision making (especially integrated MCDM) is defined as an applied linear programming model for a decision process that allows the decision-maker to evaluate various competing alternatives to achieve certain goals. Relative importance is assigned to the goal with respect to a set of chosen criteria. MCDM is appropriate for situations in which the decision-maker needs to consider multiple criteria in arriving at the best overall decisions. In MCDM, a decision-makers select the best strategy among a number of alternatives that they evaluate on the basis of two or more criteria. The alternatives can involve risks and uncertainties; they may require sequential actions at different times; and a set of alternatives might be either finite or infinite. A decision-maker acts to maximize a value or utility function that depends on the chosen criteria. Since MCDM assumes that a decision-maker is to select among a set of alternatives, its objective function values are known with certainty. Many MCDM problems are formulated as multiple objective linear, integer, nonlinear, and/or interactive mathematical programming problems.

One of the most widely used MCDM models is goal programming (GP). Charnes and Cooper (1961) conceptualized the GP technique and applied to an analytical process that solves multiple, conflicting, and noncommensurate problems. There are many different methods and models used to generate solutions for GP models. The natural decision-making heuristic is to concentrate initially on improving what appears to be the most critical problem area (criterion), until it has been improved to some satisfactory level of performance.

Classical GP assumes that there are some absolute target levels that can be specified. This means that any solution cannot always satisfy all the goals. Thus, the objective of GP is to find a solution which comes as close as possible to the target.

The formulation of a GP model assumes that all problem constraints become goals from which to determine the best possible solution. There are two types of constraints in GP: goal constraints and systems constraints. Goal constraints are called the goal equations or soft constraints. Systems constraints are called the ordinary linear programming constraints or hard constraints which cannot be violated.

One major limitation of GP is that the decision-makers must subjectively prioritize goals in advance. The concept of nondominated (noninferior) solutions for noncommensurable goals cannot make an improvement of one goal without degrading other conflicting goals. Regardless of the weighting structures and the goals, GP can lead to inefficient and suboptimal solutions. These solutions are not necessarily optimal for the decision-maker to acquire so that a satisfying solution is provided.

Among the MCDM models, the analytical hierarchy process (AHP) is another popular decision-making tool for multi-criteria decision-making problems. AHP provides a method to assess goals and objectives by decomposing the problem into measurable pieces for evaluation using a hierarchical structure. The procedure requires the decision-maker to provide judgments about the relative importance of each criterion and then specify a preference on each criterion for decision alternatives. The output of AHP is a prioritized ranking indicating the overall preference for each of the decision alternatives. An advantage of AHP is that it enables the decision-maker to handle problems in which the subjective judgment of an individual decision-maker constitutes an important role of the decision-making process (see Saaty, 1980 for a detailed analysis).

PROBLEM BACKGROUND

Problem Statement

A consortium of seven different firms developing and manufacturing the related products of the smart home system for home security was established in Korea. The consortium firm has recently released the smart home system to the general public.

The consortium firm secured $20 million for new product development in the 5-year period (2004-2008). It currently possesses a world-class frontier for developing a smart home system. Each member company has its own unique, special knowledge and human resources to carry on required manufacturing. There are five primary systems for making a smart home system: (1) multifunction home server with an Internet gateway function, (2) intelligent context awareness-based agent system, (3) digital video recorder for home security and applications, (4) biokey system with fingerprint access control solution, and (5) wireless digital home controller functions. It is intended to support a further growth and innovation in home security, home automation, remote controlling, and mobile multimedia functions. The infusion of additional information technology must be consistent with the business mission, strategic direction, business plans, and priorities of the consortium firm.

This special project for an integrated intelligent information technology is intended to address the dramatic growth in information technology use, to foster continued innovation and adoption of new technologies, and to expand information technology foundation for the next-generation smart home system. Thus, the consortium's information technology investment strategies throughout the next five years have been developed.

Data Collection

The data utilized to formulate this MCDM model was collected from the consortium of business firms developing and manufacturing the smart home system for home security. All the necessary data on budget, technical services, and personnel resources was gathered through the consortium's strategic business units. Additional data for establishing the consortium's resource allocation model was collected through the consortium's international business development directors who are in charge of outsourcing and supply-chain management. Project managers participated in the strategic planning process and identified the necessary goals and criteria derived from the proposal for strategic outsourcing and supply-chain planning.

The data was validated by the consortium decision-makers in the outsourcing and supply-chain planning process. The validation of the consortium's resource allocation model is critical to accept the model solutions and to implement the result. The validation process provides the management with a meaningful source to ensure the input, decision-making process, and the outcomes.

The success of the model is based on the accurate measurement of the established goals and criteria. Decision-makers involved in the current outsourcing and supply-chain planning process to complete the validation reviewed the results of both prioritization of the goals, as well as the related projects/alternatives. Figure 1 presents a framework for strategic goals and related criteria.

MODEL DEVELOPMENT

Goal Decomposition and Prioritization

In the MCDM model development of outsourcing and supply-chain planning process, the AHP has been utilized for establishing goal decomposition and prioritization. In order to obtain the overall relative importance of the seven goals, a synthesized priority is calculated for each goal. The proposed model requires the evaluation of goals with respect to how much these goals affect the overall effectiveness of strategic outsourcing and supply-chain planning for resource allocation in the consortium firm. Since no prior quantitative data exists for each goal combination, the decision-maker will make pairwise comparisons of each goal with all others, using the AHP judgment scale.

The AHP values for goal prioritization provide their eigenvalue and consistency ratio. There are four derived criteria, such as financial (C_1), customer (C_2), internal business (C_3), and innovation and learning criteria (C_4).

Strategic outsourcing and supply-chain management is prioritized with AHP weights as follows: quality improvement (G_1), cost effectiveness (G_2), customer satisfaction (G_3), customizing services (G_4), manpower quality (G_5), supplier competency (G_6), and strategic partnership (G_7).

Figure 1. Strategic goals and criteria

Decision Variables

The integrated GP problem consists of two types of decision variables in this study. The consortium firm wants to contract for the supply of five different smart home system components. Five outsourcing suppliers are being considered for contracting on the system components. Tables 2 and 3 present the necessary information for decision variables and constraints. The decision variables are:

X^s_{ij} = decision variables for demand levels assigned to different types of component i (i =1,2,..,5) to be selected with various suppliers j (j =1,2,..,5) in demand capacity

where $X^s_i \geq 0$

X^p_{ij} = decision variables for project i (1, 2, 3, and 4) to which available amounts can be allocated over three-stage period j (1,2 and)

where:

$$X^p_{ij} = \begin{cases} 1 & \text{if ith project is selected} \\ 0 & \text{otherwise} \end{cases}$$

Constraints

The MCDM model has 37 constraints: 14 systems constraints and 23 goal constraints. Systems constraints for this consortium firm's outsourcing and supply-chain planning are (1) demand-supply constraints for each system component, and (2) supply-chain linkages on the number of certain projects development.

Systems constraint 1: Set the demand-supply constraints for five components. 14,400 units [displayed as 144(00)].

$$X^s_{11} + X^s_{12} + X^s_{13} + X^s_{14} + X^s_{15} \leq 144(00) \quad (1)$$

$$X^s_{21} + X^s_{22} + X^s_{23} + X^s_{24} + X^s_{25} \leq 360 \quad (2)$$

$$X^s_{31} + X^s_{32} + X^s_{33} + X^s_{34} + X^s_{35} \leq 380 \quad (3)$$

$$X^s_{41} + X^s_{42} + X^s_{43} + X^s_{44} + X^s_{45} \leq 420 \quad (4)$$

Table 1. AHP results for goal prioritization

Criteria		Goal Decomposition							GEV	CEV	CR
		G_1	G_2	G_3	G_4	G_5	G_6	G_7			
C_1										.165	.083
	G_1		4	3	4	6	8	8	.352		
	G_2			2	2	4	6	7	.218		
	G_3				3	3	5	6	.144		
	G_4					3	4	5	.139		
	G_5						2	3	.070		
	G_6							2	.044		
	G_7								.032		
C_2										.620	.046
	G_1		4	3	4	6	8	8	.404		
	G_2			2	2	4	6	7	.200		
	G_3				3	3	5	6	.168		
	G_4					3	4	5	.110		
	G_5						2	3	.056		
	G_6							2	.035		
	G_7								.026		
C_3										.142	.086
	G_1		4	3	4	6	8	8	.342		
	G_2			2	2	4	6	7	.238		
	G_3				3	3	5	6	.158		
	G_4					3	4	5	.116		
	G_5						2	3	.078		
	G_6							2	.034		
	G_7								.034		
C_4										.073	.059
	G_1		4	3	4	6	8	8	.334		
	G_2			2	2	4	6	7	.258		
	G_3				3	3	5	6	.174		
	G_4					3	4	5	.099		
	G_5						2	3	.067		
	G_6							2	.041		
	G_7								.026		
Goal Priority		.347	.244	.168	.106	.068	.040	.028			

$X^s_{51} + X^s_{52} + X^s_{53} + X^s_{54} + X^s_{55} \leq 320$ (5)

$X^s_{11} + X^s_{21} + X^s_{31} + X^s_{41} + X^s_{51} = 300$ (6)

$X^s_{12} + X^s_{22} + X^s_{32} + X^s_{42} + X^s_{52} = 300$ (7)

$X^s_{13} + X^s_{23} + X^s_{33} + X^s_{43} + X^s_{53} = 300$ (8)

$X^s_{14} + X^s_{24} + X^s_{34} + X^s_{44} + X^s_{54} = 300$ (9)

$X^s_{15} + X^s_{25} + X^s_{35} + X^s_{45} + X^s_{55} = 300$ (10)

Systems constraint 2: Select one project for supply-chain management perspectives in each development stage.

$X^p_{11} + X^p_{12} + X^p_{13} = 1$ (11)

$X^p_{21} + X^p_{22} + X^p_{23} = 1$ (12)

$X^p_{31} + X^p_{32} + X^p_{33} = 1$ (13)

$X^p_{41} + X^p_{42} + X^p_{43} = 1$ (14)

There are seven goals to achieve in this study. Necessary goal priorities are presented next.

Priority 1 (P_1): Avoid overachievement of the financial resource level by providing appropriate system resources in terms of a continuous quality improvement goal (G_1), (See Table 3).

$$150X^p_{11} + 120X^p_{21} + 100X^p_{31} + 150X^p_{41} + 100X^p_{12} + 200X^p_{22} + 60X^p_{32} + 110X^p_{42} + 130X^p_{13} + 130X^p_{23} + 70X^p_{33} + 100X^p_{43} - d^+_1 = 1{,}420 \quad (15)$$

Priority 2 (P_2): Avoid underachievement of the budget level meeting to all outsourcing suppliers of $138(00,000) in terms of cost effectiveness goal (G_2), (See Table 2).

$$80X^s_{11} + 75X^s_{12} + 90X^s_{13} + 90X^s_{14} + 85X^s_{15} + 90X^s_{21} + 85X^s_{22} + 75X^s_{23} + 80X^s_{24} + 90X^s_{25} + 75X^s_{31} + 90X^s_{32} + 80X^s_{33} + 90X^s_{34} + 75X^s_{35} + 85X^s_{41} + 80X^s_{42} + 90X^s_{43} + 75X^s_{44} + 90X^s_{45} + 90X^s_{51} + 85X^s_{52} + 75X^s_{53} + 80X^s_{54} + 90X^s_{55} + d^-_2 = 138 \quad (16)$$

Priority 3 (P_3): Do not overutilize the available market resource level for each product development stage in terms of customer satisfaction goal (G_3), (See Table 3).

$$150X^p_{11} + 120X^p_{21} + 100X^p_{31} + 150X^p_{41} - d^+_3 = 520 \quad (17)$$

Table 2. Estimated price ($) per system component in each supplier group

System Component	Outsourcing Supplier Group					Monthly Demand Level (00 units)
	1	2	3	4	5	
Home Server	80	75	90	90	85	144
Awareness Agent						
	90	85	75	80	90	360
Recorder Database						
	75	90	80	90	75	380
Biokey						
Controller Box	85	80	90	75	90	420
Monthly Supply Level (00 units)	90	85	75	80	90	320
	300	300	300	300	300	

Table 3. Project categories and available budgets for three stages

Project Category	Product Development			Available Project Budget ($000)
	Stage 1	Stage 2	Stage 3	
Security	150	100	130	380
Automation	120	200	130	450
Remote control	100	60	70	230
Mobile multimedia	150	110	100	360
Total	520	470	430	1,420

$$100X^p_{12} + 200X^p_{22} + 60X^p_{32} + 110X^p_{42} - d^+_4 = 470 \tag{18}$$

$$130X^p_{13} + 130X^p_{23} + 70X^p_{33} + 100X^p_{43} - d^+_5 = 430 \tag{19}$$

Priority 4 (P_4): In terms of customizing services goal (G_4), avoid underachievement of resources to select an outsourcing supplier by using a total budget amount ($000) for (1) a home server outsourcing of $1,200; (2) an awareness agent component outsourcing of $3,060; (3) a digital recorder database component outsourcing of $3,200; (4) a biokey component outsourcing of $3,500; and (5) a controller box component outsourcing of $2,700 (see Table 2).

$$80X^s_{11} + 90X^s_{21} + 75X^s_{31} + 85X^s_{41} + 90X^s_{51} + d^-_6 = 1{,}200 \tag{20}$$

$$75X^s_{12} + 85X^s_{22} + 90X^s_{32} + 80X^s_{42} + 85X^s_{52} + d^-_7 = 3{,}060 \tag{21}$$

$$90X^s_{13} + 75X^s_{23} + 80X^s_{33} + 90X^s_{43} + 75X^s_{53} + d^-_8 = 3{,}200 \tag{22}$$

$$90X^s_{14} + 80X^s_{24} + 90X^s_{34} + 75X^s_{44} + 80X^s_{54} + d^-_9 = 3{,}500 \tag{23}$$

$$85X^s_{15} + 90X^s_{25} + 75X^s_{35} + 90X^s_{45} + 90X^s_{55} + d^-_{10} = 2{,}700 \tag{24}$$

Priority 5 (P_5): Implement projects in the three product development stages in terms of manpower balancing goal (G_5).

$$X^p_{11} + X^p_{12} + X^p_{13} + X^p_{14} + d^-_{11} – d^+_{11} = 1 \tag{25}$$

$$X^p_{21} + X^p_{22} + X^p_{23} + X^p_{24} + d^-_{12} - d^+_{12} = 1 \tag{26}$$

$$X^p_{31} + X^p_{32} + X^p_{33} + X^p_{34} + d^-_{13} - d^+_{13} = 1 \tag{27}$$

Priority 6 (P_6): Determine the demand capacity in each supplier to assign an appropriate outsourcing supplier group in terms of supplier competency goal (G_6).

$$X^s_{11} + X^s_{12} + X^s_{13} + X^s_{14} + X^s_{15} + d^-_{14} – d^+_{14} = 1 \tag{28}$$

$$X^s_{21} + X^s_{22} + X^s_{23} + X^s_{24} + X^s_{25} + d^-_{15} – d^+_{15} = 1 \tag{29}$$

$$X^s_{31} + X^s_{32} + X^s_{33} + X^s_{34} + X^s_{35} + d^-_{16} – d^+_{16} = 1 \tag{30}$$

$$X^s_{41} + X^s_{42} + X^s_{43} + X^s_{44} + X^s_{45} + d^-_{17} - d^+_{17} = 1 \quad (31)$$

$$X^s_{51} + X^s_{52} + X^s_{53} + X^s_{54} + X^s_{55} + d^-_{18} - d^+_{18} = 1 \quad (32)$$

Priority 7 (P_7): In terms of strategic supplier partnership goal (G_7), decision-makers in the consortium firm decide that all suppliers are assigned to supply a certain component.

$$X^s_{11} + X^s_{21} + X^s_{31} + X^s_{41} + X^s_{51} + d^-_{19} - d^+_{19} = 1 \quad (33)$$

$$X^s_{12} + X^s_{22} + X^s_{32} + X^s_{42} + X^s_{52} + d^-_{20} - d^+_{20} = 1 \quad (34)$$

$$X^s_{13} + X^s_{23} + X^s_{33} + X^s_{43} + X^s_{53} + d^-_{21} - d^+_{21} = 1 \quad (35)$$

$$X^s_{14} + X^s_{24} + X^s_{34} + X^s_{44} + X^s_{54} + d^-_{22} - d^+_{22} = 1 \quad (36)$$

$$X^s_{15} + X^s_{25} + X^s_{35} + X^s_{45} + X^s_{55} + d^-_{23} - d^+_{23} = 1 \quad (37)$$

Objective Function

The objective of this MCDM problem is to minimize the sum of the deviational variable values subject to constraints (1)-(37), satisfying the preemptive priority rules. The objective function depends on the preemptive priority sequence of the goals that have seven priorities.

$$\text{Minimize: } Z = \sum_{i=3}^{5}{}_1 d^{+}{}_{1}$$

$$+P_2 d \sum_{i=6}^{10}{}_2 + P_3\ d \sum_{i=11}^{13}{}_i$$

$$+ P_4\ d^{-}{}_{i} + P_5 \left(\sum_{i=14}^{18}{}^{+}{}_{i} + d^{-}{}_{i}\right)$$

$$+ P_6 \sum_{i=19}^{23} (d^{+}{}_{i} + d^{-}{}_{i}) + P_7\ (d^{+}{}_{i} + d^{-}{}_{i})$$

MODEL ANALYSIS

Model Solution and Discussion

In this MCDM model, decision-makers seek a solution that satisfies as close as possible a set of goals. Thus, GP requires the concept of measuring discrepancy from the goals. The concept of nondominated solutions for noncommensurable goals cannot make an improvement of one goal without a trade-off of other conflicting goals. In the GP problem, a nondominated solution is examined. A nondominated solution is defined in the following manner: a feasible solution to an MCDM problem which is efficient, if no other feasible solutions yield an improvement in one goal, without sacrificing another goal. This MCDM model was solved using AB: QM system software (Lee, 1996). Table 4 presents an analysis of the objective function. Table 5 exhibits the results of both decision and deviational variables.

Priority 1 (P_1) is to avoid overachievement of the financial resource level for continuous quality improvement (i.e., G_1). Priority 1 is fully satisfied ($P_1 = 0$). The related deviational variable (d^+_1) is zero.

Priority 2 (P_2) is to avoid underutilization of the budget level for cost effectiveness. Priority 2 is fully satisfied ($P_2 = 0$). The related deviational variable (d^-_2) is zero.

Priority 3 (P_3) is to not overutilize the available market resource level in each product development period for customer satisfaction. The management

Table 4. Analysis of the objective function

Priority	Goal Achievement	Values
P_1	Satisfied	0
P_2	Satisfied	0
P_3	Satisfied	0
P_4	Satisfied	0
P_5	Partially satisfied	1
P_6	Partially satisfied	1,495
P_7	Partially satisfied	1,495

Table 5. Analysis of decision and deviational variables

Decision Variable (supplier)	Solution Value	Decision Variable (project)	Solution Value	Deviational Variable*
X^s_{11}	0	X^p_{11}	0	$d^-_1 = 1030$
X^s_{12}	0	X^p_{12}	0	$d^+_2 = 125{,}102$
X^s_{13}	0	X^p_{13}	1	$d^-_3 = 420$
X^s_{14}	144	X^p_{21}	0	$d^-_4 = 310$
X^s_{15}	0	X^p_{22}	1	$d^-_5 = 300$
X^s_{21}	0	X^p_{23}	0	$d^+_6 = 24{,}300$
X^s_{22}	0	X^p_{31}	1	$d^+_7 = 23{,}840$
X^s_{23}	0	X^p_{32}	0	$d^+_8 = 19{,}300$
X^s_{24}	36	X^p_{33}	0	$d^+_9 = 21{,}340$
X^s_{25}	200	X^s_{41}	1	$d^+_{10} = 22{,}800$
X^s_{31}	0	X^s_{42}	0	$d^+_{11} = 1$
X^s_{32}	280	X^s_{43}	0	$d^+_{14} = 143$
X^s_{33}	0	X^s_{44}		$d^+_{15} = 235$
X^s_{34}	0			$d^+_{16} = 379$
X^s_{35}	100			$d^+_{17} = 419$
X^s_{41}	300			$d^+_{18} = 319$
X^s_{42}	0			$d^+_{19} = 299$
X^s_{43}	0			$d^+_{20} = 299$
X^s_{44}	120			$d^+_{21} = 299$
X^s_{45}	0			$d^+_{22} = 299$
X^s_{51}	0			$d^+_{23} = 299$
X^s_{52}	20			
X^s_{53}	300			
X^s_{54}	0			
X^s_{55}	0			

* All other deviational variables are zero.

desires that their market resource of outsourcing should not be overutilized in each development stage 1 (d^+_3), stage 2 (d^+_4), and stage 3 (d^+_5). This third priority goal is fully satisfied ($P_3 = 0$), and its related deviational variables (d^+_3, d^+_4 and d^+_5) are zero.

Priority 4 (P_4) is to avoid underachievement of resources to select outsourcing suppliers who have the industrial leading knowledge in five different smart home system components, since the management considers that all five technology resources are highly unattainable. This priority goal is fully satisfied ($P_4 = 0$). Its related deviational variables are all zero: underachievement in home server technology outsourcing resources ($d^-_6 = 0$); underachievement in awareness agent technology outsourcing resources ($d^-_7 = 0$); underachievement in recorder database technology outsourcing resources ($d^-_8 = 0$); underachievement in biokey technology outsourcing resources ($d^-_9 = 0$); and underachievement in controller box technology outsourcing resources ($d^-_{10} = 0$).

Priority 5 (P_5) is to implement appropriately four projects in the three product development periods for securing outsourcing manpower balancing. This priority goal is partially satisfied ($P_5 = 1$). Its related deviational variables are not all zero ($d^+_{11} = 1$, $d^+_{12} = 0$, $d^+_{13} = 0$, $d^-_{11} = 0$, $d^-_{12} = 0$, $d^-_{13} = 0$). There is one project with overachievement. However, this does not mean that the goal is not achieved because four projects should be assigned in any product development stage.

Priority 6 (P_6) is to meet the demand-supply level to select an appropriate outsourcing supplier group for a supplier competency goal. This priority goal is partially satisfied ($P_6 = 1{,}495$). Its related deviational variables are not all zero ($d^+_{14} = 143$, $d^+_{15} = 235$, $d^+_{16} = 379$, $d^+_{17} = 419$, $d^+_{18} = 319$, $d^-_{14} = 0$, $d^-_{15} = 0$, $d^-_{16} = 0$, $d^-_{17} = 0$, $d^-_{18} = 0$). Table 6 indicates demand levels that are assigned to sup-

Table 6. Demand level assigned supplier groups to system components

System Component	Outsourcing Supplier Group				
	1	2	3	4	5
Home Server				144	
Awareness Agent					
				36	200
Recorder Database					
		280			100
Biokey					
Controller Box	300			120	
		20	300		

plier groups for each system component. Supplier 1 is assigned to a demand level of 300 biokey components. Likewise, supplier 2 has demand levels of 280 recorder database and 20 control box components; supplier 3 for a demand level of 300 control box components; supplier 4 for demand levels of 144 home server, 36 awareness, and 120 biokey components; and supplier 5 for demand levels of 200 awareness agent and 100 recorder database components.

Priority 7 (P_7) is to assign certain contracts to supplier groups to achieve a strategic partnership goal. This priority goal is partially satisfied (P_6 = 1,495). Its related deviational variables are not all zero ($d^+_{19} = 299$, $d^+_{20} = 299$, $d^+_{21} = 299$, $d^+_{22} = 299$, $d^+_{23} = 299$, $d^-_{19} = 0$, $d^-_{20} = 0$, $d^-_{21} = 0$, $d^-_{22} = 0$, $d^-_{23} = 0$). Table 7 presents the selected projects assigned to each development stage. In stage 1, remote control function and mobile multimedia function will be recommended to develop. Home automation function will be developed in stage 2 and home security function in stage 3.

Table 7. Assigned projects in each development stage

Project Category	Product Development		
	Stage 1	Stage 2	Stage 3
Security			X
Automation		X	
Remote control	X		
Mobile multimedia	X		

Outsourcing and supply-chain planning in supply-chain management perspective has become a significant and integral activity of strategic planning in a firm. The goals surrounding outsourcing and supply-chain planning decisions are complex and conflicting. Like other business decision making problems, outsourcing problems cannot derive a single optimal solution. Most top decision-makers agree that this planning process ultimately depends on a firm's business strategies, competitiveness roadmap, and business value and mission. In order to improve the system's overall effectiveness, decision-makers should recognize the ways to improve product quality, to enhance the internal and external customer satisfaction, to provide more strong commitment to manpower management, and to establish a sound alliance and collaboration with other business partners.

Sensitivity Analysis

Sensitivity analysis is an evaluation tool that is used once a satisfying solution has been found. It provides an insight into how satisfying solutions are affected by changes in the input data. Sensitivity analysis is performed with two scenarios. The management considers three goals (G_1, G_6, and G_7) to be evaluated. Quality improvement goal (G_1) and supplier competency goal (G_6) are changed (i.e., $P_{6\rightarrow} P_1$ and $P_{1\rightarrow} P_6$); and quality improvement goal (G_1) and strategic partnership goal (G_7) are changed (i.e., $P_{7\rightarrow} P_1$ and $P_{1\rightarrow} P_7$).

Table 8. Sensitivity analysis with two scenarios

Original Option		Revised Scenario 1		Revised Scenario 2	
Decision Variables	**Solution Value**	**Decision Variables**	**Solution Value**	**Decision Variables**	**Solution Value**
X^s_{11}	0	X^s_{11}	144	X^s_{11}	0
X^s_{12}	0	X^s_{12}	0	X^s_{12}	64
X^s_{13}	0	X^s_{13}	0	X^s_{13}	0
X^s_{14}	144	X^s_{14}	0	X^s_{14}	0
X^s_{15}	0	X^s_{15}	0	X^s_{15}	80
X^s_{21}	0	X^s_{21}	0	X^s_{21}	0
X^s_{22}	0	X^s_{22}	256	X^s_{22}	236
X^s_{23}	0	X^s_{23}	0	X^s_{23}	0
X^s_{24}	36	X^s_{24}	0	X^s_{24}	0
X^s_{25}	200	X^s_{25}	0	X^s_{25}	0
X^s_{31}	0	X^s_{31}	80	X^s_{31}	0
X^s_{32}	280	X^s_{32}	0	X^s_{32}	0
X^s_{33}	0	X^s_{33}	0	X^s_{33}	0
X^s_{34}	0	X^s_{34}	0	X^s_{34}	180
X^s_{35}	100	X^s_{35}	300	X^s_{35}	200
X^s_{41}	300	X^s_{41}	76	X^s_{41}	300
X^s_{42}	0	X^s_{42}	44	X^s_{42}	0
X^s_{43}	0	X^s_{43}	0	X^s_{43}	0
X^s_{44}	120	X^s_{44}	300	X^s_{44}	120
X^s_{45}	0	X^s_{45}	0	X^s_{45}	0
X^s_{51}	0	X^s_{51}	0	X^s_{51}	0
X^s_{52}	20	X^s_{52}	0	X^s_{52}	0
X^s_{53}	300	X^s_{53}	300	X^s_{53}	300
X^s_{54}	0	X^s_{54}	0	X^s_{54}	0
X^s_{55}	0	X^s_{55}	0	X^s_{55}	0
X^p_{11}	0	X^p_{11}	0	X^p_{11}	0
X^p_{12}	0	X^p_{12}	0	X^p_{12}	0
X^p_{13}	1	X^p_{13}	1	X^p_{13}	1
X^p_{21}	0	X^p_{21}	0	X^p_{21}	0
X^p_{22}	1	X^p_{22}	1	X^p_{22}	1
X^p_{23}	0	X^p_{23}	0	X^p_{23}	0
X^p_{31}	1	X^p_{31}	1	X^p_{31}	1
X^p_{32}	0	X^p_{32}	0	X^p_{32}	0
X^p_{33}	0	X^p_{33}	0	X^p_{33}	0
X^s_{41}	1	X^s_{41}	1	X^s_{41}	1
X^s_{42}	0	X^s_{42}	0	X^s_{42}	0
X^s_{43}	0	X^s_{43}	0	X^s_{43}	0
X^s_{44}		X^s_{44}		X^s_{44}	

With sensitivity analysis available for the management, various scenarios can be evaluated more easily at less cost. Table 8 presents the results of two scenarios. It shows an important implication for strategic planning considering effective outsourcing and supplier management. Solution values of supplier decision variables in the original option and the revised scenarios indicate the new demand levels that are assigned to the supplier groups.

The top decision-makers in the consortium firm have accepted the final results as valid and feasible for implementing the outsourcing planning in their real business setting. The consortium firm has started its strategic outsourcing and supplier-customer management planning with ongoing base. The effects from these model outputs will be evaluated in the next fiscal year or two. The future outsourcing and supplier management planning agenda will be identified to compare with this proposed MCDM model for the strategic outsourcing planning. The strategic outsourcing planning based on the proposed MCDM model will provide the management with a significant insight to set an appropriate outsourcing strategy, while enhancing customer satisfaction and relationship management, and improving the firm's global competitiveness. Thus, the consortium firm currently reviews all these alternatives as possible outsourcing strategies.

CONCLUSION

This study presents an MCDM model for outsourcing and supply-chain planning in a smart home system components manufacturing industry in Korea. The proposed MCDM model will provide the management with better understanding of outsourcing and supply-chain planning. This proposed model would give a practical decision-making way for analyzing the outsourcing resource planning. This study indicates that the effective decision-making process in outsourcing and supply-chain planning can enforce the firm's competitive advantages and improve the firm's business performance. It is necessary to be able to assess the relative contribution of the individual member organizations within the supply chain. This requires a performance measurement system that can not only operate at several different levels but also link or integrate the efforts of these different levels to meeting the objectives of the supply chain.

When management considers several conflicting goals to achieve, subject to a set of constraints, MCDM models can provide effective decision-making results for strategic outsourcing and supply-chain planning in business operational environments. Subjective decision-making processes can make the multiple and complicated business problems into the worst situation of both business performance and business partnership due to the potential irrational decision-making. Thus, an appropriate use of MCDM models for effective decision-making is essential to create a long-term strategic plan for a competitive advantage and survival of any business organization in challenging environments.

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Chapter 4.17

The Cognitive Process of Decision Making

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ABSTRACT

Decision making is one of the basic cognitive processes of human behaviors by which a preferred option or a course of actions is chosen from among a set of alternatives based on certain criteria. Decision theories are widely applied in many disciplines encompassing cognitive informatics, computer science, management science, economics, sociology, psychology, political science, and statistics. A number of decision strategies have been proposed from different angles and application domains such as the maximum expected utility and Bayesian method. However, there is still a lack of a fundamental and mathematical decision model and a rigorous cognitive process for decision making. This article presents a fundamental cognitive decision making process and its mathematical model, which is described as a sequence of Cartesian-product based selections. A rigorous description of the decision process in real-time process algebra (RTPA) is provided. Real-world decisions are perceived as a repetitive application of the fundamental cognitive process. The result shows that all categories of decision strategies fit in the formally described decision process. The cognitive process of decision making may be applied in a wide range of decision-based systems such as cognitive informatics, software agent systems, expert systems, and decision support systems.

INTRODUCTION

Decision making is a process that chooses a preferred option or a course of actions from among a set of alternatives on the basis of given criteria or strategies (Wang, Wang, Patel, & Patel, 2004; Wilson & Keil, 2001). Decision making is one of the 37 fundamental cognitive processes modeled in the layered reference model of the brain (LRMB) (Wang et al., 2004; Wang, 2007b). The study on decision making is interested in multiple disciplines such as cognitive informatics, cognitive science, computer science, psychology, management science, decision science, economics, sociology, political science, and statistics (Berger, 1990; Edwards & Fasolo, 2001; Hastie, 2001; Matlin, 1998; Payne & Wenger, 1998; Pinel, 1997; Wald, 1950; Wang et al., 2004; Wilson et al., 2001). Each of those disciplines has emphasized on a special aspect of decision making. It is recognized that there is a need to seek an axiomatic and rigorous model of the cognitive decision-making process in the brain, which may be served as the foundation of various decision making theories.

Decision theories can be categorized into two paradigms: the *descriptive* and *normative* theories. The former is based on empirical observation and on experimental studies of choice behaviors; and the latter assumes a rational decision-maker who follows well-defined preferences that obey certain axioms of rational behaviors. Typical normative theories are the expected utility paradigm (Osborne & Rubinstein, 1994) and the Bayesian theory (Berger, 1990; Wald, 1950). Edwards developed a 19-step decision-making process (Edwards et al., 2001) by integrating Bayesian and multi-attribute utility theories. Zachary, Wherry, Glenn, and Hopson (1982) perceived that there are three constituents in decision making known as the *decision situation*, the *decision maker*, and the *decision process*. Although the cognitive capacities of decision makers may be greatly varying, the core cognitive processes of the human brain share similar and recursive characteristics and mechanisms (Wang, 2003a; Wang & Gafurov, 2003; Wang & Wang, 2004; Wang et al., 2004).

This article adopts the philosophy of the *axiom of choice* (Lipschutz, 1967). The three essences for decision making recognized in this article are the *decision goals*, a set of *alternative choices*, and a set of *selection criteria* or strategies. According to this theory, decision makers are the engine or executive of a decision making process. If the three essences of decision making are defined, a decision making process may be rigorously carried out by either a human decision maker or by an intelligent system. This is a cognitive foundation for implementing expert systems and decision supporting systems (Ruhe, 2003; Ruhe & An, 2004; Wang et al., 2004; Wang, 2007a).

In this article, the cognitive foundations of decision theories and their mathematical models are explored. A rigorous description of decisions and decision making is presented. The cognitive process of decision making is explained, which is formally described by using real-time process algebra (RTPA). The complexity of decision making in real-world problems such as software release planning is studied, and the need for powerful decision support systems are discussed.

A MATHEMATICAL MODEL OF DECISIONS AND DECISION MAKING

Decision making is one of the fundamental cognitive processes of human beings (Wang et al., 2004; Wang, 2007a; Wang, 2007b) that is widely used in determining rational, heuristic, and intuitive selections in complex scientific, engineering, economical, and management situations, as well as in almost each procedure of daily life. Since decision making is a basic mental process, it occurs every few seconds in the thinking courses of human mind consciously or subconsciously.

This section explores the nature of selection, decision, and decision making, and their mathematical models. A rigorous description of decision making and its strategies is developed.

The Mathematical Model of Decision Making

The *axiom of selection* (or *choice*) (Lipschutz, 1967) states that there exists a selection function for any nonempty collection of nonempty disjoint sets of alternatives.

Definition 1. Let $\{A_i \mid i \in I\}$ be a collection of disjoint sets, $A_i \subseteq U$, and $A_i \neq \emptyset$, a function

$$c: \{A_i\} \rightarrow A_i,\ \ i \in I \tag{1}$$

is a *choice function* if $c(A_i) = a_i$, $a_i \in A_i$. Or an element $a_i \in A_i$ may be chosen by c, where A_i is called the set of alternatives, U the universal set, and I a set of natural numbers.

On the basis of the choice function and the axiom of selection, a decision can be rigorously defined as follows.

Definition 2. A *decision, d*, is a selected alternative $a \in \mathcal{A}$ from a nonempty set of alternatives $\mathcal{A}$, $\mathcal{A} \subseteq U$, based on a given set of criteria C, i.e.:

$$\begin{aligned} d &= f(\mathcal{A}, C) \\ &= f: \mathcal{A} \times C \rightarrow \mathcal{A},\ \ \mathcal{A} \subseteq U,\ \mathcal{A} \neq \emptyset \end{aligned} \tag{2}$$

where × represents a Cartesian product.

It is noteworthy that the criteria in C can be a simple one or a complex one. The latter is the combination of a number of joint criteria depending on multiple factors.

Definition 3. *Decision making* is a process of decision selection from available alternatives against the chosen criteria for a given decision goal.

According to Definition 2, the *number of possible decisions, n*, can be determined by the sizes of $\mathcal{A}$ and C, for example:

$$n = \#\mathcal{A} \bullet \#C \tag{3}$$

where # is the cardinal calculus on sets, and $\mathcal{A} \cap C = \emptyset$.

According to Eq.3, in case $\#\mathcal{A} = 0$ and/or $\#C = 0$, no decision may be derived.

The previous definitions provide a generic and fundamental mathematical model of decision making, which reveal that the factors determining a decision are the alternatives $\mathcal{A}$ and criteria C for a given decision making goal. A unified theory on fundamental and cognitive decision making can be developed based on the axiomatic and recursive cognitive process elicited from the most fundamental decision-making categories as shown in Table 1.

Strategies and Criteria of Decision Making

According to Definition 2, the outcomes of a decision making process are determined by the decision-making strategies selected by decision makers when a set of alternative decisions has been identified. It is obvious that different decision making strategies require different decision selection criteria. There is a great variation of decision-making strategies developed in traditional decision and game theories, as well as cognitive science, system science, management science, and economics.

The taxonomy of strategies and corresponding criteria for decision making can be classified into four categories known as *intuitive*, *empirical*, *heuristic*, and *rational* as shown in Table 1. It is noteworthy in Table 1 that the existing decision theories provide a set of criteria (C) for evaluating alternative choices for a given problem.

As summarized in Table 1, the first two categories of decision-making, *intuitive* and *empirical*, are in line with human intuitive cognitive psychology and there is no specific rational model for explaining those decision criteria. The rational

Table 1. Taxonomy of strategies and criteria for decision-making

No.	Category	Strategy	Criterion (*C*)
1	**Intuitive**		
1.1		Arbitrary	Based on the most easy or familiar choice
1.2		Preference	Based on propensity, hobby, tendency, expectation
1.3		Common senses	Based on axioms and judgment
2	**Empirical**		
2.1		Trial and error	Based on exhaustive trial
2.2		Experiment	Based on experiment results
2.3		Experience	Based on existing knowledge
2.4		Consultant	Based on professional consultation
2.5		Estimation	Based on rough evaluation
3	**Heuristic**		
3.1		Principles	Based on scientific theories
3.2		Ethics	Based on philosophical judgment and belief
3.3		Representative	Based on common rules of thumb
3.4		Availability	Based on limited information or local maximum
3.5		Anchoring	Based on presumption or bias and their justification
4	**Rational**		
4.1	Static		
4.1.1		Minimum cost	Based on minimizing energy, time, money
4.1.2		Maximum benefit	Based on maximizing gain of usability, functionality, reliability, quality, dependability
4.1.3		Maximum utility	Based on cost-benefit ratio
4.1.3.1		- Certainty	Based on maximum probability, statistic data
4.1.3.2		- Risks	Based on minimum loss or regret
		- Uncertainty	
4.1.3.3		- Pessimist	Based on maximin
4.1.3.4		- Optimist	Based on maximax
4.1.3.5		- Regretist	Based on minimax of regrets
4.2	Dynamic		
4.2.1		Interactive events	Based on automata
4.2.2		Games	Based on conflict
4.2.2.1		- Zero sum	Based on $\sum$ (gain + loss) = 0
4.2.2.2		- Non zero sum	Based on $\sum$ (gain + loss) $\neq$ 0
4.2.3		Decision grids	Based on a series of choices in a decision grid

decision-making strategies can be described by two subcategories: the *static* and *dynamic* strategies and criteria. The *heuristic* decision-making strategies are frequently used by human beings as a decision maker. Details of the heuristic decision-making strategies may be referred to cognitive psychology and AI (Hastie, 2001; Matlin, 1998; Payne et al., 1998; Wang, 2007a).

It is interesting to observe that the most simple decision making theory can be classified into the intuitive category such as arbitrary and preference choices based on personal propensity, hobby, tendency, expectation, and/or common senses. That is, a naïve may still be able to make important and perhaps wise decisions every day, even every few seconds. Therefore, the elicitation of the most fundamental and core process of decision making shared in human cognitive processes is yet to be sought in the following sections. Recursive applications of the core process of decision making will be helpful to solve complicated decision problems in the real world.

The Framework of Rational Decision Making

According to Table 1, rational and complex decision making strategies can be classified into the static and dynamic categories. Most existing decision-making strategies are static because the changes of environments of decision makers are independent of the decision makers' activities. Also, different decision strategies may be selected in the same situation or environment based on the decision makers' values and attitudes towards risk and their prediction on future outcomes. When the environment of a decision maker is interactive with his or her decisions or the environment changes according to the decision makers' activities and the decision strategies and rules are predetermined, this category of decision making needs are classified into the category of dynamic decisions such as games and decision grids (Matlin, 1998; Payne et al., 1998; Pinel, 1997; Wang, 2005a,b).

Definition 4. The *dynamic strategies and criteria* of decision-making are those that all alternatives and criteria are dependent on both the environment and the effect of the historical decisions made by the decision maker.

Classic dynamic decision making methods are decision trees (Edwards et al., 2001). A new theory of decision grid is developed in Wang (2005a,b) for serial decision making. Decision making under interactive events and competition is modeled by games (Matlin, 1998; Payne et al., 1998; von Neumann & Morgenstern, 1980; Wang, 2005a). Wang (2005a) presents a formal model of games, which rigorously describes the architecture or layout of games and their dynamic behaviors.

An overview of the classification of decisions and related rational strategies is provided in Figure 1. It can be seen that games are used to deal with the most complicated decision problems, which are dynamic, interactive, and under uncontrollable competitions. Further discussion on game theories and its formal models may be referred to von Neumann et al. (1980), Berger (1990), and Wang (2005a,b). Decision models may also be classified among others point of views such as structures, constraints, degrees of uncertainty, clearness and scopes of objectives, difficulties of information processing, degrees of complexity, utilities and beliefs, ease of formalization, time constraints, and uniqueness or novelty.

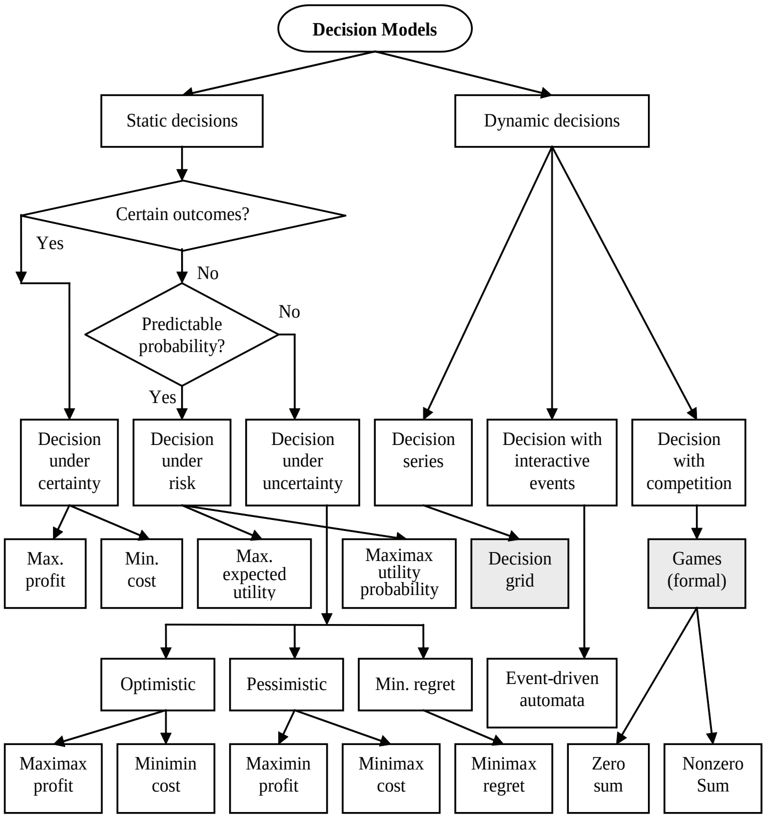
Typical Theories of Decision Making

Decision making is the process of constructing the choice criteria (or functions) and strategies and use them to select a decision from a set of possible alternatives. In this view, existing decision theories are about how a choice function may be created for finding a good decision. Different decision theories provide different choice functions. The following are examples from some of the typical decision paradigms as shown in Table 1.

(a) The Game Theory

In game theory (Osborne et al., 1994), a decision problem can be modeled as a triple, for example:

Figure 1. A framework of decisions and strategies



$$d = (\Omega, C, \mathcal{A}) \qquad (4)$$

where Ω is a set of possible states of the nature, C is a set of consequences, and $\mathcal{A}$ is a set of actions, $\mathcal{A} \subset C^{\Omega}$.

If an action $a \in \mathcal{A}$ is chosen, and the prevailing state is $\omega \in \Omega$, then a certain consequence $\alpha(\omega) \in C$ can be obtained. Assuming a probability estimation and a utility function be defined for a given action a as $p(a)$: $\mathsf{A} \rightarrow \Re$ and u: $C \rightarrow \Re$, respectively, a choice function based on the utility theory can be expressed as follows:

$$d = \{\ a\ |\sum_{\Omega} u[a(\omega)]p(a) = max\ (\sum_{\Omega} u[x(\omega)]p(x)) \wedge x \in \mathcal{A})\} \qquad (5)$$

(b) The Bayesian Theory

In Bayesian theory (Wald, 1950; Berger, 1990) the choice function is called a decision rule. A loss function, L, is adopted to evaluate the consequence of an action as follows:

$$L: \Omega \times \mathcal{A} \rightarrow \Re \qquad (6)$$

where Ω is a set of all possible states of nature, $\mathcal{A}$ is a set of actions, and $\Omega \times \mathcal{A}$ denotes a Cartesian product of choice.

Using the loss function for determining possible risks, a choice function for decision making can be derived as follows:

$$d = \{\ a\ |p[L(\omega,\alpha)] = \min_{x \in \mathrm{A}}(p[L(\omega,x)])\} \qquad (7)$$

where $p[L(\omega,\alpha)]$ is the expected probability of loss for action x on $\omega \in \Omega$.

Despite different representations in the utility theory and Bayesian theory, both of them provide alternative decision making criteria from different angles where loss in the latter is equivalent to the negative utility in the former. Therefore, it may be perceived that a decision maker who uses the utility theory is seeking optimistic decisions; and a decision maker who uses the loss or risk-based theory is seeking pessimistic or conservative decisions.

THE COGNITIVE PROCESS OF DECISION MAKING

The LRMB model has revealed that there are 37 interacting cognitive processes in the brain (Wang et al., 2004). Relationships between the decision-making process and other major ones in LRMB are shown in Figure 2. Figure 2 indicates that, according to UML semantics, the decision-making process inherits the *problem-solving* process. In other end, it functions by aggregations of or supported by the layer 6 processes *comprehension*, *qualification*, and *quantification*, as well as the layer 5 processes of *search*, *representation*, and *memorization*. Formal descriptions of these related cognitive processes in LRMB may be referred to in Wang (2003b), Wang et al., (2003), and Wang et al. (2003, 2004).

In contrary to the traditional *container* metaphor, the human memory mechanism can be described by a *relational* metaphor, which perceives that memory and knowledge are represented by the connections between neurons in the brain, rather than the neurons themselves as information containers. Therefore, the cognitive model of human memory, particularly the long-term memory (LTM) can be described by two fundamental artifacts (Wang et al., 2003): (a) *Objects*: The abstraction of external entities and internal concepts. There are also sub-objects known as *attributes*, which are used to denote detailed properties and characteristics of an object. (b) *Relations*: Connections and relationships between object-object, object–attributes, and attribute-attribute.

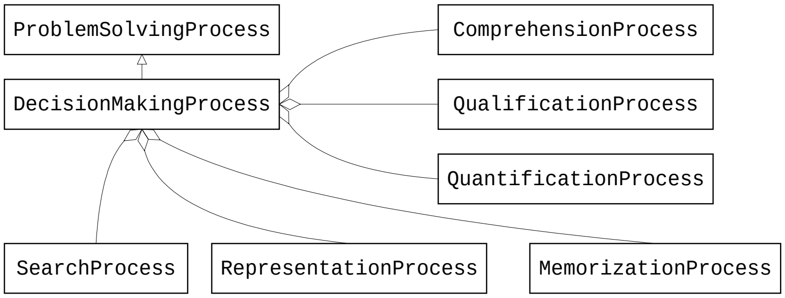
Based on the previous discussion, an object-attribute-relation (OAR) model of memory can be described as a triple (Wang & Wang, 2004; Wang et al., 2003), for example:

$$OAR = (O, A, R) \quad (8)$$

where O is a given object identified by an abstract name, A is a set of attributes for characterizing the object, and R is a set of relations between the object and other objects or attributes of them.

On the basis of the LRMB and OAR models developed in cognitive informatics (Wang, 2003a, 2007b), the cognitive process of decision making may be informally described by the following courses:

Figure 2. Relationships between decision-making process and other processes in LRMB

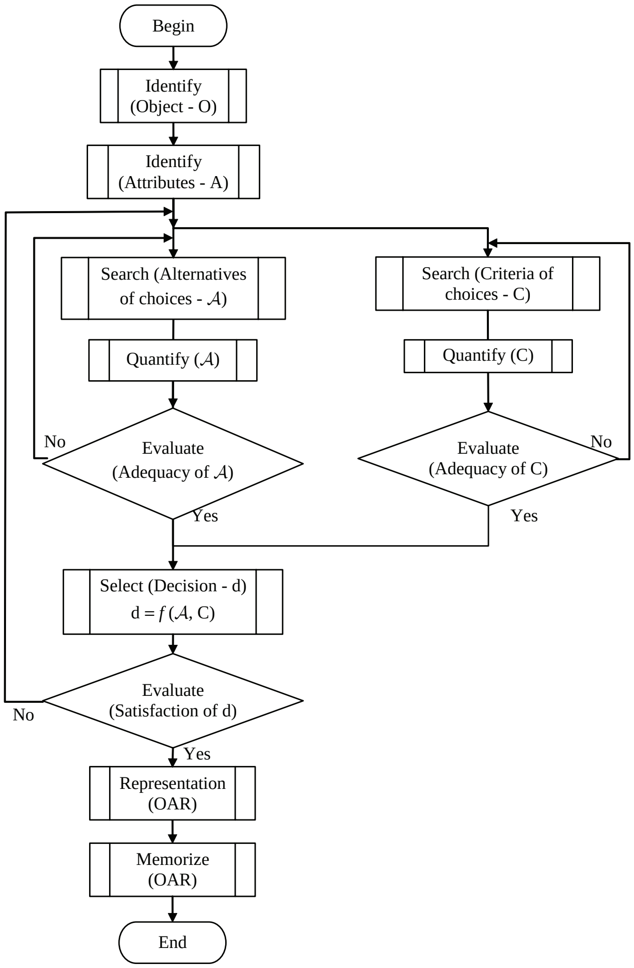


1. To comprehend the decision making problem and to identify the decision goal in terms of Object (O) and its attributes (A).
2. To search in the abstract layer of LTM (Squire, Knowlton, & Musen et al. 1993; Wang & Wang, 2004) for alternative solutions ($\mathcal{A}$) and criteria for useful decision strategies (C).
3. To quantify $\mathcal{A}$ and C and determine if the search should be go on.
4. To build a set of decisions by using $\mathcal{A}$ and C as obtained in previous searches.
5. To select the preferred decision(s) on the basis of satisfaction of decision makers.
6. To represent the decision(s) in a new sub-OAR model.
7. To memorize the sub-OAR model in LTM.

A detailed cognitive process model of decision making is shown in Figure 3 where a double-ended rectangle block represents a function call that involve a predefined process as provided in the LRMB model.

The first step in the cognitive process of decision making is to understand the given decision-making problem. According to the cognitive process of comprehension (Wang et al., 2003), the object (goal) of decision will be identified and an initial OAR model will be created. The object, its attributes, and known relations are retrieved and represented in the OAR model. Then, alternatives

Figure 3. The cognitive process of decision making



and strategies are searched, which result in two sets of $\mathcal{A}$ and C, respectively. The results of search will be quantified in order to form a decision as given in Eq. 2, for example: $d = f: \mathcal{A} \times C \rightarrow \mathcal{A}$, where $\mathcal{A} \subseteq U$ and $\mathcal{A} \neq \emptyset$.

When the decision d is derived, the previous OAR model will be updated with d and related information. Then, the decision maker may consider whether the decision is satisfied according to the current states of nature and personal judgment. If yes, the OAR model for the decision is memorized in the LTM. Otherwise, the decision-making process has to be repeated until a satisfied decision is found, or the decision maker chooses to quit without a final decision. During the decision making process, both the mind state of the decision maker and the global OAR model in the brain change from time to time. Although the state of nature will not be changed in a short period during decision making, the perception towards it may be changed with the effect of the updated OAR model.

As described in the LRMB model (Wang et al., 2004), the process of decision making is a higher-layer cognitive process defined at Layer 6. The decision making process interacts with other processes underneath this layer such as search, representation, and memorization, as well as the processes at the same layer such as comprehension, qualification, quantification, and problem solving. Relationships between the decision-making process and other related processes have been described in Figure 1 and in Wang and Wang (2004) and Wang et al. (2004).

FORMAL DESCRIPTION OF THE COGNITIVE DECISION MAKING PROCESS

On the basis of the cognitive model of decision making as described in Figure 3, a rigorous cognitive process can be specified by using RTPA (Wang, 2002; Wang, 2003b). RTPA is designed for describing the architectures, static and dynamic behaviors of software systems (Wang, 2002), as well as human cognitive behaviors and sequences of actions (Wang, 2003b; Wang et al., 2003).

The formal model of the cognitive process of decision making in RTPA is presented in Figure 4. According to LRMB and the OAR model of internal knowledge representation in the brain, the result of a decision in the mind of the decision maker is a new sub-OAR model, or an updated version of the global OAR model of knowledge in the human brain.

As shown in Figure 4, a decision-making process (DMP) is started by defining the goal of decision in terms of the object attributes. Then, an exhaustive search of the alternative decisions ($\mathcal{A}$) and useful criteria (C) are carried out in parallel. The searches are conducted in both the brain of a decision maker internally, and through external resources based on the knowledge, experiences, and goal expectation. The results of searches are quantitatively evaluated until the searching for both $\mathcal{A}$ and C are satisfied. If nonempty sets are obtained for both $\mathcal{A}$ and C, the n decisions in d have already existed as determinable by Eqs. 2 and 3.

It is noteworthy that learning results, experiences, and skills of the decision maker may dramatically reduce the exhaustive search process in DMP based on known heuristic strategies.

When one or more suitable decisions are selected from the set of d by decision makers via evaluating the satisfaction levels, satisfied decisions will be represented in a sub-OAR model, which will be added to the entire knowledge of the decision maker in LTM.

SOLVING COMPLEX PLANNING PROBLEMS BY DECISION SUPPORT SYSTEMS

The decision-making models and the formal description of the cognitive decision-making process

Figure 4. Formal description of the cognitive process of decision-making in RTPA

The Decision Making Process (DMP)

```
DMP_Process(I:: OS; O:: OAR(dS)ST) ≙
{ //  I. Form decision goal(s)
↣ Identify (O)                       // The decision making goal
↣ Identify (A)                       // Sub decision making goals
→ {  $\overset{\mathrm{T}}{\underset{\text{Satisfication of As} = \mathrm{F}}{R}}$  ( ↣ Search ($\mathcal{A}$)
                                       ↣ Quantify ($\mathcal{A}$)
                                       ↣ Evaluate ($\mathcal{A}$)
                                     )
     ||  $\overset{\mathrm{T}}{\underset{\text{Satisfication of C} = \mathrm{F}}{R}}$  ( ↣ Search (C)
                                       ↣ Quantify (C)
                                       ↣ Evaluate (C)
                                     )
  }

//  II. Select decisions
→ d = f: $\mathcal{A} \times C \rightarrow \mathcal{A}$             // Refers to Eq. 2
↣ Evaluate (d)
→ ( � s(d) ≥ k                       // k: a satisfaction threshold
        ↣ Memorize (OARST)
        → ⊗
    | � ~                            // Otherwise
        → ( � GiveUpBL = F
                ↣ DMP_Process(I:: OS; O:: OAR(d)ST)
            | � ~
                →
          )
  )

//  III. Represent decisions
   → R = <d, $\mathcal{A}$, C>              // Form new relation on d
   → OARST = <O, A, R>               // Form new OAR model for d
}
```

as presented in the second through fourth sections, can be used to address the solution of wicked planning problems in software engineering. Wicked planning problems are not only difficult to solve but also difficult to be explicitly formulated. The notion of a wicked planning problem was introduced by Rittel and Webber (1984), where several characteristics were given to classify a problem as wicked. One of them states that there is no definite formulation of the problem. Another one states that wicked problems have no stopping rule. So, in these cases, does it make sense to look into a more systematic approach at all or shouldn't we just rely on human intuition and personnel experience to figure out a decision?

A systematic approach for solving the wicked planning problem of software release planning was given in Ngo-The and Ruhe (2006). Release planning is known to be cognitively and computationally difficult (Ruhe & Ngo-The 2004).

Different kinds of uncertainties make it hard to be formulated and solved because real-world release planning problems may involve several hundred factors potentially affecting the decisions for the next release. Thus, a good release plan in decision-making is characterized as:

- It provides a maximum utility value from offering a best possible blend of features in the right sequence of releases.
- It is feasible to the existing hard constrains that have to be fulfilled.
- It satisfies some additional soft constraints sufficiently well. These soft constraints, for example, can be related to stakeholder satisfaction, consideration of the risk of implementing the suggested releases, balancing of resources or other aspects which are either hard to formalize or not known in advance.

It seems that uncertain software engineering decision problems are difficult to be explicitly modeled and completely formalized, since the constraints of organizations, people, technology, functionality, time, budget, and resources. Therefore, all spectrum of decision strategies as identified in Table 1 and Figure 1 need to be examined. This is a typical case where the idea of decision support arises when human decisions have to be made in complex, uncertain, and/or dynamic environments. Carlsson and Turban (2002) point out that the acceptance of theses systems is primarily limited by human related factors: (1) cognitive constraints, (2) understanding the support of such a model, (3) difficulty in handling large amounts of information and knowledge, and (4) frustration caused by complicated theories.

The solution approach presented in Ngo-The et al. (2006) address the inherent cognitive and computational complexity by (1) an evolutionary problem solving method combining rigorous solution methods to solve the actual formalization of the problem combined with the interactive involvement of the human experts in this process; (2) offering a portfolio of diversified and qualified solution at all iterations of the solution process; and (3) using the multi-criteria decision aid method ELECTRE (Roy, 1991) to assist the project manager in the selection of the final solution from the set of qualified solutions. Further research is ongoing to integrate these results with the framework of the decision-making models and the improved understanding of the cognitive process of decision-making as developed in this article.

CONCLUSION

Decision-making is one of the basic cognitive processes of human behaviors by which a preferred option or a course of actions is chosen from among a set of alternatives based on certain criteria. The interest in the study of decision-making has been widely shared in various disciplines because it is a fundamental process of the brain.

This article has developed an axiomatic and rigorous model for the cognitive decision-making process, which explains the nature and course in human and machine-based decision-making on the basis of recent research results in cognitive informatics. A rigorous description of the decision process in real-time process algebra (RTPA) has been presented. Various decision-making theories have been comparatively analyzed and a unified decision-making model has been obtained, which shows that existing theories and techniques on decision-making are well fit in the formally described decision process.

One of the interesting findings of this work is that the most fundamental decision that is recurrently used in any complex decision system and everyday life is a Cartesian product of a set of alternatives and a set of selection criteria. The larger both the sets, the more ideal the decisions generated. Another interesting finding of this work is that, although the cognitive complexities of new decision problems are always extremely high, they become dramatically simpler when a rational or formal solution is figured out. Therefore, the reducing of cognitive complexities of decision problems by heuristic feedbacks of known solutions in each of the categories of decision strategies will be further studied in intelligent decision support systems. According to case studies related to this work, the models and cognitive processes of decision-making provide in this article can be applied in a wide range of decision-support and expert systems.

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Chapter 4.18

Performance Evaluation of Consumer Decision Support Systems

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ABSTRACT

Consumer decision support systems (CDSSs) help online users make purchasing decisions in e-commerce Web sites. To more effectively compare the usefulness of the various functionalities and interface features of such systems, we have developed a simulation environment for decision tasks of any scale and structure. Furthermore, we have identified three criteria in an evaluation framework for assessing the quality of such CDSSs: users' cognitive effort, preference expression effort, and decision accuracy. A set of experiments carried out in such simulation environments showed that most CDSSs employed in current e-commerce Web sites are suboptimal. On the other hand, a hybrid decision strategy based on four existing ones was found to be more effective. The interface improvements based on the new strategy correspond to some of the advanced tools already developed in the research field. This result is therefore consistent with our earlier work on evaluating CDSSs with real users. That is, some advanced tools do produce more accurate decisions while requiring a comparable amount of user effort. However, the simulation environment will enable us to efficiently compare more advanced tools among themselves, and indicate further opportunities for functionality and interface improvements.

INTRODUCTION

With the rising prosperity of the World Wide Web (WWW), consumers are dealing with an increasingly large amount of product and service information that is far beyond any individual's cognitive effort to process. In early e-commerce practice, online intermediaries were created. With the help of these virtual storefronts, users were able to find product information on a single Web site that gathers product information from thousands of merchants and service suppliers. Examples include shopping.yahoo.com, froogle.com, shopping. com, cars.com, pricegrabber.com, and so forth. However, due to the increasing popularity of electronic commerce, the amount of online retailers proliferated. As a result, there are now easily millions (or 16-20 categories) of brand-name products available on a single online intermediary Web site. Finding something is once again difficult, even with the help of various commercially available search tools.[1] Recently, much attention in e-commerce research has focused on designing and developing more advanced search and product recommender tools (Burke, Hammond, & Young, 1997; Pu & Faltings, 2000; Reilly, McCarthy, McGinty, & Smyth, 2004; Shearin & Lieberman, 2001; Shimazu, 2001; Stolze, 1999). However, they have been not employed in large scales in practicing e-commerce Web sites. Pu and Kumar (2004) gave some reasons as to why this is the case and when such advanced tools are expected to be adopted. This work was based on empirical studies of how users interact with product search tools, providing a good direction as to how to establish the true benefits of these advanced tools. However, insights gained from this work are limited. This is mainly due to the lack of a *large* amount of *real* users for the needed user studies and the high cost of user studies, even if real users were found. Each of the experiments reported in Pu and Kumar (2004) and Pu and Chen (2005) took more than 3 months of work, including the design and preparation of the study, the pilot study, and the empirical study itself. After the work was finished, it remains unclear whether a small amount of users recruited in an academic institution can forecast the behavior of the actual user population, which is highly diverse and complex.

Our main objective in this research is to use a simulation environment to evaluate various search tools in terms of interaction behaviors: what users' effort would be to use these tools and what kind of benefits they are likely to receive from these tools. We base our work on some earlier work (Payne, Bettman, & Johnson, 1993) in terms of the design of the simulation environment. However, we have added important elements to adapt such environments to online e-commerce and consumer decision support scenarios. With this simulation environment, we hope to more accurately forecast the acceptance of research tools in the real world, and curtail the evaluation of each tool's performance from months of user study to hours of simulation and a week of fine tuning the simulation results against a small but diverse amount of real users. This should allow us to evaluate more tools and, more importantly, discover design opportunities of new tools.

Our initial work of measuring the performance of various decision support strategies in e-commerce environments was reported in a conference paper (Zhang & Pu, 2005). The current article is an extended version of the conference paper. Besides adding significantly more details on the work already reported, there are a number of important and new contributions:

- In the conference paper, we only reported the performance evaluation results of various decision strategies such as the lexicographical (LEX) strategy, the elimination-by-aspects (EBA) strategy, and so forth; in this paper, we consider the evaluation of a consumer decision support system as an integral unit compromising decision strategies, user interfaces, and the underlying product catalog;
- In the extended effort-accuracy framework described in the conference paper, we only used a classical definition of decision accuracy; here we propose two new definitions of decision accuracy that correspond more precisely with a user's choice behavior in

e-commerce situations rather than the classical choice problem in decision literature;

- Based on the new definitions, we were able to draw more conclusions from the simulation results: not only can we establish that hybrid decision approaches can reduce user's effort while achieving a high level of decision accuracy, but we can also see some opportunities for improving consumer decision support systems by designing better interfaces and decision approaches, courtesy of the simulation environment.

This paper is organized as follows: the second section reviews some related research work; the third section defines the consumer decision support system (CDSS) and clarifies its relationship with our earlier published concepts on multi-attribute decision problem (MADP) and various decision strategies; the fourth section describes in detail the simulation environment for the performance evaluation of CDSSs; the fifth section describes the extended effort-accuracy framework consisting of three performance criteria: cognitive effort, elicitation effort, and decision accuracy; the sixth section reports the performance evaluation of various CDSSs with respect to a set of simulated MADPs and user preferences; the seventh section discusses the main research results obtained, followed by the conclusion section.

RELATED WORK

In traditional environments where no computer aid is involved, behavioral decision theory provides adequate knowledge describing people's choice behavior, and presents typical approaches of solving decision problems. For example, Payne et al. (1993) established a well-known effort-accuracy framework that described how people adapted their decision strategies by trading off accuracy and cognitive effort to the demands of the tasks they faced. The simulation experiments carried out in that work were able to give a good analysis of various decision strategies that people employ, and the decision accuracy they would expect to get in return.

In the online electronic environment where the support of computer systems is pervasive, we are interested in analyzing users' choice behaviors when tools are integrated into their information processing environments. That is, we are interested in analyzing when given a computer tool with its system logic, how much effort a user has to expend and how much decision accuracy he or she is to obtain from that tool. On one hand, though the decision maker's cognitive effort is still required, it can be significantly decreased by having computer programs carry out most of the calculation work automatically; on the other hand, the decision makers must expend some effort to explicitly state their preferences to the computer according to the requirements of the underlying decision support approach employed in that system. We would like to call this extra user effort (in addition to the cognitive effort) preference elicitation effort. We believe that elicitation effort plays an important role in the new effort-accuracy model of users' behavior in online choice environments.

Many other researchers have carried out simulation experiments in evaluating the performance of their systems or approaches. Payne et al. (1993) introduced a simulation experiment to measure the performance of various decision strategies in off-line situations. Recently, Boutilier (Boutilier, Patrascu, Poupart, & Schuurmans, 2005) carried out their experiments by simulating a number of randomly generated synthetic problems, as well as user responses to evaluate the performance of various query strategies for eliciting bounds of the parameters of utility functions. In Reilly et al. (2005), various users' queries were generated artificially from a set of off-line data to analyze the recommendation performance of the incremental critiquing approach. These related works generally suggest that simulating the interaction between users and the system is a promising methodology for performance evaluation. In our work, we go further in this direction and propose the general simulation environment that can be adopted to evaluate the performance of various CDSSs systematically within the extended effort-accuracy framework. To the best of our knowledge, our simulation work is the first attempt in systematically evaluating the performance of various CDSSs with simulation methodology.

CONSUMER DECISION SUPPORT SYSTEM

In a scenario of buying a product (such as a digital camera), the objective of consumers is to choose the product that most closely satisfies their needs and preferences (decision result), and furthermore, they are not likely to regret the products that they have bought (how accurate their decision is). They usually face a large amount of product alternatives (or options) and need a decision support system in order to process the entire product catalog without having to examine all items exhaustively. Therefore, a consumer decision support system consists of three components: (1) the product catalog that is accessible to consumers via an interface; (2) the underlying decision support approach that helps a consumer to choose and determine the product most satisfying his or her preferences; (3) the user interface with which a consumer interacts in order to state his or her preferences. We will now introduce these three components respectively.

The product catalog or more precisely an electronic product catalog (EPC) (Palmer, 1997; Torrens, 2002) provides a list of products, each one represented by a number of attributes. The process of determining the most preferred product from the EPC can be formally described as solving a multi-attribute decision problem[2] $\Psi = \langle \mathbf{X}, \mathbf{D}, \mathbf{O}, \mathbf{P} \rangle$, where $\mathbf{x}=\{x_1, ..., x_n\}$ is a finite set of attributes the product catalog has, $\mathbf{D}=D_1 \times ... \times D_n$ indicates the space of all possible products in the catalog (each $D_i (1 \leq i \leq n)$ is a set of possible domain values for attribute X_i), $\mathbf{O}=\{O_1,...,O_m\}$ is a finite set of available products (also called alternatives or outcomes) that the EPC offers, and $\mathbf{P}=\{P_1,...,P_t\}$ denotes a set of preferences that the decision maker may have. Each preference P_i may be identified in any form as required by the decision methods. The solution of a MADP is an alternative O most satisfying the decision maker's preferences.

In traditional decision making environments, consumers usually adopt various decision strategies such as EBA or LEX to obtain decision results (Payne et al., 1993). In a computer assisted scenario, the distribution of work is quite different. It is the CDSS that will perform these decision strategies to help the consumer to make decisions. The consumer is only required to input his or her preferences as required by the specific decision strategy; and then the solution can be chosen for the consumer automatically. When a decision strategy is adopted in the consumer decision support system, we also say it is a decision support approach for that system. In this paper, we focus on the following decision strategies and study the performance of CDSSs based on these decision strategies.

1. The weighted additive (WADD) strategy. It is a normative approach based on multi-attribute utility theory (MAUT) (Keeney & Raiffa, 1993). In our simulation experiment, we use it as the baseline strategy.
2. Some basic heuristic strategies. They are the equal weight (EQW) strategy, the elimination-by-aspects strategy, the majority-of-confirming dimensions (MCD) strategy, the satisficing (SAT) strategy, the lexicographic (LEX) strategy and the frequency of good and bad features (FRQ) strategy. Their detailed definitions can be found in Payne et al. (1993) and Zhang and Pu (2005).

3. Hybrid decision strategies. Besides the basic heuristic strategies, people may also use a combination of several of them to make a decision to try to get a more precise decision result. These kinds of strategies are called hybrid decision strategies. As a concrete example of hybrid decision strategies, The C4 strategy (Zhang & Pu, 2005), which is a combination of four basic heuristic strategies: EBA, MCD, LEX, and FRQ, is also studied in this paper.

In a CDSS, the user-interface component is used to obtain the consumers' preferences. However, such preferences are largely determined by the underlying decision support approach that has been adopted in the system. For example, the popular ranked list interface is in fact an interface implementing the lexicographical strategy. Also, if we adopt the weight additive strategy in a consumer decision support system, the user interface will be designed in the manner of asking the user to input corresponding weight and middle values for each attribute. In our current work, we assume the existence of a very simple user interface. Thus, we regard the underlying decision support approach as the main factor of the consumer decision support system.

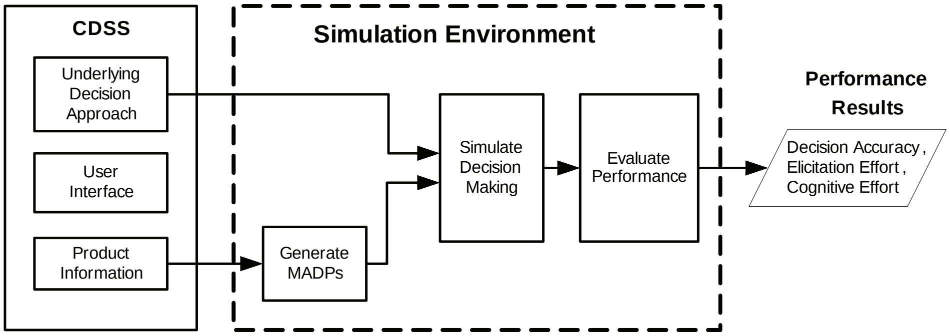
SIMULATION ENVIRONMENT FOR PERFORMANCE EVALUATION

Our simulation environment is concerned with the evaluation of how users interact with consumer decision support systems (CDSSs), how decision results are produced, and the quality of these decision results.

The consumer first interacts with the system by inputting his or her preferences through the user interface. With the help of decision support, the system generates a set of recommendations to the consumer. This interactive process can be executed multiple times until the consumer is satisfied with the recommended results (i.e., a product to purchase) or gives up due to loosing patience.

As shown in Figure 1, for a given CDSS, we evaluate its performance in a simulated environment by the following procedure: (1) we generate a set of MADPs using Monte Carlo method to simulate the presence of an electronic catalog up to any scale and structure characteristics; (2) we generate a set of consumer preferences also with the Monte Carlo method, taking into account user diversity and scale; (3) we carry out the simulation of the underlying decision approach of the CDSS to solve these MADPs; (4) we obtain associated decision results for the given CDSS (which product has been chosen given

Figure 1. An architecture of the simulation environment for performance evaluation of a given consumer decision support system



the consumer's preferences); and finally, (5) we evaluate the performance of these decision results in terms of cognitive effort, preference elicitation effort, and decision accuracy under the extended accuracy-effort framework (detailed discussion of this framework in the next section).

The simulation environment can be used in many ways to provide different performance measures of a given CDSS. For instance, if both the detail product information of CDSS and the consumer's preferences are unknown, we can simulate both the alternatives and the consumer's preferences, and the simulation results would be the performance of the CDSS independently of users and the set of alternatives; if the detail product information of the CDSS is provided, we then only need to simulate the consumer's preferences, and the alternatives of the MADPs can be copied from the CDSS instead of being randomly generated. The simulation results would be the performance of the CDSS under the specified product set.

As a concrete example to demonstrate the usage of such a simulation environment, we will show a procedure in evaluating the performance of various CDSSs in terms of the scale of the MADPs, which is determined by two factors: the number of attributes *n* and the number of alternatives *m*. Since we are trying to study the performance of different CDSSs (currently built on heuristic decision strategies) in different scales of MADPs, we assume that users and alternatives are both unknown and they are simulated to give results independently of the user and the system. More specifically, we classify the decision problems into 20 categories according to the scales of *n* (the number of attributes) and *m* (the number of alternatives): *n* has five values (5, 10, 15, 20, and 25), and *m* has four (10, 100, 1,000, and 10,000). To make the performance evaluation result more accurate, each time we randomly generate 500 different MADPs in the same scale and use their average performance as the final result. The detail simulation result will be reported in the experimental result section.

THE EXTENDED EFFORT-ACCURACY FRAMEWORK

The performance of the system can be evaluated by various criteria such as the degree of a user's satisfaction with the recommended item, the amount of time a user spends to reach a decision, and the decision errors that the consumer may have committed. Without real users' participation, the satisfaction of a consumer with a CDSS is hard to measure. However, the other two criteria can be measured.

The amount of time a user spends to reach a decision is equivalent to the amount of time he or she uses to express preferences and process the list of recommended items in order to reach a decision. The classical effort-accuracy framework mainly investigated the relationship of decision accuracy and cognitive effort of processing information by different decision strategies in the off-line situation. In the online decision support situation, however, the effort of eliciting preferences must be considered as well.

Furthermore, most products carry a fair amount of financial and emotional risks. Thus, the accuracy of users' choices is extremely important. That is, there is a posterior process where users evaluate the search tools in terms of whether the products they have found via the search tool are really what they want and whether they had enough decision support. This is what we mean by decision accuracy.

We therefore propose an extended effort-accuracy framework by explicitly measuring three factors of a given consumer decision support system: cognitive effort, elicitation effort, and decision accuracy. In the remainder of this section, we first recall the measurement of cognitive effort in the classical framework, we give various definitions of accuracy, and then we detail the method of measuring elicitation effort. Finally, the cognitive and elicitation effort of these decision strategies are analyzed in section 5.4, in an online situation.

Measuring Cognitive Effort

Based upon the work of Newell and Simon (1972), a decision approach can be seen as a sequence of elementary information processes (EIPs), such as reading the values of two alternatives on an attribute, comparing them, and so forth. Assuming that each EIP takes equal cognitive effort,[3] the decision maker's cognitive effort is then measured in terms of the total number of EIPs. Conformed with the classical framework, a set of EIPs for the decision strategies is defined as (1) READ: read an alternative's value on an attribute into short-term memory (STM), (2) COMPARE: compare two alternatives on an attribute, (3) ADD: add the values of two attributes in STM, (4) DIFFERENCE: calculate the size of the difference of two alternatives for an attribute, (5) PRODUCT: weight one value by another, (6) ELIMINATE: eliminate an alternative from consideration, (7) MOVE: move to next element of the external environment, and (8) CHOOSE: choose the preferred alternative and end the process.

Measuring Decision Accuracy

Accuracy and effort form an important performance measure for the evaluation of consumer decision support systems. On one hand, consumers expect to get highly accurate decisions. On the other hand, they may not be inclined (or able) to expend a high level of cognitive and elicitation effort to reach a decision. Three important factors influence the decision accuracy of a consumer decision support systems: the underlying decision approach used; the number of interactions required from the end user (if a longer interaction is required, a user may give up before he finds the best option); the number of options displayed to the end user in each interaction cycle (a single item is likely to miss the target choice compared to a list of items; however, a longer list of items requires more cognitive effort to process information). In our current framework, we investigate the combined result of these three factors (i.e., decision approach as well interface design components) of a given consumer decision support system.

In the following sections, we start with classical definitions of decision accuracy, analyze their features and describe their weaknesses for the online environments, and then we propose two definitions, which we have developed, that are likely to be more adequate for measuring decision accuracy in e-commerce environments. To eliminate the effect of a specific set of alternatives on the decision accuracy results, in the following definitions we assume that there is a set of N different MADPs to be solved by a given consumer decision support system that implements a particular decision strategy S. The accuracy will be measured in average among all those MADPs.

Accuracy Measured by Selection of Nondominated Alternatives

This definition comes from Grether and Wilde (1983). After adapting it to decision making with the help of a computer system, this definition says that a solution given by CDSS is correct if and only if it is non-dominated by other alternatives. So the decision accuracy can be measured by the numbers of solutions which are *Pareto optimal* (i.e., not dominated by other alternatives, see also Viappiani, Faltings, Schickel-Zuber, & Pu, 2005). We use O_S^i to represent the optimal solution given by the CDSS with strategy S when solving $MADP_i (1 \le i \le N)$. The accuracy of selection of nondominated alternatives $Acc_{NDA}(S)$ is defined as the following:

$$Acc_{NDA}(S) = \frac{N - \sum_{i=1}^{N} \text{Dominated}(O_S^i)}{N}, \quad (1)$$

where

$$\text{Dominated}(O_S^i) = \begin{cases} 1 & \text{if } O_S^i \text{ is dominated in } MADP_i \ (1 \le i \le N) \\ 0 & else \end{cases}$$

According to this definition, it is easy to see that a system employing the WADD strategy has 100% accuracy because all the solutions given by WADD are *Pareto optimal*. Also, this definition of accuracy measurement is effective only when the system contains some dominated alternatives, otherwise the accuracy of the system is always 100%.

This definition of accuracy can distinguish the errors caused by choosing dominated alternatives of the decision problems. However, measuring decision accuracy using this method is limited in e-commerce environments. In an efficient market, it is unlikely that the consumer products or business deals are dominated or dominating. That is, it is unlikely an apartment would be both spacious and less expensive compared to other available ones. We believe that although this definition is useful, it is not helpful to distinguish various CDSSs in terms of how good they are for supporting users to select the best choice (not just the nondominated ones).

Accuracy Measured by Utility Values

This definition of measuring accuracy was used in the classical effort-accuracy framework (Payne et al., 1993). Since no risk or uncertainty is involved in the MADPs, the expected value of an alternative is equivalent to the utility value of each alternative. The utility value of each alternative is assumed to be in the weight additive form. Formally, this accuracy definition can be represented as:

$$Acc_{UV}(S) = \frac{\sum_{i=1}^{N} \frac{V(O_S^i)}{V(O_{WADD}^i)}}{N}, \qquad (2)$$

where $V(O_S^i)$ is the value function given by the WADD strategy in $MADP_i$. In this definition, a system employing the WADD strategy is also 100% accurate because it always gives out the solution with the maximal utility value.

One advantage of this measure of accuracy is that it can indicate not only that an error has occurred, but also the severity of the error of the decision making. For instance, a system achieving 90% accuracy indicates that an average consumer is expected to choose an item that is 10% less valuable from the best-possible option. While this definition is useful for choosing a set of courses to take for achieving a particular career objective, it is not most suitable in e-commerce environments. Imagine that someone has chosen and purchased a digital camera. Two months later, she discovers that the camera that her colleague has bought was really the one she wanted. She did not see the desired camera, not because the online store did not have it, but because it was difficult to find and compare items on the particular e-commerce Web site. Even though the camera that she bought satisfied some of her needs, she is still likely to feel a great sense of regret, if not outright disappointment. Her likelihood of returning to that Web site is in question. Given that bad choices can cause great emotional burdens (Luce, Payne, & Bettman, 1999), we have developed the following definition of decision accuracy.

Accuracy Measured by Selection of Target Choice

In our earlier work(Pu & Chen, 2005), we defined decision accuracy as measured by the percentage of users who have chosen the right option using a particular decision support system. We call that option the target choice. In empirical studies with real users, we first asked users to choose a product with the consumer decision support system, and then we revealed the entire database to them in order to determine the target choice.

If the product recommended by the consumer decision support system was consistent with the target choice, we said that the user had made an accurate decision.

In simulation environment, we take the WADD strategy as the baseline. That is, we assume the solution given by WADD is the user's final most-preferred choice. For another given strategy *S*, if the solution O_S^i is the same as the one determined by WADD, then we count it as one *hit* (this definition is called the *hit ratio*). The accuracy is measured statistically by the ratio of hit numbers to the total number of decision problems:

$$Acc_{HR}(S) = \frac{\sum_{i=1}^{N} Hit(O_S^i)}{N}, \qquad (3)$$

where

$$Hit(O_S^i) = \begin{cases} 1 & \text{if } O_S^i = O_{WADD}^i \text{ in } MADP_i \\ 0 & \text{else} \end{cases}$$

This measure of decision accuracy is ideally consistent with the consumers' attitude towards the decision results. However, by this definition, it is assumed that the consumer decision support system only recommends one product to the consumer each time. In reality, the system may show a list of possible products to the consumer, and the order of the product list is also important to the consumer: the products displayed at the top of the list are more likely to be selected by the consumer. Therefore, we have developed the following definition to take into account that a list of products is displayed, rather than a single product.

Accuracy Measured by Selection of Target Choice Among K-best Items

Here we propose measuring the accuracy of the system according to the ranking orders of the K-best products it displays. This is an extension of the previous definition of accuracy. For a given $MADP_i$, instead of using strategy *S* to choose a single optimal solution, we can use it to generate a list of solutions with ranking order $L_S^i = \{O_{S,1}^i, O_{S,2}^i, \ldots, O_{S,K}^i\}$, where $O_{S,1}^i$ is the most-preferred solution according to the strategy S, and $O_{S,2}^i$ is the second-preferred solution, and so on. The first *K-best* solutions consist of the solution list. If the user's final choice (which is assumed to be given by the WADD strategy O_{WADD}^i) is in the list, we assign a *rank value* to the list according to the position of O_{WADD}^i in the list. Formally, we define this accuracy of choosing K-best items as:

$$Acc_{HR\_in\_Kbest}(S) = \frac{\sum_{i=1}^{N} RankValue(L_S^i)}{N}, \qquad (4)$$

where

$$RankValue(L_S^i) = \begin{cases} 1 - \frac{k-1}{K} & \text{if } O_{S,k}^i = O_{WADD}^i \text{ in } MADP_i \quad (1 \le k \le K, 1 \le n \le N) \\ 0 & else \end{cases}$$

According to this definition, the WADD strategy still achieves 100% accuracy and is used as the baseline. A special case of this accuracy definition is that when *K=1*, it degenerates to the previous definition of *hit ratio.* In the simulation experimental results that we will show shortly, we have set *K* to 5.

In practice, it is required to eliminate the effect of random decision, and we expect that the strategy of *random choice* (selecting an alternative randomly from the alternative set, denoted as *RAND* strategy) could only produce *zero* accuracy. By doing so, we define the *relative accuracy* of the consumer decision support system with strategy *S* according to different definitions as:

$$RA_Z(S) = \frac{Acc_Z(S) - Acc_Z(RAND)}{1 - Acc_Z(RAND)}, \qquad (5)$$

where

Z= NDA, UV, HR, or HR_in_Kbest.

For example, $RA_{HR}(LEX)$ denotes the relative accuracy of the *LEX* strategy under the accuracy measure definitions of *hit ratio.*

From the previous definitions, we can see that each definition represents one aspect of the accuracy of the decision strategies. We think that the definitions of *hit ratio* and *K-best items* are more suitable to measure the accuracy of various consumer decision support systems, particularly in e-commerce environments. In the sixth section, we will study the performance of various decision strategies with these accuracy measurement definitions.

Measuring Elicitation Effort

In computer-aided decision environments, a considerable amount of decision effort goes into preference elicitation since people need to "tell" their preferences explicitly to the computer system. So far, no formal method has been given to measure the preference elicitation effort. An elicitation process can be decomposed into a series of basic interactions between the user and the computer, such as selecting an option from a list, filling in a blank, answering a question, and so forth. We call these basic interaction actions elementary elicitation processes (EEPs). In our analysis, we define the set of EEPs as follows: (1) SELECT: select an item from a menu or a dropdown list, (2) FILLIN: fill in a value to an edit box, (3) ANSWER: answer a basic question, (4) CLICK: click a button to execute an action.[4]

It is obvious that different EEPs require different elicitation effort (for instance, the EEP of one CLICK would be much easier than an EEP of FILLIN a weight value for a given attribute). For the sake of simplification, we currently assume that each EEP requires an equal amount of effort from the user. Therefore, given a specific decision approach, elicitation effort is measured by the total amount of EEPs it may require.

This elicitation effort is a new factor for the online environment. The main difference between cognitive effort and elicitation effort lies in the fact that cognitive effort is a description of the mental activities in processing information, while the elicitation effort is about the interaction effort between the decision maker and the computer system through predesigned user interfaces. Even though the decision makers already have clear preferences in their mind, they must still state their preferences in a way that the computer can "understand." With the help of computer systems, the decision maker is able to reduce the cognitive effort by compensating with a certain degree of elicitation effort.

Let us consider a simple decision problem with three attributes and four alternatives. When computer support is not provided, the cognitive effort of solving this problem by the WADD strategy will be 24 READS, 8 ADDS, 12 PRODUCTS, 3 COMPARES, and 1 CHOOSE. The total number of EIPs is therefore 48.[5]

However, with the aid of a computer system, the decision maker could get the same result by spending two units of elicitation effort (FILLIN the weight value of first two attributes) and one unit of cognitive effort (CHOOSE the final result).

Analysis of Cognitive and Elicitation Effort

With the support of computer systems, the cognitive effort for WADD, as well as the basic heuristic strategies, is quite low. The decision maker inputs his or her preferences, and the decision support system executes that strategy and shows the proposed product. Then the decision maker chooses this product and the decision process is ended. Thus, the cognitive effort is equal to one EIP: CHOOSE the final alternative and exit the process. For the *C4* strategy, the cognitive effort of solving an MADP with *n* attributes and *m* alternatives is equal to that of solving a problem with *n* attributes and *4* alternatives in the traditional situation, the cognitive effort of which has been studied in (Payne et al., 1993).

According to their definitions, various decision strategies require that preferences with different parameters be elicited. For example, in the WADD strategy, the component value function and the weight for each attribute must be obtained, while for the EBA strategy, the importance order and cutoff value for each attribute are required. The required parameters for each strategy are shown in Table 1.

For each parameter in the aforementioned strategies, a certain amount of elicitation effort is required. This elicitation effort may vary with different implementations of the user interface. For example, to elicit the weight value of an attribute, the user can just FILLIN the value to an edit box, or the user can ANSWER several questions to approximate the weight value. In our analysis and the following simulation experiments, we follow the *at least* rule: the elicitation effort is determined by the least number of EEP(s). In the above example, the elicitation effort for obtaining a weight value is measured as 1 EEP.

SIMULATION RESULTS

In this section, we report our experimental results of the performance of various consumer decision support systems under the simulation environment that was introduced earlier. To simplify the experiments, we only evaluate those CDSSs built on the decision strategies listed in Table 1. Without loss of generality, we will also use the term *decision strategy* to represent the CDSS built on that decision strategy.

Table 1. Elicitation effort analysis of decision strategies

Strategy	**Parameters required to be elicited**
WADD	Weights, component value functions
EQW	Component value functions
EBA	Importance order, cutoff values
MCD	*None*
SAT	Cutoff values
LEX	Importance order
FRQ	Cutoff values for good and bad features
C4	Cutoff values, importance order

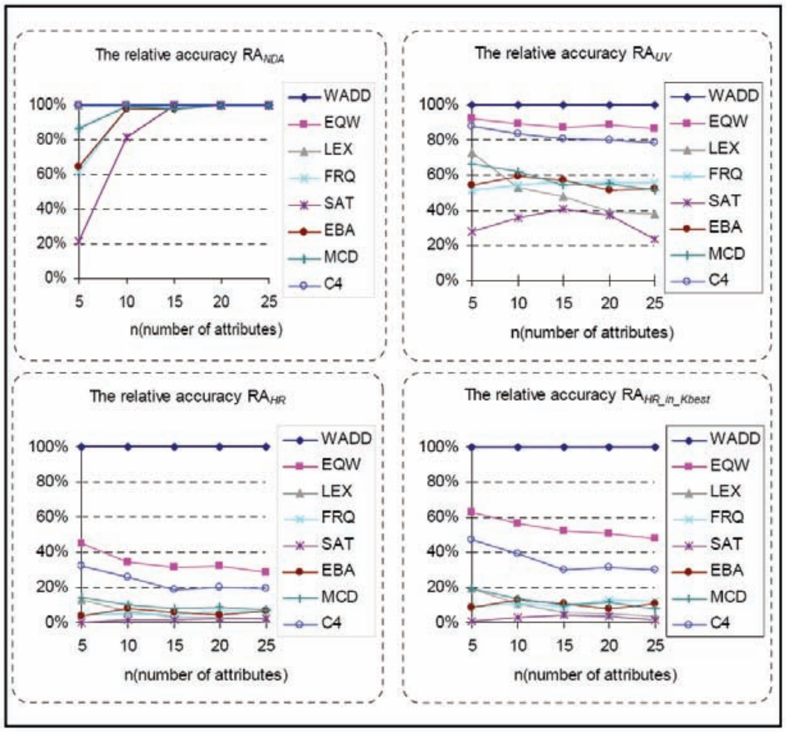
For each CDSS, we first simulate a large variety of MADPs, and then run the corresponding decision strategy on the computer to generate the decision results. Then the elicitation effort and decision accuracy are calculated according to the extended effort-accuracy framework. For each MADP, its domain values for a given attribute are determined randomly: the lower bound of each attribute is set to 0, and the upper bound is determined randomly from the range of 2 to 100. Formally speaking, for each attribute X_i, we define $D_i = [0,z_i]$ where $z_i \in [2,100]$.

As shown in Table 1, each decision strategy (except MCD) requires the elicitation of some specific parameters such as attribute weights or cutoff values to represent the user's preferences. To simulate the component value functions required by the WADD strategy, we assume that the component value function for each attribute is approximated by three midvalue points, which are randomly generated.[6] Thus, each component value function requires three units of EEPs. Other required parameters, such as the weight and cutoff value (each requires one unit of EEP) for each attribute are also simulated by the random generation process. The order of importance is determined by the weight order of the attributes for consistency.

In our simulation experiments, the WADD strategy is appointed as the baseline strategy, and the relative accuracy of a strategy is calculated according to equation (5). The elicitation effort is measured in terms of the total number of EEPs required by the specific strategy, and the cognitive effort is measured by the required units of EIPs. Since the relationship between accuracy and cognitive effort has already been studied and analyzed by Payne et al. (1993), in this section, we only focus on the performance of each strategy in terms of decision accuracy and elicitation effort.

Figure 2 shows the changes in *relative accuracy* with four different accuracy measure definitions for the listed decision strategies as *the number of attributes* increases in the case that each MADP has 1,000 alternatives. In all cases, the WADD is the baseline strategy; thus it achieves 100% accuracy. When measured by the selection of nondominated alternatives (RA_{NDA}), the relative accuracy of each heuristic strategy increases as the number of alternatives increases. This is mainly because the alternatives are more likely to be *Pareto optimal* when more attributes are involved. Furthermore, the RA_{NDA} of all strategies could achieve 100% accuracy when the attributes number is 20 or 25. This shows that the RA_{NDA} is not able to distinguish the decision errors occurred with the heuristic strategies in the simulated environment. When the accuracy is measured under the definitions of $\mathrm{RA}_{\mathrm{UV}}$, $\mathrm{RA}_{\mathrm{HR}}$ and $\mathrm{RA}_{\mathrm{HR\_in\_Kbest}}$, the EQW strategy achieves the highest accuracy besides the baseline WADD strategy, and the SAT strategy has the lowest relative accuracy. The four basic heuristic strategies EBA, MCD, LEX, and FRQ are in the middle-level range. The LEX strategy, which has been widely adopted in many consumer decision support systems, is the least accurate strategy among the EBA, FRQ, and MCD strategies when there are over 10 attributes. When the accuracy is measured by $\mathrm{RA}_{\mathrm{UV}}$, the EQW strategy could gain over 90% relative accuracy, while it could only achieve less than 50% relative accuracy when measured by $\mathrm{RA}_{\mathrm{HR}}$. This comparison generally suggests that most of the decision results given by EQW strategy may be very close to a user's target choice (which is determined by the

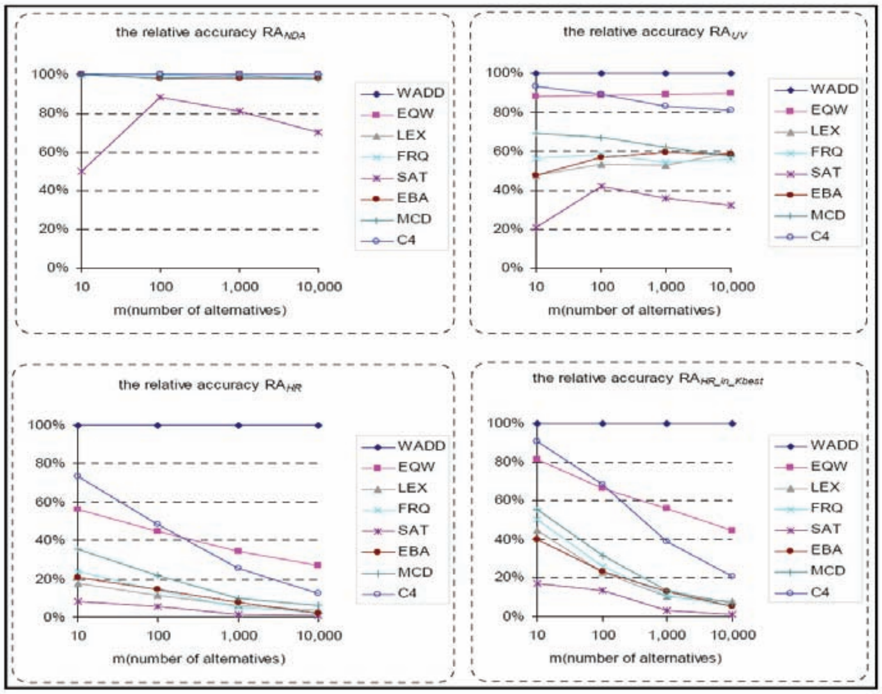
Figure 2. The relative accuracy of various decision strategies when solving MADPs with different number of attributes, where m*(number of alternatives)* = 1,000



WADD strategy), but are not identical. Also, in all cases, the accuracy measured by $RA_{HR\_in\_Kbest}$ (where *K=5* in the experiment) is always higher than that measured by $\mathrm{RA}_{\mathrm{HR}}$ (which is a special case of $RA_{HR\_in\_Kbest}$ when *K=1*). This shows that under this definition, the possibility of containing the final target choice in a K-item list is higher when K is larger. Of particular interest is that the proposed *C4* strategy, which is a combination of the four basic strategies, could achieve a much higher accuracy than any of them alone. For instance, when there are 10 attributes and 1,000 alternatives in the MADPs, the relative accuracy of *C4* strategy could exceed the average accuracy of the four basic strategies by over 27% when the definition of $RA_{HR\_in\_Kbest}$ is adopted.

Figure 3 shows the relationship between *relative accuracy* and *the number of alternatives* (or the number of available products in a catalog) for the listed decision strategies. When the accuracy is measured by the selection of nondominated alternatives (RA_{NDA}), all strategies except SAT could gain nearly 100% of relative accuracy without a significant difference. This generally shows that the RA_{NDA} is not a good definition of accuracy measurement in the simulated environment. When the accuracy is measured by the utility values (RA_{UV}), the accuracy of the heuristic strategies remains stable as the number of alternatives increases. With the definitions of *hit ratio* (RA_{HR}) and *hit ratio in K-best items* ($\mathrm{RA}_{HR\_in\_Kbest}$), however, the heuristic strategies strongly descend into a lower range of accuracies as the size of a catalog increases. This corresponds to the fact that consumers have increasing difficulties finding the best product as the number of alternatives in the catalog increases. The *C4* strategy, though its accuracy decreases when the number of alternatives increases, could still maintain a considerably higher relative accuracy than that of the EBA, MCD, LEX, and FRQ strategies when using the accuracy definition of RA_{HR} and $RA_{HR\_in\_Kbest}$.

Figure 3. The relative accuracy of various decision strategies when solving MADPs with a different number of alternatives, where n*(number of attributes)* = 10



The effect of the number of attributes on elicitation effort for each strategy is shown in Figure 4. As we can see, the elicitation effort of the heuristic strategies increases much slower than that of the WADD strategy as the number of attributes increases. For instance, when the number of attributes is *20*, the elicitation effort of the FRQ strategy is only about *25%* of that of WADD strategy. The FRQ and SAT strategies require the same level of elicitation effort, since both of them require the decision maker to input a cutoff value for each attribute. Except the MCD strategy, which requires no elicitation effort in the simulation environment, the LEX strategy is the one that requires the least elicitation effort in all cases among the listed strategies. The combined C4 strategy, which could share preferences among its four underlying basic strategies, requires only a slightly higher elicitation effort than the EBA strategy.

Figure 5 shows the relationship between *elicitation effort* and *the number of alternatives* for each strategy. As the number of alternatives increases exponentially, the level of elicitation effort for WADD, EQW, MCD, SAT, and FRQ strategies remains unchanged. This shows that the elicitation effort of these strategies is unrelated to the number of alternatives that a decision problem may have. For the LEX, EBA, and *C4* strategies, the elicitation effort increases slowly as the number of alternatives increases. As a whole, Figure 5 shows that the elicitation effort of the studied decision strategies is quite robust to the number of alternatives that a decision problem has.

A combined study from Figure 2 to Figure 5 can lead to some interesting conclusions. For each category of MADPs, some decision strategies, such as WADD and EQW, could gain relatively high-decision accuracy with proportionally high-elicitation effort. Other decision strategies, especially *C4*, MCD, EBA, FRQ, and LEX, could achieve a reasonable level of accuracy with much lower elicitation effort compared to the baseline WADD strategy. Figure 6 illustrates the relationship between elicitation effort and $RA_{HR\_in\_Kbest}$ for various strategies when solving different scales of decision problems. For the MADPs with 5 attributes and 100 alternatives, the MCD strategy could achieve around *35%* relative accuracy without any elicitation effort. The *C4* strategy, in particular, could achieve over *70%* relative ac-

Figure 4. The elicitation effort of various decision strategies when solving MADPs with a different number of attributes, where m*(number of alternatives)* = 1,000

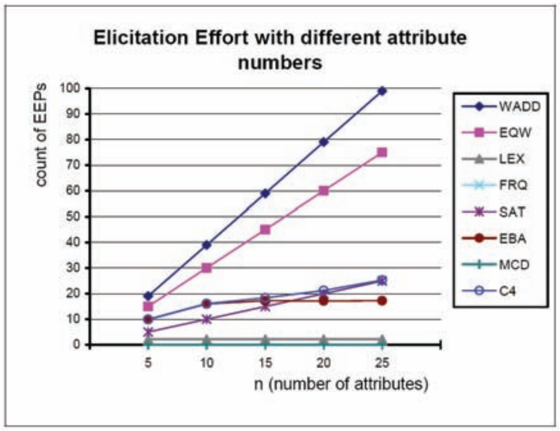
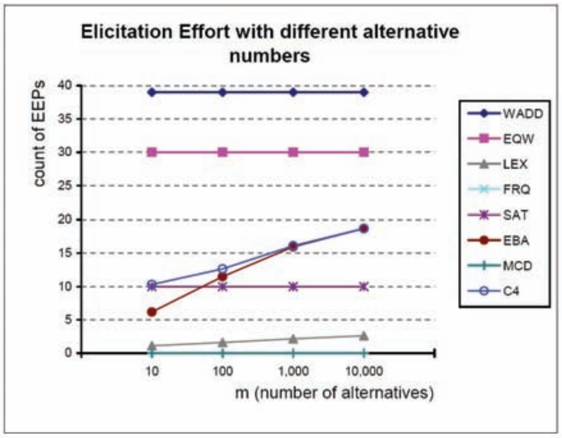


Figure 5. The elicitation effort of various decision strategies when solving MADPs with a different number of alternatives, where n*(number of attributes)* = 10



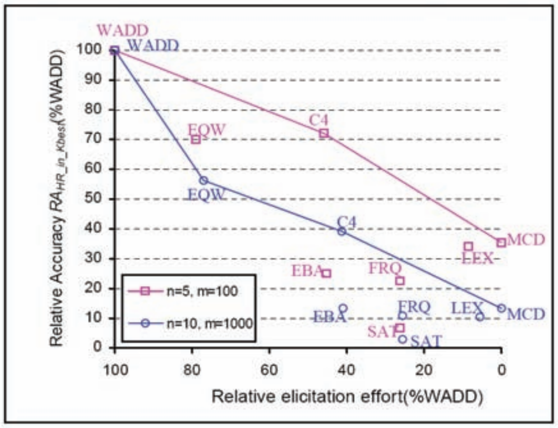
curacy while only requiring about 45% elicitation effort compared to the WADD strategy.

For all the decision strategies we have studied here, we say that a decision strategy *S* is *dominated* if and only if there is another strategy *S'* that has higher relative accuracy and lower cognitive and elicitation effort than *S* in the decision problem. Figure 6 shows that when the MADPs have 10 attributes and 1,000 alternatives, the WADD, EQW, *C4*, and MCD are nondominated approaches. However, for a smaller scale of MADPs (5 attributes and 100 alternatives), only the WADD, *C4*, and MCD strategies have the possibility of being the optimal strategy. This figure also shows that if the user's goal is to make decisions as accurately as possible, WADD is the best strategy among the listed strategies; while if the decision maker's goal is to have reasonable accuracy with a certain elicitation effort, then the *C4* strategy may be the best option.

DISCUSSION

The simulation results suggest that the tradeoff between decision accuracy and elicitation effort is the most important design consideration for inventing high-performance CDSSs. That is, while advanced tools are desirable, we must not ignore the effort that users are required to make when stating their preferences.

Figure 6. Elicitation effort/relative accuracy trade-offs of various decision strategies



To show how this framework can provide insights to improve user interfaces for the existing CDSSs, we have demonstrated the evaluation of the simplest decision strategies: WADD, EQW, LEX, EBA, FRQ, MCD, and SAT (Payne et al., 1993). The performance of these strategies was measured quantitatively in the proposed simulation environment within the extended effort-accuracy framework. Since the underlying decision strategy determines how a user interacts with a CDSS system (preference elicitation and result processing), the performance data allowed us to discover better decision strategies and eliminate suboptimal ones. In this sense, our work provides a new design method for developing user interfaces for consumer decision support systems.

For example, LEX is the underlying decision strategy used in the ranked list interface that many e-commerce Web sites employ (Pu & Kumar, 2004). However, our simulation results show that LEX produces relatively low-decision accuracy, especially as products become more complex. On the other hand, a hybrid decision strategy, *C4*, based on any combinations of LEX, EBA, MCD, and FRQ was found to be more effective. Combining LEX and EBA together, for example, we can derive an interface that looks like SmartClient. EBA (elimination by aspect) corresponds to eliciting constraints from users, and this feature was implemented as a constraint problem-solving engine in SmartClient (Torrens, Faltings, & Pu, 2002). After users have eliminated the product space by preference constraints, they can use the LEX strategy (ranked list) to further examine the remaining items. Even though this hybrid strategy does not include any interface features to perform trade-off navigation, the simulation results are still consistent with our earlier empirical work on evaluating CDSSs with real users (Pu & Chen, 2005; Pu & Kumar, 2004). That is, advanced tools such as SmartClient can achieve a higher accuracy while requiring users to expend slightly extra cognitive and elicitation effort than the basic strategies it contains.

The strongest implication of the simulation results is that we will be able to efficiently evaluate more-advanced tools and compare them in terms of effort and accuracy. Our plan for the future therefore includes evaluating SmartClient (Pu & Faltings, 2000) and its trade-off feature, FindMe (Burke et al., 1997), Dynamic Critiquing (Reilly et al., 2004), and Scoring Trees (Stolze, 2000), and comparing their strengths and weaknesses. We will also perform more simulations using different scales of K with the accuracy definition of $RA_{HR\_in\_Kbest}$. Because K is the size of the result set displayed in each user interaction cycle, we hope to gain more understanding on the display strategy used for CDSSs.

Finally, we do emphasize that the simulation results need to be interpreted with some caution. First of all, the elicitation effort is measured by approximation. As mentioned earlier, we assumed that each EEP requires an equal amount of effort from the users. Currently, it is unknown whether this approximation would affect the simulation results largely. In addition, when measuring the decision accuracy, the WADD strategy is chosen as the baseline, assuming that it contains no error. However, this is not the case in reality. Moreover, as the MADPs in the simulation experiments are generated randomly, there is a potential gap between the simulated MADPs and the product catalog in real applications. We are currently addressing these limitations, and fine-tune some of the assumptions with real user behaviors.

CONCLUSION

The acceptance of an e-commerce site by consumers strongly depends on the quality of the tools it provides to help consumers reach a decision that makes them confident enough to purchase. Evaluation of these consumer decision support tools on real users has made it difficult to compare their characteristics in a controlled environment, thus slowing down the optimization process of the interface design of such tools. In this paper, we described a simulation environment to evaluate the performance of CDSSs more efficiently. In this environment, we can simulate the underlying decision support approach of the system based on the consumers' preferences and the product catalog information that the system may have. The decision results can then be evaluated quantitatively in terms of decision accuracy, elicitation effort, and cognitive effort described by the extended effort-accuracy framework. More importantly, we were able to discover new decision strategies that led to interface improvements of existing CDSSs. Even though this is the first step, we hope to be able to evaluate and design new user interfaces for high performance CDSSs, and forecast users' acceptance of a new interface based on benefits such as effort and accuracy.

ACKNOWLEDGMENTS

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ENDNOTES

[1] Search tools and consumer decision support systems are two terms used interchangeably throughout this article although the latter is considered to be more advanced in terms of its implementation and interface features.

[2] It is also known as multicriteria decision making (MCDM) problem (Keeney & Raiffa, 1993). Our definition emphasizes on the term *attribute*, which is an objective aspect of products, not related to the decision maker's preferences.

[3] Though this assumption is obviously imprecise, more studies by assigning different weighting of effort for the various EIPs show that the key relationships between the decision strategy and the decision environments were largely unchanged. See page 137 of Payne et al. (1993).

[4] We assume that the actions are in their basic forms only. For example, the FILLIN operation is not allowed to elicit more than one value or even an expression. Otherwise a usability issue will arise.

[5] The detail analysis is given at pages 80–81 of Payne et al. (1993). This example assumes the values of all attributes are numeric and consistent with the decision maker's preferences.

[6] The procedure of assessing component value functions with midvalue points is introduced in page 120 of Keeney and Raiffa (1993).

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Chapter 4.19

Nonparametric Decision Support Systems in Medical Diagnosis:

Modeling Pulmonary Embolism

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ABSTRACT

Patients face a multitude of diseases, trauma, and related medical problems that are difficult to diagnose and have large treatment and diagnostic direct costs, including pulmonary embolism (PE), which has mortality rates as high as 10%. Advanced decision-making tools, such as nonparametric neural networks (NN), may improve diagnostic capabilities for these problematic medical conditions. The research develops a backpropagation trained neural network diagnostic model to predict the occurrence of PE. Laboratory database values for 292 patients who were determined to be at risk for PE, with almost 15% suffering a confirmed PE, were collected and used to evaluate various NN models' performances. Results indicate that using NN diagnostic models enables the leveraging of knowledge gained from standard clinical laboratory tests, specifically the d-dimer assay and reactive glucose, significantly improving overall positive predictive value, compared to using either test in isolation, and also increasing negative predictive performance.

INTRODUCTION

Medical and surgical patients today face a variety of conditions that are both difficult and costly to diagnose and to treat. With ever skyrocketing medical costs (Benko, 2004), the use of information technology is seen as a much-needed means to help control and potentially to reduce medical direct costs (Intille, 2004). Deep vein thrombosis (DVT) and pulmonary embolism (PE) are medical conditions that are particularly difficult to diagnose in the acute setting (Mountain, 2003). Frequent usage of costly clinical laboratory tests to screen patients for further treatment is commonplace. All too commonly, hospitals provide treatment to patients without PE as a preventative measure (Mountain, 2003). Furthermore, patient mortality, morbidity, and both direct and indirect costs for delayed diagnosis of these conditions also may be substantial. Recent studies show that 40% to 80% of patients that die from PE are undiagnosed as having a potential PE (Mesquita et al., 1999; Morpurgo, Schmid, & Mandelli, 1998).

DVT may occur as the result of patient genetic and environmental factors or as a side effect of lower extremity immobility (e.g., following surgery). When a blood clot in the veins of a lower extremity breaks away, it may travel to the lungs and lodge in the pulmonary arterial circulation causing PE. If the clot is large enough, it may wedge itself into the large pulmonary arteries, leading to an acute medical emergency with a significant mortality rate. Approximately 2 million people annually experience DVT, with approximately 600,000 developing PE and approximately 10% of those PE episodes resulting in mortality (Labarere et al., 2004, Mesquita et al., 1999). Documented occurrence of DVT in postoperative surgical populations ranges from 10% (Hardwick & Colwell, 2004) to 28% (Blattler, Martinez, & Blattler, 2004).

Direct costs associated with DVT and PE come from the expensive diagnostic and even more expensive treatment protocols. It may be possible to lower these direct costs, especially when additional testing or treatment may be ruled out due to available knowledge. Nonparametric neural network (NN) systems enable the economic examination (Walczak, 2001) and nonlinear combination of various readily available clinical laboratory tests. Laboratory tests typically performed on surgical patients (e.g., blood chemistry) form the foundation for analysis and diagnostic model development.

One such test is the D-dimer assay that measures patient plasma for the concentration of one molecular product released from blood clots. When blood vessels are injured or when the movement of blood is too slow through veins of lower extremities, blood may begin to clot by initiating a series of steps in which fibrin molecules are cross-linked by thrombin to form a structure that entraps platelets and other coagulation molecules — a blood clot. As healing begins to occur, plasmin begins to break down the clot and releases, among other things, D-dimer molecules. D-dimers are actually small fragments of cross-linked fibrin and provide the basis for assessing blood-clotting activity. Patients with DVT and PE frequently have elevated levels of D-dimer in their plasma. Consequently, many hospitals now employ the D-dimer assay as a first test in the diagnostic pathway for these conditions. Usage of the results of a D-dimer assay effectively reduces the direct costs of DVT by reducing the requirement for downstream testing and treatment, specifically Doppler ultrasound tests (Wells et al., 2003). The use of nonparametric models enables the analysis of laboratory tests without regard to the population distribution, which may be a problematic factor when combining more than one laboratory test for the diagnostic prediction. Additionally, NNs provide nonlinear modeling capabilities that may be beneficial in combining pathology tests.

The research reported in this article will examine the efficacy of using NN models to predict the likelihood of a PE in surgical patient populations. A corollary research question is whether less invasive and less costly diagnostic methods are both available and reliable in predicting PE. The benefit of the reported research is twofold. First, the reported research examines new combinations of laboratory tests in order to determine if a combined model may be more reliable than currently used single variable medical models. Second, the research evaluates the viability of utilizing an NN model to predict PE (and potentially DVT). The NN provides improved positive predictive performance of the combined laboratory test model over the more traditional stepwise logistic regression models that currently are employed in medical modeling (León, 1994; Tran, VanOnselen, Wensink, & Cuesta, 1994; Walczak & Scharf, 2000). The cost effectiveness of utilizing the described neural network pathology tool is determined by examining the direct costs to patients, where direct costs represent the costs of diagnostic workups and the costs of any goods, services, and other resources utilized in any subsequent intervention (Patwardhan et al., 2005; Wildner, 2003). Implementing the described NN-based PE predictive model is capable of reducing patient evaluation direct costs by well over $1,200 per patient suspected of having a potentially life-threatening PE as well as reducing medical risks associated with some of the more advanced diagnostic methods.

The organization of the remainder of this article follows. The next section gives background on some of the issues associated with diagnosing and treating PE and DVT as well as examining the utilization of NN systems in medicine and issues surrounding the design of NN systems. The methodology section describes the patient population and development of the neural network models for predicting PE occurrence. The next section performs an analysis of the NN system's performance and consequent savings in direct costs. The last section concludes with a summary of the research findings and directions for future research.

BACKGROUND AND LITERATURE REVIEW

Diagnostic Difficulties of PE

Various tests exist for attempting to detect the presence of DVT or PE and commonly are administered to patients viewed as being at risk, based on medical history as well as patient signs and symptoms. For example, leg pain or swelling may indicate a patient with DVT; however, such symptoms are far from specific. Venography (x-ray with injected intravenous radioactive contrast dye) of the legs, Doppler ultrasound scans, plethysmography (measuring differential blood pressure between arms and legs), and the D-dimer assay blood test are some of the tests that may be employed in the evaluation of DVT (see http://www.nlm.nih.gov/medlineplus/ ency/article/000156.htm). Venography is the gold standard for diagnosing DVT, which commonly is treated with anticoagulant therapy such as intravenous heparin, requiring hospitalization, or injected low molecular weight heparin combined with oral warfarin medication, which may be continued for six months.

Patients with a sudden onset of chest pain or tachycardia or rapid shallow breathing may have PE, but these are also general signs of a wide variety of medical conditions (Mesquita et al., 1999; Mobley et al., 2005). PEs often are evaluated first using ventilation perfusion scanning (cost is $300 to $500 and involves the injection of radioactive tagged material) and chest x-rays that may be followed by pulmonary angiography (see http://www.nlm.nih.gov/medlineplus/ency/article/000132.htm). If the diagnosis of PE is made, the patient requires emergency treatment, typically thrombolytic therapy in order to dissolve the clot, and hospitalization.

While the pulmonary angiogram is considered the gold standard for determining PE presence (Evander et al., 2003; Mountain, 2003), it has a direct cost between $800 and $1,200 and involves injecting radio contrast die through a catheter that has been threaded into major coronary blood vessels with associated morbidity and mortality risks. If use of the D-dimer assay can determine better the likelihood or absence of PE, then a significant reduction in risks to the patient and costs ensues. The D-dimer assay has a direct cost of less than $7. Another factor that encourages the use of the D-dimer and other blood tests is the timeliness of the test, which averages approximately 30 minutes total time, including acquisition of the sample, transportation, analysis, and delivery of results. Improved detection of PE and early management will decrease the mortality and morbidity associated with PE (Stein, Kayali, et al., 2004).

Currently, the D-dimer assay has strong negative predictive reliability that excludes DVT or PE patients who are exceedingly unlikely to benefit from further invasive testing (e.g., angiography) or very few false negatives. Unfortunately, the test does not appear to have reliable positive predictability (Stein, Hull, et al., 2004), leaving the diagnostic role of the D-dimer uncertain. A potential cause of the lack of positive predictability is that, due to the potential life-threatening outcome of PE, the screening threshold for the D-dimer result is set very low (e.g., 400 or 450) in order to avoid false negative tests. As a result, many patients who do not have PE must undergo a pulmonary angiogram or other expensive testing procedures to determine if PE exists. Additionally, no standard for the D-dimer result threshold has been established, allowing for a wide range of cutoff values between hospitals (Stein, Hull, et al., 2004) and subsequent variation, though usually high, of patient population percentages undergoing unnecessary treatment.

Neural Networks in Medicine

The issues related to the use of D-dimer assay results — lack of standardized cutoff value, lack of positive predictive capability, and other influencing factors—pose a modeling problem. NNs provide strong modeling capabilities when population dynamics of the independent variables are unknown or nonlinear (Smith, 1993; Walczak & Cerpa, 2002), as would happen when using multiple laboratory test results to perform a diagnosis.

Before examining the factors that affect NN development (in the next section), a brief review of NN applications in medical domains is provided in this section. Neural networks or artificial neural networks applied to solve or provide decision support for a variety of medical domain problems started nearly two decades ago (Leese, 1986).

Many physicians are reluctant to utilize artificial intelligence technologies, including NN, especially neural networks that attempt to perform diagnosis or treatment in other than a decision support role (Baxt, 1995; Baxt & Skora, 1996; Hassoun, Wang, & Spitzer, 1994; Hu, Chau, Sheng, & Tam, 1999; Kleinmuntz, 1992; Walczak, 2003). The reluctance of physicians to adopt neural networks has led to the usage of neural networks as primarily image processing and laboratory test analysis tools. Table 1 provides a brief overview of historic and more recent neural network applications in medicine. A full review of all neural network applications in medicine is beyond the scope of this article,[1] and as such, Table 1 only provides a representative sample of research over the past decade.

Although representative and not comprehensive, Table 1 indicates that NN applications in medical domains tend to be used either in imaging or in laboratory settings (Walczak & Scharf, 2000), with diagnostic neural networks occurring rarely. Of interest from Table 1 for the research presented in this article are the three PE-related NN applications. Each of these NN research applications (Evander et al., 2003; Fisher, Scott, & Palmer, 1996; Serpen, Iyer, Elsamaloty, & Parsai, 2003) examines the improvement in identification or validation of PE from chest x-ray images or pulmonary angiogram data. Thus, each of these

Table 1. Types of neural network applications in medicine

Classification	NN applications research
Imaging (detect indicators in images)	Breast disease (Khuwaja & Abu-Rezq 2004, Papadopoulos et al. 2005), Coronary artery disease (Baxt 1991, Baxt & Skora 1996, Dorffner & Porenta 1994, Lapuerta et al. 1995, Scott et al. 2004), Electromyography (Hassoun 1994), Lung disease (Lin et al. 2005, Suzuki et al. 2004), Pulmonary embolism (Evander et al. 2003, Fisher et al. 1996, Serpen et al. 2003), Tomography (Bruyndonckx et al. 2004, Tourassi & Floyd 1995)
Laboratory (produce test results)	Breast disease (Mattfeldt et al. 2004), EEG (Güler et al. 2005b, Nowack et al., 2002, Walczak & Nowack 2001), General blood test pathology (Liparini et al. 2005) Head injury (Erol et al. 2005), Heart disease (Andrisevic et al. 2005, Haraldsson et al. 2004, Mobley et al. 2005), Hematology (Zini 2005), Lung disease (Güler et al. 2005a, Folland et al. 2004),
Resource Planning	Blood transfusions (Covin et al. 2003, Pereira 2004, Ruggeri et al. 2000, Walczak 2005, Walczak & Scharf 2000), Pharmacology (Gaweda et al. 2005, Polak et al. 2004)
Diagnostic	Breast cancer (Übeyli 2005)
Other	Medical cost estimation (Crawford et al. 2005, Goss & Vozikis 2002, Polak et al. 2004), Medical data mining (Petrovsky & Brusic 2004) Patient Outcomes Assessment (Buchman et al. 1994, Frye et al. 1996, Izenberg et al. 1997, Orunesu et al. 2004, Walczak et al. 2003, Yeong et al. 2005)

existing methods still requires the usage of and incurrence of the direct costs associated with these more costly diagnostic methods.

While NNs previously performed image analysis in order to confirm a diagnosis of PE, the use of NNs to predict a PE from standard low direct-cost blood tests is a novel application of this nonparametric modeling paradigm. The next section examines factors impacting the development of NN models, with an emphasis on the medical domain application of predicting PE.

Neural Network Design Issues

Patient treatment information necessarily must be of high quality (Silverman, 1998), since the consequences of prediction error can lead to increased morbidity and even mortality. NNs have been shown to outperform various statistical modeling methods in medical domains with respect to the accuracy of results (Baxt & Skora, 1996; Buchman, Kubos, Seidler, & Siegforth, 1994; Dybowski & Gant, 1995; Lapuerta, Azen, & LaBree, 1995; León, 1994; Stair & Howell, 1995; Walczak, 2005; Walczak & Scharf, 2000; White, 1992). NN design can be problematic and should account for the following influencing design factors (Walczak & Cerpa, 1999, 2002): training algorithm selection, input variable selection, and hidden layer architecture.

Various NN training algorithms exist; however, Alpsan, Towsey, Ozdamar, Ah, & Ghista (1995) have claimed that the backpropagation training algorithm produces classification and prediction models that generalize (on out of sample data) as well as or better than most other NN training algorithms, at least for their specific medical domain problem. Backpropagation-trained NN, in particular have been proven to be robust models of arbitrary complex equations (Hornik, 1991; Hornik, Stinchcombe, & White, 1989; White, 1990). Backpropagation-trained NNs are used commonly to provide solutions to business and engineering problems and also are the most common NN type for medical domain applications, which facilitates cross-research comparison of methodologies (Alpsan et al., 1995; Baxt, 1995; Cherkassky & Lari-Najafi, 1992; Dorffner & Porenta, 1994; Dybowski & Gant, 1995; Montague & Morris, 1994; Rodvold, McLeod, Brandt, Snow, & Murphy, 2001).

A reason for selecting another training algorithm besides backpropagation, such as the radial basis function, is to overcome problems with very noisy input data in the training sets (Barnard & Wessels, 1992; Carpenter, Grossberg, & Reynolds, 1995). Since the proposed NN prediction model utilizes the results of laboratory tests, many that already are controlled by computers and robotics, the resultant error rate in the input data is minimal and should not require a training algorithm that may not generalize well in order to alleviate error-prone data problems. Generally considered the best and most robust training method for NN classification and prediction models, backpropagation works well when low noise input data exist (Walczak & Cerpa, 2002). The backpropagation algorithm has been discussed widely in literature, and readers should see Fu (1994), Hertz, Krogh, and Palmer (1991), Jain, Mao, and Mohiuddin (1996), and Rodvold et al. (2001) for further details on the function of the backpropagation NN training methodology.

A critical step in the design of any NN model and especially in medical applications is the selection of high-quality predictive input (independent) variables that are not highly correlated with each other (Pakath & Zaveri, 1995; Smith, 1993; Tahai, Walczak, & Rigsby, 1998; Walczak & Cerpa, 1999). Domain expert physicians identify all available data that are related to the PE diagnosis problem.

The final influencing factor from the previous in developing NN models is the determination of the hidden node architecture (Smith, 1993; Walczak & Cerpa, 1999). The quantity of hidden nodes has a direct effect on generalization performance (Hung, Hu, Shanker, & Patuwo, 1996) with both too few and too many hidden nodes decreasing performance. The number of hidden layers also affects the smoothness and closeness of fit of the solution surface (Barnard & Wessels, 1992). A common heuristic method to determine the optimal number of hidden nodes is to start with a small quantity of hidden nodes (commonly one-fourth to one-half of the quantity of input nodes) and increment the hidden node quantity by one, until generalization performance begins to deteriorate. This method will safeguard against underfitting and overfitting the model (Walczak & Cerpa, 1999).

The research reported next will evaluate the efficacy of utilizing an NN methodology for developing a diagnostic model of PE that utilizes tests with a lower direct cost.

METHODOLOGY: A NEURAL NETWORK DIAGNOSTIC MODEL FOR PE BASED ON THE D-DIMER

As stated previously, the evaluation mechanisms for determining if a patient has a PE and requires treatment currently have high direct costs (e.g., ventilation perfusion scan that costs from $300 to $500, and pulmonary angiogram that costs from $800 to $1,200). In addition to other demographic and medical risk factors, the purpose of this research is to determine if less costly evaluation mechanisms for PE are available, especially using the D-dimer assay results, which have a direct cost of less than $7 and is used commonly to negatively screen out patients for PE (Stein, Hull, et al., 2004).

Research Population Description

The patient population in this research was 292 surgical patients admitted to a large Midwest teaching hospital during a nine-and-a-half-month period. All patients during the period of the study diagnosed by physicians as being at risk either for

DVT or for PE were included in the study with no exclusions. Database records maintained by the hospital clinical laboratory as well as clinical information provided from radiology and chart records provide the data used in the NN input vector (independent variables). Patient records used in this study only come from patients clinically identified as being at risk for a DVT or possible PE by attending physicians based on signs (e.g., swelling in legs or irregular breathing) and symptoms (e.g., report of pain in legs for DVT or chest for PE). Just over 15% of this patient population, 44 out of 292, suffered a confirmed PE, which is consistent with other findings on the rate of DVT occurrence in surgical populations and consequent occurrence of PE (Hardwick & Colwell, 2004; Blattler et al., 2004). A pulmonary angiogram confirmed or negated the presence of PE.

The at-risk population of surgical patients for DVT and a possible PE has some basic statistical measures that are displayed in Table 2. From Table 2, it can be seen that the D-dimer results alone are not significantly different between patients with PE and patients without PE, although the PE patients have a much larger average D-dimer result and also a wider distribution. High D-dimer values may result from a variety of causes in addition to DVT or PE, which further confuses the application of the D-dimer for diagnosing PE.

NN Design of a PE Diagnosis Model

The focus of this study is on the use of the D-dimer assay results in possible combination with other values to improve the overall positive predictive performance to reduce false positives, which leads to unnecessary PE evaluation direct costs. As discussed in the "Neural Network Design Issues" section, the small error associated with laboratory tests and the reported robustness of the backpropagation training algorithm implied selection of backpropagation as the training algorithm for implementing the NN-based PE diagnosis model. Radial basis function (RBF) neural networks and stepwise logistic regression (LR) models also were implemented simultaneously in order to produce multiple models for comparison and to evaluate if a backpropagation-trained neural network would produce the optimal model. Using the model selection perspective (Swanson & White, 1995), comparison of each of the independent model types yielded the backpropagation NN model as the optimal model. The backpropagation models, with regard to overall accuracy (the sum of true positives and true negatives divided by all cases) outperformed both of the other model types ($p <$ .01 against the RBF-trained NN and $p < 0.10$ for the LR models).

Domain expert physicians identified blood test results with minimal direct costs that would be available for suspected DVT and PE patients prior to the performance of an angiogram. Since the research question of trying to determine if one or more of these test results could improve the PE diagnosis accuracy, a correlation matrix of all blood chemistry and other blood test results is performed to determine those variables that appear to be correlated with a positive diagnosis of PE. The variables include D-dimer, reactive glucose (Glu-R), blood urea nitrogen, serum creatinine,

Table 2. Typical d-dimer surgical population values

	D-dimer minimum	**D-dimer maximum**	**D-dimer μ (average)**	**D-Dimer σ (std dev)**	**Age μ** **Age σ**	**Gender**
Patients w/ confirmed PE	145	35450	4218.7	5862.75	48.45 22.38	47.5 % male
Patients w/o PE	124	22375	1782.63	1264.16	53 16.64	38.34 % male

serum sodium, serum potassium, serum chloride, serum carbon dioxide level, serum calcium, white blood cell count, red blood cell count, hemoglobin, hematocrit, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, red cell distribution width, and platelet count. Other values, including mean platelet volume, absolute neutrophil count (and percent), absolute lymphocyte count (and percent), absolute monocyte count (and percent), absolute eosinophil count (and percent), and absolute basophile count (and percent), were considered for use but eliminated due to missing data for many of the patients (i.e., the tests had not been ordered by their attending physician). The predictive correlation of different blood test results measured by a Pearson's correlation matrix indicated that the D-dimer had the highest correlation with a validated PE for those test results included in the matrix and that randomized glucose (Glu-R) and CO_2 also both had significant ($p < 0.05$) predictive correlations with the PE-dependent variable. The age and sex of the patient also are included as independent variables to determine if these may be predictive when combined with blood test results.[2] Different backpropagation-trained NN models use various combinations of these five variables: age, sex, D-dimer, Glu-R, and CO_2 as the input vector of independent variables, producing 23 different sets of input variables and corresponding diagnosis models.

NN models for each of the 23 different input vectors start with a single hidden processing node. Both one- and two-hidden-layer architectures are evaluated, since the complexity of the diagnosis solution surface is unknown (Fu, 1994). When a second hidden layer is implemented, it also is started with a single hidden processing node. The quantity of processing nodes in each layer is incremented independently of the other layer and by a quantity of one. Reinitialization of each new larger model produces random interconnection weights before training occurs. Hidden node expansion stops, once the generalization performance begins to deteriorate and the model with the best generalization performance is kept.

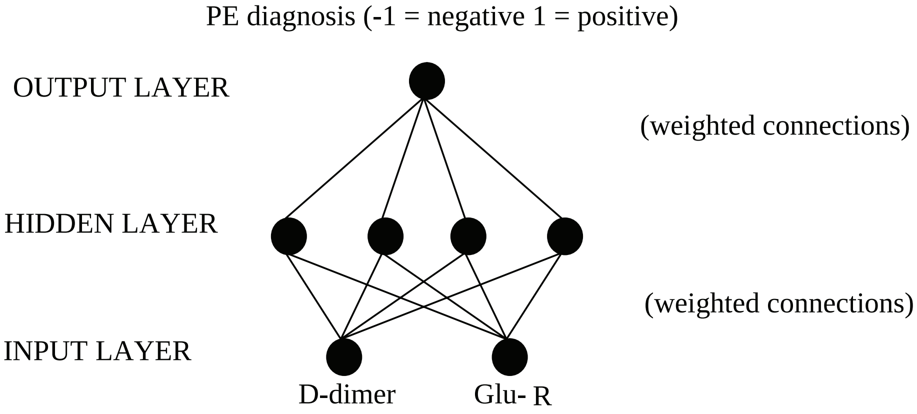
Training of each NN model uses one sample of data, and then validation uses a separate holdout sample. Due to the relatively small size of the population data, we use an eightfold cross validation technique in order to increase the quantity of holdout samples analyzed in the results to the full population of 292. The majority of the NNs evaluated performed similarly to just using the D-dimer result alone, meaning they had very good specificity (identifying positive PE cases) but very poor sensitivity (identifying negative PE cases). The finding that the sex-independent variable did not influence the performance of the various neural supports the findings of Stein et al. (2003b), who found that sex was not a factor in the diagnosis of PE.

The best performing NN model utilized both the D-Dimer and the GLU-R result for each patient. The name of the NN PE diagnosis model is PEDimeNet, since it utilizes the D-dimer laboratory test in combination with another test in order to maximize positive PE-predictive performance. The hidden node architecture for this backpropagation-trained NN is two input nodes representing the D-dimer and Glu-R results, four hidden nodes, and one output node, as shown in Figure 1. This NN is the one discussed in the next section.

RESULTS AND DISCUSSION

Backpropagation-trained NNs provide a real number output between -1 and 1 (though some NN shell tools allow this range to be extended) and not a true or false result for predicting the occurrence of a PE in a patient. These real-number output values require interpretation in order to determine the optimal cutoff point for partitioning the solution space into the two desired groups: probable PE and unlikely PE. An ROC (Receiver Operating Characteristic) curve analysis is performed commonly

Figure 1. PEDimeNet NN architecture



by those involved in medical diagnostics in order to determine the optimal threshold cutoff value for maximizing positive predictive performance on the generalization sample (Kamierczak, 1999; Obuschowsk, Lieber, & Wians, 2004), and this technique is used with the NN training sample output values in order to determine the optimal real number threshold value for performing the classifications. A similar and independent ROC curve analysis for the RBF and LR models reported in the previous section determines each model's cutoff value. The area under the ROC curve for the training data was 0.79. Once the ROC threshold value is determined, it is then applied universally to all out-of-sample output values produced by the NN in order to determine the NN's PE diagnosis for the corresponding patient.

Table 3 displays the prediction results of the resulting NN model. Similar to increasing the D-dimer cutoff value to include more of the patient population in the group that undergoes further evaluation via an angiogram or other PE verification method, a tradeoff exists between the positive predictive accuracy and the negative predictive accuracy using the NN model. Lowering the PE cutoff point causes the positive predictive accuracy to increase and creates a corresponding decrease in the negative predictive accuracy. Due to the possible outcome of mortality for PE patients, a positive predictive performance of 90% sensitivity is desired, as specified by the domain expert physicians (where the TP rate in Table 3 is the sensitivity, and the TN rate is the specificity). The overall diagnosis accuracy ([TP+TN]/Total) performance of the PEDimeNet NN model is 62.33% with almost 91% of all PE patients identified as well as nearly 57% of patients that do not have a PE and, therefore, do not require any additional testing for PE with subsequent reduction in direct costs.

Recall that traditional usage of the D-dimer with a relatively low threshold value produces a

Table 3. NN diagnostic prediction results for PE

	NN positive PE	NN negative PE
Actual PE (positive)	TP = 40 (90.91%)	FN = 4 (9.09%)
No PE (negative)	FP = 107 (43.15%)	TN = 141 (56.85%)

(TP = True Positive, FN = False Negative, FP = False Positive, and TN = True Negative)

false negative (FN) rate very close to 0%. As a result, a negative PE result usually means that the patient truly will not have a PE. The false positive rate for the standard D-dimer test is very high, which leads to increased medical costs through unnecessary costly procedures for follow-up evaluation (e.g., pulmonary angiogram).

For the test population used in the research reported in this article, a simulation of adjusting the D-dimer cutoff value to produce a false negative rate identical to the proposed NN model produced a false positive rate of 91.53% (227 patients that require unnecessary evaluation tests), meaning that only 21 of 248 patients did not have further costly PE evaluation procedures recommended. Whereas, the PEDimeNet NN was able to save additional laboratory testing for 141 patients, as opposed to just 21 when using the traditional D-dimer only diagnosis. Therefore, an NN model of PE that utilizes both D-dimer and Glu-R test results provides a high-quality positive predictor. The NN PE prediction model exceeds using a non-NN D-dimer-based evaluation mechanism with respect to true negatives (patients without PE) by well over 600%, resulting in significant cost savings for the patients. Direct cost savings would be approximately $96,000 to $144,000 for the nine-and-a-half-month period of the research study, which translates to a $121,000 to $182,000 direct-cost annualized savings.

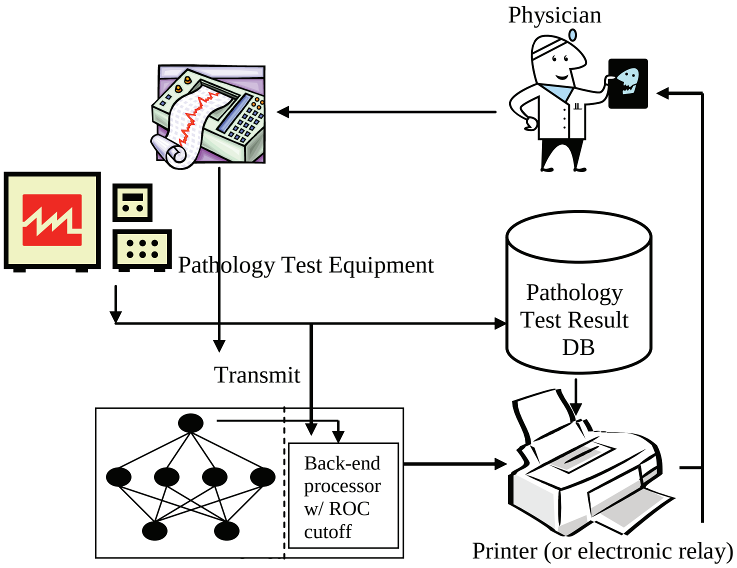
A limitation of the reported research is that the NN diagnosis model only models the population at a single hospital. While this hospital is one of the larger providers in a major metropolitan area and, as such, has a demographically diverse population, differences in the correspondence between the D-dimer and Glu-R values with an actual PE may exist in different geographic populations (Stein, Kayali, et al., 2004). As such, the methodology described would require each hospital to independently train their own NN model and to establish their own ROC cutoff threshold value for interpreting the generalization (out-of-sample) diagnosis values of the NN.

Utilizing the proposed NN system would require only very minor workflow changes in the emergency department and clinical laboratory of the studied hospital and would integrate similarly at most hospitals that follow similar diagnostic methodologies. Medical user acceptance of new decision support technology is highly dependent on two factors: (1) that the decision support technology not be perceived as attempting to make diagnosis (Baxt, 1995; Baxt & Skora, 1996; Walczak & Scharf, 2000) and (2) that the new information technologies not disrupt normal workflows (Kirkley & Stein, 2004; Walczak, 2003). Physicians receive laboratory results at most hospitals either electronically or on paper after encoding and storing the results in a pathology database. The PEDimeNet NN-based decision support system would be positioned architecturally in the pathology departments' IT framework, as displayed in Figure 2. This integration of the PEDimeNet NN diagnostic tool then would appear seamless to physicians, integrating with their existing workflow simply by adding the analysis to the pathology report already received by the physician.

The PEDimeNet PE diagnosis decision support tool is composed of the PEDimeNET NN, an interface that allows the entry of D-dimer and Glu-R laboratory test results (which may be handled electronically through an EDI interface or performed manually at a keyboard), a backend program that contains the ROC curve analysis-based decision cutoff value (which also may be read from a database to allow for movement in the cutoff value over time, perhaps due to new pathology equipment sensitivity) and produces the go/no-go diagnostic recommendation for probable PE in a patient. Future enhancements would include a database or agent-oriented Web browser to recommend additional tests, if necessary, and treatment protocols.

The following scenario presents an illustration of the functioning of the proposed PEDimeNet system within a hospital setting. A physician

Figure 2. PEDimeNet relative to other pathology IT systems



would request a diagnostic workup, including a patient blood draw. The clinical laboratory receives the patient's blood sample. Laboratory tests are completed using the existing laboratory equipment. The results are delivered to the physician either electronically (with EDI requiring a small hardware modification to interface with the existing pathology instrumentation) or on paper (after entering the results into the laboratory database with a simultaneous transmission to the PEDimeNet). A software interface to the database or other peripheral devices (in C# or Java) encodes the received value into the format required by the NN. The PEDimeNet diagnostic decision support system then would interpret the NN's results, based on a cutoff value established by applying the ROC curve analysis determined threshold. The backend analysis of the NN output provides a report of the interpreted NN prediction in either electronic or printed format for the attending physician, who then would determine if any further evaluation was required. Other than the step in the lab necessary to transmit the results to the PEDimeNet decision support system, the automated process is similar to standard decision-making processes for evaluating the need to screen for a PE. From the physician's perspective, there is no change in workflow from the traditional receipt of the original noninterpreted D-dimer assay results.

CONCLUSION

The research presented in this article demonstrates the efficacy of utilizing NNs for predicting the occurrence of PE in patients presenting to the emergency department and those at risk of PE following surgery. The reported results were able to match the very low false negative rate of a more traditional test that relied on the D-dimer alone. Although the usage of a D-dimer screening test is questioned in cases of PE (Stein, Hull, et al., 2004), it has proved reliable for evaluating the presence of DVT (Wells et al., 2003), a leading cause of PE. Furthermore, over a 600% increase in true negative predictions with a corresponding decrease in associated medical risks to patients and decreased medical costs of hundreds of thousands of dollars per hospital per year demonstrates the benefits of using a nonlinear and nonparametric modeling technique such as the backpropagation train NN.

Another benefit derived from this research is the identification of the superior positive predictive performance for PE when using the combination of the D-dimer result value in combination with the Glu-R result value. The D-dimer individually was not able to distinguish reliably between positive PE cases and negative ones, creating a high corresponding false positive assessment rate so that only a very small number of actual PEs would be misdiagnosed. The utilization of an NN as the statistical analysis component of the PEDimeNet NN decision support system enabled the rapid combination of input values in nonlinear ways without regard to population distribution characteristics. A potential drawback of using NNs as a model determination mechanism in order to evaluate the contribution of various independent variables is the need to determine the ideal architecture. While the current research utilized a brute force incremental process to analyze both single- and two-hidden-layer networks, new neural network shell tools are able to automate some or all of the NN node architecture optimization process.

While the research reported in this article focused on the prediction of PE, the relationship between PE and DVT and previous research has indicated a strong positive correlation between the D-dimer assay results and accurate DVT diagnosis (Wells et al., 2003), which indicates that a similar NN model would be able to accurately predict DVT. This would permit the operation of two side-by-side (or possibly one) NNs in the PEDimeNet decision support system in order to evaluate both PE and DVT simultaneously, which is a topic of future research.

In addition to the specific research benefits just described, generalizing the research method and results provides implications for both researchers and practitioners. Future research efforts will benefit by realizing that nonparametric modeling techniques in general and neural networks specifically are a viable method for analyzing complex and potentially ill-defined (unknown population and error distributions) problems. Researchers should embrace the most advanced modeling techniques available, especially since neural networks repeatedly have demonstrated increased performance over more traditional parametric statistical methods. The data set for the presented NN PE diagnosis application is relatively error-free. Researchers should note that designing optimal neural network models has many implementation factors, and careful attention in selecting input variables, selecting the training algorithm, and determining the hidden-layer and hidden-node architecture will help to produce the optimal NN model (Smith, 1993; Walczak & Cerpa, 1999, 2002).

An implication for practice is to challenge existing protocols and heuristics. The addition of a low direct-cost variable to the PE diagnosis model significantly increases the accuracy and reduces direct costs. Other medical diagnostic and assessment problems may derive benefit from examining new sets of variables. The NN modeling method provides an inexpensive and reliable way to rapidly assess the impact of adding new variables or removing existing decision variables (Walczak, 2001). Previous research (Walczak et al., 2003) demonstrates this by showing that a commonly used variable for determining acute pancreatitis patient outcomes, RANSON score, detracts from the predictive performance of other readily available variables.

The research reported in this article demonstrates the impact of NN diagnosis models through the reduction of direct costs. Future research is needed to realize the overall benefit gained from NN diagnosis models by examining the impact on indirect costs, such as reduced patient healing times and overall quality of care received.

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ENDNOTES

[1] A database inquiry on EBSCO using the terms *neural network* AND (medicine OR medical) produced 997 articles. A similar query on PubMed, the NIH article database, produced 6,120 articles.

[2] The occurrence of PE between blacks and whites has been found to be comparable (Stein et al., 2003a) and, as such, is not included in the variables considered for the NN input vector. Additionally, this variable is subjective, being either self-reported by patients or reported as an observation by the admitting nurse in the studied hospital and, as such, may have a higher than acceptable error rate for use in a backpropagation-trained NN.

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Chapter 4.20

Decision Making by Emergency Room Physicians and Residents:

Implications for the Design of Clinical Decision Support Systems

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ABSTRACT

Clinical Decision Support Systems (CDSS) are typically constructed from expert knowledge and are often reliant on inputs that are difficult to obtain and on tacit knowledge that only experienced clinicians possess. Research described in this article uses empirical results from a clinical trial of a CDSS with a decision model based on expert knowledge to show that there are differences in how clinician groups of the same specialty, but different level of expertise, elicit necessary CDSS input variables and use said variables in their clinical decisions. This article reports that novice clinicians have difficulty eliciting CDSS input variables that require physical examination, yet they still use these incorrectly elicited variables in making their clinical decisions. Implications for the design of CDSS are discussed. [Article copies are available for purchase from InfoSci-on-Demand.com]

INTRODUCTION

Clinical decision-making is a complex process frequently complicated by a variety of uncertainties. It is dependent on accurate information, that according to proponents of evidence based medicine (EBM) and decision making should include the integration of clinical expertise with the best available clinical evidence generated by high quality research (Sackett, Rosenberg, Gray, Haynes & Richardson, 1996). EBM is gaining support and momentum and has been called the prevailing clinical decision making paradigm for medicine (Haynes, 2002). A need to follow EBM guidelines has resulted in a situation where clinicians are dependent on massive amounts of information and knowledge to make decisions that are in the best interest of the patient. These information and knowledge sources include electronic medical records, clinical practices guidelines, academic and practitioner journals among others. Increasingly, information technology (IT) solutions are being considered as crucial decision support mechanism to ensure that clinicians have access to appropriate knowledge sources while making clinical decisions. One particular class of IT solutions that the medical community is showing increased interest in is Clinical Decision Support Systems (CDSS).

According to a well accepted definition, a CDSS is "any program designed to help healthcare professionals make clinical decisions" (Musen, Shahar & Shortcliffe, 2001). This definition includes several categories of IT solutions, including:

- *Systems for information management* that provide general data and knowledge for a variety of healthcare workers, including medical information retrieval systems for managing and extracting medical knowledge, and electronic patient record systems (EPRS: Shortcliffe, 1993) for managing patient data.
- *Systems for focusing attention* that are normally present in the intensive care units and are used to remind clinicians about actions that might require attention.
- *Systems for providing patient-specific recommendations* that assess or advise using patient-specific clinical data. These include systems ranging from direct implementation of clinical practice guidelines (Seroussi, Bouaud & Antoine, 2001) to advanced techniques of artificial intelligence (Hanson & Marshall, 2001).

CDSS from the first two categories have been relatively well accepted and used in clinical practice for more than three decades (Anderson, 1997). Increasing interest in systems from the third category is driven by a move towards EBM (deDombal, Leaper & Staniland, 1972), and the efforts to improve patient outcomes (Hunt, Haynes, Hanna & Smith, 1998). Patient-specific recommendation systems usually help clinicians make two types of decisions – diagnostic (what is the underlying health condition of the patient) and management (what is the treatment plan for the patient). Although it is rather artificial to separate the diagnostic process from the management one, many clinicians believe that it is for the management process that they would most often seek support (Musen et al., 2001).

Almost all patient-specific CDSS decision models reflect encoded clinician expertise and are reliant on accurate input to produce appropriate output that is in the best interest of the patient. The implication is that clinicians using such systems have to provide values for input variables to the CDSS that may be correctly elicited only with an appropriate level of expertise. That is, only experienced clinicians will be able to provide such information in a reliable and comprehensive manner, while inexperienced clinicians may be forced to gather information and make assessments for activities that they may lack the clinical acumen to do accurately. Thus, the resulting 'treatment plan' output provided by the CDSS may be inappropriate for the patient under question due to the poor quality of the inputs provided by the clinician.

The purpose of this article is to challenge a common perception that a CDSS designed for a specific and well-defined clinical domain, and for users from the same domain, can satisfy the needs of clinicians who may have varying degrees of domain experience. Research described in this article uses empirical results from a clinical trial of a CDSS to show that there are differences in how the clinician groups of the same specialty, but different level of expertise, elicit necessary CDSS input variables and use said variables in their clinical decisions. By establishing differences between the quality and use of CDSS input variables by clinicians of differing expertise we can then offer prescriptive guidance on improvements to CDSS design that ultimately should assist in providing better care to patients.

This article is organized as follows. First, relevant background literature on expert and novice clinical decision-making is reviewed and used to formulate two research hypotheses. This is followed by a brief description of the MET-AP CDSS along with an explanation of the clinical input variables that are required by the system. Next, descriptions of the experimental design is provided, along with the analytical methodology that was used. This is followed by a discussion of the results and implications for CDSS design.

BACKGROUND AND RESEARCH HYPOTHESES

Patient-specific CDSS are deployed in different settings and used by different classes of users. Decision models implemented in patient-specific CDSS are normally based on expert clinician knowledge, either discovered from past data, elicited from medical books or practice guidelines, or elicited directly from clinicians using a variety of knowledge acquisition strategies such as repertory grids or think aloud protocols. While techniques for obtaining expert knowledge vary, resulting patient-specific CDSS decision models almost always reflect clinician expertise. Sometimes, these models reflect 'best practice' by representing knowledge that has been culled from valid scientific research (for example, the encoding of a clinical practice guideline into a decision model that has been generated from systematic observations of research results). Other times, these decision models need to become part of the scientific research base from which clinicians can draw on to improve patient outcomes.

Clinicians, especially in a teaching hospital, can be considered either novice or expert, based on their medical experience and associated knowledge. Differences between these two categories of decision makers have been widely documented in the decision making and medical literature. It has been stated that in complex domains such as medicine, it typically takes 10 years of training before one can be considered an expert (Prietula & Simon, 1989). Over time, experts develop a capability to systematize information and to form complex networks of knowledge that is stored in long term memory (Arocha, Wang & Patel, 2005; Prietula & Simon, 1989). Novices lack such complex knowledge networks, and, thus, when faced with new informational cues they need to produce more hypothesis than experts (Kushniruk, 2001), are unable to filter out irrelevant cues (Patel, Arocha & Kaufman, 1994; Patel & Groen, 1991), and resultantly take a longer time in making their decisions.

In order to improve these generally weaker information gathering and decision making skills (Johnson & Carpenter, 1986; Mangione et al., 1995), medical graduates and specialty residents undergo practical training during their residency, where they learn how to assess and diagnose patients under the supervision of experienced physicians. Research has shown that residents often have deficiencies in their physical examination skills, yet they place great clinical importance on the physical examination and desire to have greater educational attention put on those skills (Mangione et al., 1995). Through self-recognizing weak skills that are widely considered critical to making important decisions, novice clinicians compensate by placing more emphasis on scientific evidence, as opposed to experts who rely on clinical experience (Patel, Groen & Patel, 1997; Patel et al., 1994). This observation was confirmed in a prospective cohort trial of a handheld CDSS for antibiotic prescribing in critical care (Sintchenko, Iredell, Gilbert & Coiera, 2005). The system offered four types of support functions: patient reports, local antibiotic guidelines, antibiotic susceptibility data and a clinical score calculator. During the trial it was observed that senior physicians used antibiotic susceptibility data more often then other support functions, while it was the least frequently used by junior physicians. The junior physician tended to use the remaining functions with local antibiotic guidelines being most frequently accessed.

Empirical studies have shown that clinicians with different levels of expertise exhibit differences in their ability to elicit information from physical examinations (Pines, Uscher Pines, Hall, Hunter, Srinivasan & Ghaemmaghami, 2005; Yen, Karpas, Pinkerton & Gorelick, 2005). In comparing abdominal examinations of Emergency Department (ED) pediatric patients undertaken by residents and attending physicians, it was found that all parts of the examination had less than moderate agreement (Yen et al., 2005). Similar results were found in studying abdominal examinations of adult patients by residents and attending physicians (Pines et al., 2005). Additional studies of residents have confirmed that they are deficient in performing physical examinations (Mangione, Burdick & Peitzman, 1995). Performing physical examinations accurately, among other clinical tasks, requires tacit knowledge that is "expressed in actions rather than conscious thoughts" (Goldman, 1990). While none of these studies involved the use of a patient-specific CDSS, the implications are that there are distinct differences between the abilities of novice and expert clinicians, and these differences may affect the novice clinicians' ability to provide accurate inputs into the expert generated CDSS decision models. The inexperienced clinicians may lack the clinical acumen necessary to make accurate elicitations and could potentially enter incorrect inputs. Such a situation may not only diminish the usefulness of the CDSS and the validity of the advice generated by the system, but also might lead to the rejection of the system by a broad group of clinicians.

The study reported here is based on a clinical trial of the Mobile Emergency Triage (MET-AP) CDSS that was developed for supporting triage decisions of pediatric abdominal pain in the ED. While the trial was originally designed to assess the CDSS's performance in terms of accuracy of the suggested decisions (Farion, Michalowski, Slowinski, Wilk & Rubin, 2004), our focus is on the CDSS decision model's input variables and the resulting decisions made by the clinicians. The decision model embedded in MET is based upon 13 input variables. We show how different clinician user groups (staff physicians (experts) and residents (novices)) used the system and made clinical decisions based on the required CDSS input variables. We also evaluate differences between these two groups and draw more general conclusions for supporting clinical decision-making with IT. Our research addresses a call for a better understanding of real decision makers making ill structured decisions in a naturalistic setting as mediated by technology (Kushniruk, 2001).

Research described here is structured around two research hypotheses. The first hypothesis builds on the results reported earlier on the differences in clinician elicitation capabilities is:

H1: *Residents will not accurately elicit all values of decision making variables required by a CDSS model built from expert knowledge*

It is our contention that because residents have limited clinical experience and associated tacit knowledge, they will not be able to accurately elicit values of all of the input variables for a CDSS decision model derived from expert knowledge.

The overall goal of the research described in this article is to challenge the idea that a single CDSS is able to appropriately support clinicians of varying experience and associated expertise. To accomplish this goal we need a comprehensive assessment of both the elicitation of input variables and whether said variables are predictive of the actual decision making of clinicians of varying expertise. So while assessment of the accuracy of elicitation of CDSS input variables is critical, we are also interested in whether novice clinicians use different input variables in their clinical decisions than do staff physicians. More specifically we are concerned with whether residents rely on input variables that are relatively easy to elicit properly and that are not normally associated with clinical experience, or whether they incorporate variables that are more difficult to elicit, and traditionally require experience, into their decision making models.

Thus, our second research hypothesis is:

H2: *Residents and physicians will use different decision model input variables in making their clinical decisions*

Because of the clinical expertise required for certain model inputs to be correctly elicited, we expect that residents and physicians will use different input variables in their decision making models. Further, we expect that these differences will be moderated by the ‘type of input variable’, with variables requiring tacit knowledge and clinical experience to be less important in residents decision making models. This would be consistent with classical decision making where it is stated that decision makers will use the best information available and if there is uncertainty, the decision makers will act in a way to reduce uncertainty if possible (Simon, 1957).

CDSS: MET-AP

The MET-AP CDSS was designed and developed to support ED clinicians in making triage decisions about children with abdominal pain (Michalowski, Slowinski, Wilk, Farion, Pike & Rubin, 2005). It facilitates early patient management by ED clinicians who need to make decisions about the clinical management of patients based on initial clinical history and assessment. In this sense MET-AP is not a diagnostic CDSS because it does not provide clinicians with a differential diagnosis but rather with broad management categories (i.e. discharge from the ED, keep for further observation, or request specialist consult). The MET-AP system architecture consists of a server that interfaces with the hospital’s electronic patient record system using the HL7 protocol (Quinn, 1999) and clients that reside on mobile devices such as a Personal Digital Assistant (PDA). The client facilitates the collection of clinical data (CDSS input variables) at the point of care and is used during patient examination by the physician.

The system provides a user interface composed of a series of screens to collect 11 out of 13 CDSS input variables required by the pediatric abdominal pain triaging model. These include variables related to physical findings as well as patient history. The remaining two variables, gender and age, are extracted automatically from the electronic patient record system. All variables are detailed in Table 1 and were identified using retrospective chart analysis. The triage decision making model was created using knowledge discovery techniques based on rough set theory (Pawlak, 1991; Slowinski, 1995) and implemented as a rule-based model.

Based on the values of the input variables the MET-AP’s triage model generates suggested triage decision which can be one of the following three outcomes:

Table 1. Abdominal pain triaging attributes

Attribute Name & Description	Possible Values
Age	0-5, >5 years
Localized guarding: localized muscle sustained contraction noted when palpating the abdomen	Absent, Present
Duration of pain	<=24 hrs, 1-7 and >7 days
Shifting of pain	Absent, Present
Site of maximal pain	Right lower quadrant (RLQ), lower abdomen, other
Type of maximal pain	continuous, other
Previous visits in the ED for abdominal pain during the last 48 hours (irrespective of site)	yes, no
Rebound tenderness: pain felt at site of maximal tenderness, produced by altering intra-abdominal pressure	absent, present
Gender	male, female
Temperature	<37, 37-39, > 39 Cel
Site of maximal tenderness	RLQ, lower abdomen, other
Vomiting	yes, no
WBC (white blood cells)	<=4000, 4000-12000, >=12000

- *Discharge*: patient can be discharged home as his/her pain is caused by a non-serious problem,
- *Observation/Investigation*: further in-hospital evaluation (either in the ED or hospital ward) is required to better evaluate the cause of the pain,
- *Consult*: surgical consult is required due to suspicion of acute appendicitis (most common surgical emergency in children with abdominal pain).

Values of all numerical input variables (WBC, temperature, duration of pain) were collected by physicians entering direct numerical values using either a virtual keyboard or a handwriting recognition system. Entered values were then discretized for the rule based decision models according to discretization norms developed with physician experts. Values of all input variables that involved a specific location within the abdomen (site of maximal pain, site of maximal tenderness) were collected by physicians tapping on an abdomen pictogram on the mobile device. Other input variables were collected via standard user interfaces for mobile devices. For example, figure 1 shows the MET-AP screen for 'type of maximal pain'. All screens were designed and developed with participation from multiple physicians. This ensured that the resulting user interface mimicked clinicians' natural data collection procedures as closely as possible.

METHODS

This research on staff physician and resident decision making was part of a larger clinical trial that was designed to evaluate MET-AP decision accuracy in comparison with clinicians' triage predictions. Results of that clinical trial can be found in Farion, Michalowski, Rubin, Wilk, Correll and Gaboury (2008).

Figure 1. MET-AP Screen for type of pain

Doe, John

Site of pain: RLQ

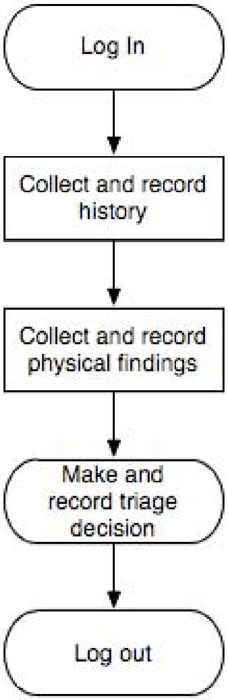
Durat. of pain: 12.5 hrs

Type of pain: Intermit.

☐ Constant

☑ Intermittent

Figure 2. MET-AP usage scenario



Sample and Data Collection

A convenience sample of 574 eligible children with acute abdominal pain, aged 1 to 16 years, were enrolled with consent between July 2, 2003 and February 29, 2004 in the ED of the Children's Hospital of Eastern Ontario, Ontario, Canada. Under some conditions, convenience samples are not representative of the population under study (in this case, children with acute abdominal pain). While there were a variety of factors that effected enrolment of patients, including how busy the ED was and the attending clinician's level of comfort with technology, because of the long enrolment period (8 months), the number of clinicians involved (150), and the number of patients seen (574), it is likely that the patient sample is reasonably representative of the population under study.

A typical MET-AP usage scenario for clinicians participating in the study is presented in figure 2. After logging in to the MET-AP system, the attending resident or staff physician would enroll a patient and collect and record their medical history into the system. The attending clinician would then typically collect physical findings from the patient through physical examination and verbal interaction and enter the relevant input variables into the MET-AP system via the user interface. Participating clinicians were instructed to only record data for those input variables they felt were relevant to the patient's presentation. After reflecting on the findings the attending clinician, blinded to the CDSS recommendation, entered his/her prediction of which triage category the patient was most likely to fit (i.e., discharge, observation/investigation, or consult). Where possible, a clinician with a different level of expertise (i.e., resident or staff physician) from the attending clinician was asked to complete an independent interrater assessment within one hour of the original assessment using the MET-AP system as described above.

Forty staff physicians and one hundred and ten residents enrolled patients. This type of prospective evaluation of CDSS is rare, as all physicians were asked to use the MET-AP, not just those few associated with the development team. The physicians had varying degrees of experience with handheld computers before entering the trial and all of them participated in in-depth training sessions after which they were able to easily use the CDSS. Two hundred and twenty two of the patients were seen by both a resident and a staff physician.

Analysis

The analysis starts by addressing H1 to establish whether residents are accurate at eliciting the input variables required by MET-AP. Once that is established, H2 is addressed to compare which MET-AP input variables predict the triage decision in the resident and staff physician decision making models. In this study, the more experienced staff physicians' inputs represent the benchmark to which residents' values are compared. This approach is widely used in the literature to evaluate performance of less experienced clinicians and can take the form of comparing novices to experts performing the same task (Nodine, Kundel, Mello-Thoms, Weinstein, Orel, Sullivan & Conant, 1999; Sklar, Hauswald & Johnson, 1991), or having expert clinicians evaluating the performance of novice clinicians (Burdick et al., 1996; Steinbach, 2002; Wray & Friedland, 1983). As a measure of proper elicitation, we use a level of agreement beyond chance between values for CDSS input variables provided by staff physicians and residents. Statistically, this is measured using the Cohen's Kappa statistic (Cohen, 1960) which was calculated for each of input variables across the two groups of clinicians who have seen the same patient.

Addressing H2 involves the use of logistic regression to determine which CDSS input variables are significant in predicting the clinicians' triage decision. In this analysis, the CDSS input variables are independent variables, and the triage decision made by staff physicians and residents is the dependent variable. It should be clear that the dependent variable is the clinician's actual triage decision, not the decision provided by the CDSS. Logistic regression was chosen given that the dependent variable was categorical. In conducting this analysis we collapsed the original three possible values for the dependent variable (the clinician's triage decision) into two distinct values. This was done by combining 'observation/investigation' and 'discharge' into one category. 'Consult' remained a distinct category. This isolated the significance of the input variables associated with the 'consult' value of the dependent variable. This situation serves as a proxy for a critical triage decision typical of a diagnosis of acute appendicitis.

The regression analysis was conducted separately for data derived from patients who were seen by residents, and patients who were seen by staff physicians so we could investigate and compare decision making models across clinician type. Typical model building strategies suggest doing extensive univariant analyss for each potential independent variable to determine which variables should be added to the model (Hosmer & Lemeshow, 2000). However, epidemiological researchers suggest including all clinically and intuitively relevant variables into the initial model regardless of their significance. Because the input variables included in the MET-AP were derived from a retrospective chart study and were validated with ED physicians, all of them were included in the analysis. Before running the regression, we studied the contingency tables for all independent variables against the dependent variable to ensure that no zero cells existed. This basic logistic regression requirement was met successfully for both resident and staff physician data.

Design Effect

Because this study involved a prospective trial in the ED, it was unrealistic to obtain random sampling of patients, residents and staff physicians. In situations like this, the cluster sampling of a population may suffer from a sampling bias. In order to determine if this is the case, design effects (DEFF) are calculated. This measure assumes that the respondents in the same cluster are likely to be similar to one another and thus each respondent from a cluster typically contributes less new information than would a randomized respondent. The DEFF is calculated as a ratio of the variance under the sampling method employed to the variance computed using simple random sampling (Skinner, Holt & Smith, 1989):

DEFF = 1 + δ (n-1), where:

- δ is the intercluster correlation for the statistic in question
- n is the average size of the cluster

The sample used in our study is not independent because there were multiple staff physicians and multiple residents, each of whom saw more than one patient. A cluster was formed by grouping together the multiple patients seen by a given staff physician and the multiple patients seen by a single resident. Because information on the performance of individual clinicians was not permitted by the Research Ethics Board, the association between staff physician/resident to individual patients is unavailable, and thus it is impossible to calculate δ and subsequently DEFF. To alleviate the concern around clustering, we calculated a 'critical DEFF' defined as the DEFF that would adjust the statistic in question to the point where it was no longer significant at value of 0.05. This approach has been used successfully in previous research (Thomas & Cyr, 2002). The critical DEFF was calculated as:

$$\text{Critical DEFF} = \frac{\hat{W}}{c^2}$$

Where $\hat{W}$ is the calculated Wald Statistic for the CDSS input variable in question, and c^2 is the critical chi square value for n-1 degrees of freedom. While values of DEFF can vary depending on the study design and individual variable in question, research suggests that a well-designed study should result in values of DEFF between 1 and 3 (Shackman, 2001). While it is impossible to accurately estimate the DEFF for this study, we would expect its value to be very low. For the physicians clustering, we would not expect the likelihood that a randomly selected staff physician from the overall population would provide input variable values much different from those currently elicited. While we expect there would be higher variance for the residents (because of less expertise), the cluster size for the resident population in the study is small (because of the large number of residents participating) which might contribute to a lower value of DEFF.

RESULTS

H1: *Accuracy of Collected Inputs*

Kappa measures and associated interpretation information (Posner, Sampson, Caplan, Ward & Cheney, 1990) of agreement between staff physicians and residents for CDSS input variables are presented in table 2. It should be noted that all of the input variables were assessed using discretized values. While some of the input variables are naturally scalar data (for example, temperature), the discretizations adopted were generated by a panel of experts and reflect critical threshold as used by clinicians in daily practice. As expected, input variables which are objective and easily measured or assessed (vomiting, temperature) have high levels of agreement indicating that residents are able to accurately elicit this information. However, all other input variables had only fair or moderate levels of agreement. Except for 'previous visit', the elicitation of these input variables are more difficult and subjective than the previous mentioned input variables. 'Previous visit' is defined as a "previous visit to the ED for abdominal pain during the last 48 hours (irrespective of site)". We suspect that the low value of the Kappa statistic may be attributed to the fact that some of the patient/parent(s) interpreted the first examination (conducted by staff physician/

Table 2. Values of Kappa statistic: resident vs. staff physician

Attribute	Kappa	Agreement Quality[1]
Localized guarding	0.31	Fair
Rebound tenderness	0.45	Moderate
Previous visit	0.48	Moderate
Type of pain	0.48	Moderate
Site of pain	0.51	Moderate
Shifting of pain	0.52	Moderate
Site of tenderness	0.57	Moderate
Duration of Pain	0.83	Very Good
Vomiting	0.89	Very Good
Temperature	0.95	Very Good

resident) as a previous visit when they were asked the same question by the second observer.

The values of Kappa statistic indicate that residents are less accurate eliciting input variable values that require experience and clinical acumen, as opposed to straight application of 'textbook knowledge'. Of the input variables that had fair to moderate levels of agreement, the ones with the lowest values of Kappa (localized guarding and rebound tenderness) are more dependent on experience in conducting physical examination than the remaining attributes (type of pain, site of pain, shifting of pain, site of tenderness) and are typically considered the most difficult to accurately elicit. The elicitation of these physical examination input variables can be obstructed due to the child's sensitivity to being touched, his/her fear, and other factors that may cause muscle contraction leading to misinterpretation. The examination for rebound tenderness is painful for patients when it is present, so repeated examinations to confirm this finding is discouraged. Thus, experience in carrying out examinations is likely to increase the reliability of eliciting values for physical examination input variables. Residents may not have enough experience to distinguish the subtle difference between a patient with true guarding and one that is just uncomfortable with the physical examination (Mangione et al., 1995). At the same time it is important to recognize that according to clinical knowledge, the combination of the presence of localized guarding and rebound tenderness is a 'strong indicator' for surgical consult due to possible appendicitis. In the case of MET-AP input variables, those that are the most difficult for residents to elicit provide the most insight into the patient's state. In summary, those attributes that required physical examination, and thus clinical acumen and experience, to accurately elicit their values for CDSS inputs were done poorly by residents.

The remaining input variables having moderate level of agreement (type of pain, site of pain, shifting of pain, and site of tenderness) are reliant on the ability of the physician to 'touch and ask' to elicit accurate values from the patient. The capability to elicit an accurate response through the dynamic interplay between clinician and patient is affected by level of expertise, with less experienced physicians having weaker information gathering skills (Johnson & Carpenter, 1986; Mangione et al., 1995).

Based on these results H1 is supported. The results add further evidence to the literature that residents do not have sufficient clinical expertise required to reliably elicit information that is dependent on the physical examination. In the next step of our research we wanted to determine differences between MET-AP input variables used by residents and staff physicians in making their triage decisions. Because of the clinical experience required for certain input variables to be correctly elicited, we expect that residents and physicians will use different input variables in their mental decision making models.

H2: *Critical Decision Making Variables*

The results for residents and staff physicians are shown in Tables 3 and 4 respectively. The values of Nagelkerke's R^2 is 0.568 and 0.699 for the resident and staff physician models indicating that the CDSS input variables provide a better fit for staff physician mental model than for the resident model.

The design effects are reflected in critical DEFF values that are shown in Tables 3 and 4 to the immediate right of the calculated p-values. For example, for the 'localized guarding' input variable for the resident analysis, a critical DEFF value of 3.508 is the minimal value required to categorize 'localized guarding' as insignificant. Based on the critical DEFF values for the physician analysis, we would expect one of the 'significant

Table 3. Logistic regression for residents (n = 294 patients)

Variable	β	std. Error	Wald Statistic	p-value	Critical DEFF
Age	0.498	0.994	0.251	0.617	0.065
Gender	-0.939	0.528	3.159	0.076	0.823
Pain Duration			0.325	0.850	0.085
Pain Duration (1)	-0.288	0.509	0.319	0.572	0.083
Pain Duration (2)	-5.306	63.417	0.007	0.933	0.002
Pain Site			0.153	0.926	0.040
Pain Site(1)	0.177	0.906	0.038	0.845	0.010
Pain Site(2)	0.440	1.124	0.153	0.696	0.040
Pain Type	0.692	0.511	1.833	0.176	0.477
Vomiting	0.035	0.487	0.005	0.944	0.001
Previous Visit	-6.895	29.973	0.053	0.818	0.014
Temperature			1.327	0.515	0.346
Temperature(1)	0.040	0.489	0.007	0.935	0.002
Temperature(2)	-1.911	1.695	1.271	0.260	0.331
Tenderness Site			9.971	0.007**	2.597
Tenderness Site(1)	2.741	0.944	8.427	0.004**	2.195
Tenderness Site(2)	0.361	1.305	0.076	0.782	0.020
Localized Guarding	1.863	0.508	13.469	0.000***	3.508
Rebound Tenderness	1.503	0.526	8.164	0.004**	2.126
Pain Shifting	0.766	0.514	2.222	0.136	0.579
Constant	-5.142	1.130	20.686	0.000	5.387
Nagelkerke R^2	0.568				

**$p < 0.05$*
***$p < 0.01$*
****$p < 0.001$*

Table 4. Logistic regression for staff physicians (n = 385 patients)

Variable	β	std. Error	Wald Statistic	p-value	Critical DEFF
Age	1.315	1.306	1.013	0.314	0.264
Gender	-0.593	0.528	1.260	0.262	0.328
Pain Duration			0.614	0.736	0.160
Pain Duration (1)	0.377	0.514	0.537	0.464	0.140
Pain Duration (2)	-5.517	20.305	0.074	0.786	0.019
Pain Site			6.862	0.032*	1.787
Pain Site(1)	2.467	0.973	6.429	0.011*	1.674
Pain Site(2)	2.376	1.381	2.960	0.085	0.771
Pain Type	1.611	0.614	6.879	0.009**	1.791
Vomiting	1.299	0.601	4.674	0.031*	1.217
Previous Visit	2.691	1.417	3.604	0.058	0.939
Temperature			2.312	0.315	0.602
Temperature(1)	0.619	0.534	1.343	0.246	0.350
Temperature(2)	2.421	2.097	1.333	0.248	0.347
Tenderness Site			3.194	0.203	0.832
Tenderness Site(1)	1.082	0.953	1.288	0.256	0.335
Tenderness Site(2)	-1.256	1.384	0.823	0.364	0.214
Localized Guarding	1.539	0.556	7.662	0.006**	1.995
Rebound Tenderness	2.306	0.576	16.005	0.000***	4.168
Pain Shifting	0.968	0.560	2.985	0.084	0.777
Constant	-8.380	1.692	24.533	0.000	6.389
Nagelkerke R^2	0.699				

$^{*}p < 0.05$
$^{**}p < 0.01$
$^{***}p < 0.001$

variables' to become insignificant if simple random sampling was used. Specifically, vomiting (with a critical DEFF of 1.217) will most likely become insignificant. The critical DEFF values for the input variables that are significant for the residents' model are all high enough to expect that these input variables would remain significant if randomized sampling was used. Because of the difficulties associated with calculating values of DEFF and a need to resort to using critical DEFF instead, the results presented here should be interpreted with caution. While this could be viewed as a limitation it should be noted that prospective trial data of CDSS use in a naturalistic setting is rare and efforts should be taken to use the data in a responsible academic fashion.

Localized guarding and rebound tenderness are highly significant in the residents' mental model for making the consult decision. This is not surprising considering the importance of these input variables in determining acute appendicitis. When taken in concert with the Kappa statistic for the same input variables we have a situation where residents rely on input variables that they have trouble eliciting correctly while making a decision to ask for a surgical consult. There are several plausible diverging explanations for this result dependent upon whether residents are cognizant of their (in)ability to properly elicit certain input variables.

Residents may be aware of their deficiencies in eliciting certain input variables, but that awareness is counter balanced or overridden by an accepted clinical guideline that is reliant on aforementioned variables. While this seems counter-intuitive, it is not entirely inconsistent with previous research where residents have been shown to be deficient at performing physical examinations, yet they acknowledge both their own deficiencies and the importance of being able to properly and reliably do physical examinations (Mangione et al., 1995). Our results indicate that the perceived importance of localized guarding and rebound tenderness by the residents outweighs their perception of the degree of difficulty in eliciting the input variable values and the degree of reliability in collecting this information, and thus they use these input variables when making a consult triage decision.

Alternatively, residents may incorrectly feel confident in their ability to elicit all input variables required by the CDSS decision model. In this case we would expect the residents to consider and apply the variables as specified in their training and education into decision making activities. Previous studies have shown that residents cannot accurately estimate their performance and that they have a tendency to overestimate their performance (Parker, Alford & Passmore, 2004). It has also been shown that while residents and physicians both overestimate the accuracy of their clinical diagnoses, residents overestimate more often than physicians (Friedman, Gatti, Franz, Miller & Elstein, 2005). More research is required to investigate perceptions of accuracy of CDSS input variables and resulting clinical decisions.

Overall, staff physicians have more significant variables that predict their triage decision making than do residents. Specifically, site of pain, type of pain, localized guarding and rebound tenderness are significant predictors for physicians. Alternatively, significant predictive variables in the residents' model are site of tenderness, localized guarding and rebound tenderness. H2 is thus supported. These results are consistent with the literature on strategic experts, which states that experts have complex structures that assist in the recognition and interpretation of environmental signals and events (Lyles & Schwenk, 1992) and that these structures are more complex and contain more links among elements than the cognitive structures of less experienced strategists (Day & Lord, 1992; Lurigio & Carrol, 1985; McKeithen, Reitman, Rueter & Hirtle, 1981).

LIMITATIONS, CONCLUSION AND IMPLICATIONS FOR CDSS DESIGN

There are several limitations associated with this study that are worth mentioning. First, a convenience sample of patients was used which can limit the generalizability of the results as there is no guarantee that enrolled patients were representative of the overall population of interest (children with abdominal pain). An additional limitation was the time lag between the assessments made by the clinicians of differing expertise on the same patient (< 1 hour). It is possible in some cases that the patient's condition could change during the time between assessments. There was nothing to indicate that this effect was occurring during the data collection process. As mentioned previously, the sample used in our study is not independent because there were multiple staff physicians and multiple residents, each of whom saw more than one patient. Without the knowledge of which physician and which resident saw which patients, we were unable to apply more advanced statistical techniques such as hierarchical linear modeling to determine the decision making models of the different clinician groups. However, we did attempt to alleviate the above problem by calculating critical DEFF values and applying said values to refine the final logistic regression models. A final limitation relates to the enrollment of patients by the attending clinicians. Those clinicians who were less comfortable with the MET-AP technology could be less likely to enroll patients into the trial.

The quality of any patient specific CDSS is reliant on the quality of the underlying decision model(s). These models have to reflect clinical expertise associated with expert decision makers (staff physicians in our situation). Models associated with such expertise will usually require inputs that are difficult to assess and interpret by novice users. Broadly speaking, customizing CDSS technology for users of different expertise has been proposed by several researchers (Kushniruk, 2001; Patel, Arocha, Diermeier, How & Mottur-Pilson, 2001), but to our knowledge this research is one of the first that provides empirical evidence gathered through the prospective evaluation of a CDSS, that such an approach is required. In typical CDSS designs, residents and physicians would be treated as a single user group, and thus would be interacting and accessing the same interface and underlying decision models.

In evaluating the use of a CDSS for ED triage of patients with abdominal pain, we found that staff physicians and residents elicited several of the CDSS input variables differently while examining the same patients. Specifically, for CDSS input variables involving physical examination typically in concert with verbal elicitation, calculated Kappa values were low indicating that the values recorded by the residents were different than those recorded by staff physicians. Considering that we use staff physicians' values as the benchmark (in accordance with expert vs novice literature), we interpret this discrepancy as indicative of the difficulties the residents had with correctly eliciting values of such input variables. When individual mental decision making models (operationalized as significant CDSS input variables for predicting triage decisions) were examined it was found that the staff physicians and residents models were similar, albeit the staff physicians' model had one more significant variable. The importance of the input variables that required physical examination was underlined by their presence in both staff physicians' and residents' mental models, even though the residents were not eliciting this information accurately. In order to take into account differences in clinical experience and to ensure appropriate support is available to these different user groups, we propose that the CDSS designers should (a) differentiate between information values provided by the data coming from expert and novice assessments, and (b) implement logical attribute monitoring that warns users when a single attribute value or a combination of attribute values is outside of expected ranges or patterns.

To design and implement aids that consider the information value of the inputs, the input variables used in CDSS models must be categorized. Required input variables could be logically categorized based on how difficult they are to elicit and to what extent they are reliant on tacit, explicit, or declarative knowledge. Subsequently, each input variable could be indicated as 'low confidence' or 'high confidence'. While this is a broad categorization, it reflects the ability of different physician user groups to accurately elicit different values of the input variables. While the categorization of the variables is encoded into the system, it can remain relatively transparent to the user (i.e., there would be nothing that would explicitly label a variable as being 'low confidence'). According to the proposed categorization, a typical novice physician would have elicitation difficulty with 'low confidence' input variables. Therefore, the user interface for the 'low confidence' attributes should provide extensive explanations and guidelines to assist the process of collection. Some progress has been made in providing explanations and guidelines for CDSS input elicitation. AI/RHEUM (Kingsland, Lindberg & Sharp, 1983) is an expert-based system for diagnosing rheumatic diseases and was created to provide knowledge elicited from rheumatology experts to physicians with no training in rheumatology. To support physicians in providing accurate input information, AI/RHEUM included an extensive repository of 180 definitions of items from the finding list (Porter, Kingsland, Lindberg, Shah, Benge, Hazelwood, Kay, Homma, Akizuki, Takano & Sharp, 1988). A more recent version of the system this information was augmented with multimedia presentations including videos and pictures and a function to search for referenced articles directly on Medline (Athreya, Cheh & Kingsland, 1998).

Provision for recording imprecise or uncertain information (e.g., selecting several values instead of a single one, entering some 'confidence' factor associated with a value, or having a discrete option for 'uncertain') should be provided. Additional factors related to the process of eliciting values for 'low confidence' input variables should be considered by expanding the clinical value set with conditional information such as 'recorded with difficulty', or 'child crying and fidgeting'. This will allow a dynamic confidence factor to be calculated. Moreover, to help with 'learning by analogy', at any time, and at the users discretion, similar patient cases could be retrieved based on values of individual input variables or on a more complete clinical model. This approach is consistent with knowledge transfer literature that states that while tacit knowledge cannot necessarily be made explicit, it can be transferred through repeated exposure to similar situations and cases (Nickols, 2000). 'High confidence' input variables would not require such additional assistance and could be elicited in the usual manner. Finally, following accepted principles of interaction design, the additional input support functionality for low confidence attributes discussed above should be automatically turned on for less experienced clinicians, while more experienced clinicians could bypass the additional support if desired (Shneiderman, 1998).

In clinical decision making, values of selected attributes often form a certain pattern that is indicative of an underlying health condition. For example, as stated earlier, for pediatric abdominal pain, pain and tenderness located in the right lower quadrant in concert with presence of guarding are indicative of possible acute appendicitis. It is possible to use information about such patterns to develop context sensitive monitoring for values of both individual input variables and their combinations. If values entered by a clinician significantly deviate from the dynamically adjusting thresholds, either assessed individually or within clinical patterns, a CDSS would issue specific warning alerting the clinician to this situation. While this will provide additional support for novice clinicians, it will also help minimize the potential error between user and technology which has recently been identified as an important source of clinical error (Kohn, Corrigan & Donaldson, 2000). The derivation of the thresholds of the input variables should be generated dynamically based on an abstraction of the patient profile and subsequent heuristic matching against a set of likely profiles developed on a basis of past cases. The case base could provide the core knowledge repository on which to derive the threshold values that can be obtained in a manner similar to case-based reasoning in artificial intelligence. Machine learning algorithms and induction techniques could also be adopted to derive threshold values, rules, and patterns that new patient profile information can be compared to. These approaches assume a sufficiently large case database to ensure realistic variances are reflected in establishing the threshold values.

Many decision models implemented into CDSS encapsulate knowledge that relies on evaluating attributes that require experience and significant clinical acumen. Results of the research reported here indicate that residents have not completely mastered this knowledge and thus encounter difficulties with providing the required input to the CDSS. This creates uncertainty about the quality of the recommendations produced by the CDSS. It is clear that customized decision support, taking into account the level of clinical expertise and background of a given physician, is required to ensure that the accuracy of the CDSS is maximized. Such expanded support is as important for the acceptance of a CDSS by physicians as the quality of the underlying decision model and user interface.

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ENDNOTE

[1] The guidelines for 'interpreting Kappa' are as follows:

Agreement	Agreement quality
< 0.20	Poor
< 0.40	Fair
< 0.60	Moderate
< 0.80	Good
to 1	Very good.

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Chapter 4.21

Decision Support Systems for Cardiovascular Diseases Based on Data Mining and Fuzzy Modelling

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INTRODUCTION

The widespread availability of new computational methods and tools for data analysis and predictive modelling requires medical informatics researchers and practitioners to systematically select the most appropriate strategy to cope with clinical prediction problems. In particular, data mining techniques offer methodological and technical solutions to deal with the analysis of medical data and construction of decision support systems. Furthermore, fuzzy modelling deals with the ambiguity inherent in all medical problems. These methods can be used to design and develop clinical decision support systems (CDSSs), which, after evaluated from the experts, can be integrated into clinical environments.

Cardiovascular diseases (CVDs) are the leading cause of death in many countries worldwide. According to the World Health Organization, CVDs are the cause of death of 16.6 million people around the globe each year. The multifaceted nature of these diseases, combined with a wide variety of treatments and outcomes, and complex relationships with other diseases, for example, diabetes, have made diagnosis and optimal treatment of cardiovascular diseases a problem for all but experienced cardiologists.

This article addresses the decision support regarding cardiovascular diseases, using computer-based methods, focusing on the coronary artery disease (CAD) diagnosis and on the prediction of clinical restenosis in patients undergoing angioplasty. Methods reported in the literature are reviewed with respect to (i) the medical information that are employing in order to reach the diagnosis and (ii) the data analysis techniques used for the creation of the CDSSs. In what concerns medical information, easily and noninvasively-obtained data present several advantages compared to other types of data, while data analysis techniques that are characterized by transparency regarding their decisions are more suitable for medical decision making. A recently developed approach that complies with the above requirements is presented. The approach is based on data mining and fuzzy modelling. Using this approach, one CDSS has been developed for each of the two cardiovascular problems mentioned above. These CDSSs are extensively evaluated and comments about the discovered knowledge are provided by medical experts. The later is of great importance in designing and evaluating CDSSs, since it allows them to be integrated into real clinical environments.

BACKGROUND

Data Mining is the process of discovering patterns and correlations from large amounts of data, using artificial intelligence, statistical, and mathematical techniques (Tan, Steinbach, & Kumar, 2005). Fuzzy logic is the extension of the classical crisp (binary) logic into a multivariate form. Fuzzy logic is closer to the human logic, thus being able to deal with real world noisy and imprecise data (Wang, 1986). CDSSs are computerized tools developed to assist physicians through the process of decision making. A known approach for the development of CDSSs is the use of experts' knowledge combined with an inference engine. However, recent advances in designing CDSSs employ automated knowledge extraction from data, using data mining techniques, while fuzzy logic provides several advantages in designing inference engines, compared to the classical crisp logic. The combination of data mining and fuzzy modelling provides a powerful tool for fully automated creation of CDSSs, experiencing several advantages: (i) transparency in decision making, (ii) addressing the ambiguity inherent in clinical data, and (iii) ability to interpret all decisions in a medical manner. All the above are of great importance for physicians, when performing decision making.

Coronary artery disease (CAD) is the development of atherosclerotic plaques in coronary arteries, resulting in coronary luminal narrowing and subsequently occlusion, and thus leading to myocardial infarction or sudden cardiac death. Coronary angiography (CA) is considered to be the "gold standard" method for the diagnosis of CAD and it is widely used. However, CA is an invasive and costly procedure that needs high level technical experience and technology and cannot be used for screening of large populations or close follow-up of treatment (Escolar, Weigold, Fuisz, & Weissman, 2006). Computer aided methodologies for CAD diagnosis have also been proposed in the literature; in this case the data obtained by some of the above mentioned methods or other sources (i.e., laboratory examinations, demographic, and/or history data, etc.) are evaluated by a computer-based application, leading to a CAD diagnosis. These methodologies can be divided into various categories, based on the type of data they use for subject characterization. Several methods are based on heart sounds associated with coronary occlusions (Akay & Welkowitz, 1993). Also, methods which employ the resting or exercise electrocardiogram (ECG) of the patient, extracting features from it, like the R wave (Szildgyi, Szildgyi, & David, 1997), the QT interval (Ng, Wong, Mora, Passariello, & Almeida, 1998), the T wave amplitude (Sabry-Rizk et al., 1999), the heart rate variability (Tkacz & Kostka, 2000), and the ST segment (Lewenstein, 2001) have been proposed. Furthermore, there are methods using medical images, such as SPECT (Haddad, Adlassnig, & Porenta, 1997), and methods based on arterio-scillography (Pouladian, Golpayegani, Tehrani-Fard, & Bubvay-Nejad, 2005). There exist also methods that employ demographic, history, and laboratory data (Frossyniotis et al., 2001; Mobley, Schechter, Moore, McKee, & Eichner, 2005; Tsipouras et al., 2006) and methods that combine more than one type of data (Kukar, Kononenko, Groselj, Kralj, & Fettich, 1999; Scott, Aziz, Yasuda, & Gewirtz, 2004).

The evolution and widespread adoption of percutaneous transluminal coronary angioplasty (PTCA) represents a major advance in the management of acute coronary syndromes, resulting in a significant reduction in early and late mortality compared to pharmacologic reperfusion therapy. Coronary artery restenosis remains a major limitation of PTCA and is usually defined as $\geq 50\%$ stenosis in the treated segment at follow up, or at least 50% loss of the original gain in the minimal luminal diameter. Many clinical, angiographic, and procedural features have been studied as predictors for restenosis but it has proven difficult to stratify patients with regard to the risk of restenosis. Knowledge of risk factors for restenosis may help to refine indications of PTCA, reduce the frequency of restenosis, and select optimal candidates for a PTCA procedure. Despite lowering the restenosis rate with the implantation of coronary stents, it occurs in approximately 12-60% of the patients within 6 months after intervention depending mainly on the patients' and procedural characteristics. Computer aided methodologies for the prediction of clinical restenosis have also been proposed in the literature. These can be divided into two categories, regarding the data they use for the analysis: methods that employ only CAD risk factors such as demographic, history, and clinical data (Budde, 1999; Tsipouras et al., 2006) and methods that combine CAD risk factors with angiographic features (Maier, Mini, Antoni, Wischnewski, & Meier, 2001; Resnic, Popma, Ohno-Machado, 2000).

CDDSS FOR CARDIOVASCULAR DISEASES

A recently developed method for automated CDSSs creation is based on data mining and fuzzy modeling (Tsipouras et al., 2006). Specifically, in order to create the CDSS, a three stage methodology is used: (i) creation of a rule-based classifier using data mining techniques, (ii) development of a fuzzy logic model, and (iii) optimisation of the fuzzy logic model's parameters. Briefly, in the first stage, a set of crisp rules is generated. This is performed by inducing a decision tree from a training dataset and then transforming the tree into a set of rules. In the second stage, the crisp set of rules is transformed to a fuzzy set of rules, using a membership function instead of the crisp ones and S and T norms instead of the binary AND and OR operators. Finally, in the third stage, all thresholds and parameters involved in the fuzzy model are optimized with respect to a training dataset. The fuzzy model with the optimized parameters comprises the final CDSS. To apply the above methodology in a specific domain, an annotated dataset is required. The quality of this dataset is very important for developing an effective CDSS. This methodology has been used in order to create CDSSs for CAD diagnosis and prediction of clinical restenosis in patients undergoing angioplasty.

Application to CAD Diagnosis

The dataset used for CAD diagnosis included 199 subjects suspected of having CAD and who underwent coronary angiography for the first time. Patients with known CAD were excluded from the study. Of the subjects, 89 had normal angiograms and in the remaining 110 subjects the presence of CAD was confirmed by two experts. In order to characterise each subject, 19 features (shown in Table 1) were used. Two demographic features were recorded: the age and sex of the patient. From the subject's history data, the family history of CAD, smoking history, history of diabetes mellitus, and measurements of hypertension or hyperlipidaemia were used. The incorporated laboratory investigations were creatinine, glu-

Table 1. Features for CAD CDSS

#	Feature	Units
1	Age	Years
2	Sex	male(1), female(0)
3	Family History (FH)	yes(1), no(0)
4	Smoking (Sm)	smoker (2), ex-smoker (1), non-smoker (0)
5	Diabetes mellitus (DM)	FBGC ≥ 126mg/dl (1) else (0)
6	Hypertension (HT)	DBP>90mmHg and/or SBP>140mmHg (1) else (0)
7	Hyperlipidemia (HL)	total cholesterol over 220mg/dl (1) else (0)
8	Creatinine (Cre)	mg/dL
9	Glucose (Glu)	mg/dL
10	Total Cholesterol (TC)	mg/dL
11	High Density Lipoprotein (HDL)	mg/dL
12	Triglyceride (TG)	mg/dL
13	Body Mass Index (BMI)	kg/ m^2
14	Waist	Cm
15	Heart Rate (HR)	Bpm
16	Systolic Blood Pressure (SBP)	mmHg
17	Diastolic Blood Pressure (DBP)	mmHg
18	Carotid femoral pulse wave velocity (PWVcf)	m/sec
19	Augmentation Index (AIx)	%

cose, total cholesterol, high density lipoprotein, and triglycerides. In addition, Carotid-Femoral Pulse Wave Velocity and Augmentation index were also used as non-invasive indices of arterial stiffness (Van Bortel et al., 2002; Woodman & Watts, 2003). In order to confirm the presence or absence of CAD, coronary angiography was performed by the Judkins technique. All coronary angiograms were visually assessed by two experienced cardiologists to reach consensus agreement. Significant CAD was defined as at least one stenosis of 50% or greater diameter in at least one coronary artery vessel. The absence of CAD was defined as completely smooth epicardial coronary arteries.

In Figure 1 an indicative set of rules is presented. These rules are extracted using data mining and (before fuzzification) were commented by the experts. According to the experts, gender is the most important feature in the produced set of rules. However, this is partially driven from the dataset since 64% of our male population (98/152) was diagnosed with CAD as compared with 25% (12/47) in the female population. Smoking has also been proven to be an important marker for CAD prediction in women; 77% of non smoking women did not suffer from CAD (33/42). In the male population, low HR (i.e., <=49 beats per minute) was found to be an important predictor of CAD; this might be explained by the use of β-blockers (antianginal medications that lower HR) in subjects with very high clinical suspicion of CAD. Also, it appears that elderly males (i.e., age>69 years) with symptoms and signs of CAD have high probability to be diagnosed with CAD, since CAD was found in 92% (24/26) of our elderly male population. In males aged less than 69 years, family history of CAD appears to be a relatively important diagnostic feature for CAD (76% of those with positive family history had CAD, i.e., 26/34). However, some of the derived rules cannot be fully explained based on standard medical knowledge, mainly due to the data-driven nature of the proposed method, which can also discover non important and spurious rules.

Figure 1. Indicative rules (crisp) for CAD diagnosis

```
IF (Sex = 0 and Sm = 0  and HR  ≤ 65 and PWVcf ≤ 10.5 and AIx ≤ 48 and FH = 0)                           THEN    normal
IF (Sex = 0 and Sm = 0  and HR  ≤ 65 and PWVcf ≤ 10.5 and AIx ≤ 48 and FH = 1 and TC ≤ 240)              THEN    normal
IF (Sex = 0 and Sm = 0  and HR  ≤ 65 and PWVcf ≤ 10.5 and AIx ≤ 48 and FH = 1 and TC > 240)              THEN    CAD
IF (Sex = 0 and Sm = 0  and HR  ≤ 65 and PWVcf ≤ 10.5 and AIx > 48)                                      THEN    CAD
IF (Sex = 0 and Sm = 0  and HR  ≤ 65 and PWVcf > 10.5)                                                   THEN    CAD
IF (Sex = 0 and Sm = 0  and HR  > 65)                                                                    THEN    normal
IF (Sex = 0 and Sm = 2  and Glu ≤ 94)                                                                    THEN    CAD
IF (Sex = 0 and Sm = 2  and Glu > 94)                                                                    THEN    normal
IF (Sex = 1 and HR ≤ 49)                                                                                 THEN    CAD
IF (Sex = 1 and HR > 49 and Age ≤ 69 and FH = 0 and DM = 0 and BMI ≤ 27.99 and TRG ≤ 191 and Age ≤ 50)   THEN    normal
IF (Sex = 1 and HR > 49 and Age ≤ 69 and FH = 0 and DM = 0 and BMI > 27.99 and  HR > 53  and HDL > 27)   THEN    normal
IF (Sex = 1 and HR > 49 and Age ≤ 69 and FH = 1 and HT = 0)                                              THEN    CAD
IF (Sex = 1 and HR > 49 and Age ≤ 69 and FH = 1 and HT = 1 and Glu ≤ 103)                                THEN    normal
IF (Sex = 1 and HR > 49 and Age ≤ 69 and FH = 1 and HT = 1 and Glu > 103)                                THEN    CAD
IF (Sex = 1 and HR > 49 and Age > 69 and DM = 0)                                                         THEN    CAD
IF (Sex = 1 and HR > 49 and Age > 69 and DM = 1 and Cre ≤ 1)                                             THEN    normal
IF (Sex = 1 and HR > 49 and Age > 69 and DM = 1 and Cre > 1)                                             THEN    CAD
```

In Table 2, several computer aided diagnosis methodologies for CAD are presented. Some of the noninvasive methods, such as computerized tomography or magnetic resonance imaging, suffer from similar problems as CA, that is, being costly and requiring specialized technology and expertise, while they are not widely available (Escolar et al., 2006). Most of the computer based methods are based on the analysis of data obtained by examinations, such as stress ECHO and SPECT, which are also expensive, not widely available, and suffer from technical limitations (Merz, 2005). Exercise stress testing is inexpensive and widely available, but cannot be applied to all patients and has low sensitivity and specificity in the diagnosis of CAD. The populations and the parameters collected and analyzed differ among studies; in some of the studies, only male subjects (Lewenstein, 2001; Mobley et al., 2005) or subjects with previous myocardial infarction (MI) or coronary artery bypass grafting (CABG) (Kukar et al., 1999), were included. It should be mentioned that most of the methods reported in Table 2 are based on neural networks (Akay & Welkowitz, 1993, Frossyniotis et al., 2001; Kukar et al., 1999; Mobley et al., 2005; Scott et al., 2004). These methods are not able to provide clear interpretation for their decisions.

Application to Prediction of Clinical Restenosis in Patient Undergoing Angioplasty

The dataset used for prediction of clinical restenosis in patients undergoing angioplasty consisted of 1,000 subjects that underwent angioplasty. In order to characterise the subjects, the 15 features shown in Table 3 were used. Family history, hypertension, diabetes mellitus, current smoking, and hyperlipidemia were defined as for the CAD CDSS. Clinical presentation of CAD was classified as unstable angina, stable angina, or acute myocardial infarction. The vessels treated with angioplasty were the right coronary artery, left

Table 2. Comparison of several computer aided methodologies for CAD diagnosis

Author – Year	Number of subjects	Method – analysis	Se (%)	Sp (%)	Acc (%)
Akay & Welkowitz, 1993	112	Heart sounds – Neural network	78	89	
Haddad et al., 1997	100	SPECT – Case based reasoning	98	70	93
Kukar et al., 1999	327	Subject's data, exercise ECG, SPECT – Neural network	96	84	92
Frossyniotis et al., 2001	139	Exercise ECG, subject's data, indices of arterial stiffness – Neural network	78	75	78
Lewenstein, 2001	776	Exercise ECG	97	98	
Scott et al., 2004	102	SPECT, subject's data – Neural network	88	65	
Mobley et al., 2005	2004	Subject's data – Neural network	100	26	
Pouladian et al., 2005	51	Arterio-oscillography – signal processing	73	90	
Tsipouras et al., 2006	199	Subject's data, indices of arterial stiffness – data mining, fuzzy modelling	80	65	73

main stem, left anterior descending artery, left circumflex artery, and bypass grafts. The patients underwent either angioplasty with balloon alone or balloon followed by stenting with a noncoated metal stent. All patients were followed up for at least 12 months. The composite end point of the study was clinical restenosis manifested as cardiac death, a new non fatal myocardial infarction or a new revascularisation attempt of the stented vessel in less than 6 months after the initial angioplasty procedure.

In Figure 2, some indicative rules are presented. The experts agree that the most important feature in the production of rules for the prediction of clinical restenosis is the number of diseased coronary vessels since 15.4% (i.e., 87/565) of the multivessel cases presented with restenosis in less than 6 months after the percutaneous coronary intervention (PCI) procedure in contrast to only 7.9% (i.e., 29/365) of the single vessel patients. Patients who underwent the angioplasty in a stable condition (i.e., stable angina) had probably a favourable prognosis (only 8.3% of patients with stable angina presented with restenosis in less than 6 months compared to 13.5% of those with unstable coronary syndromes), except perhaps for older (i.e., > 65 years old) or diabetic people. On the other hand, unstable coronary syndromes (i.e., unstable angina and myocardial infarction) are related to worse prognosis in terms of clinical restenosis even in younger ages (i.e., 55 years old) or patients without many severe cardiovascular risk factors. History of a previous PCI procedure and especially history of coronary aortic bypass surgery (occurrence of restenosis in 19.4% of patients with previous CABG compared to 12.2% without CABG history) are associated with increased risk of restenosis after coronary angioplasty. However, some of the derived rules could not be explained based on current medical knowledge on various interactions among the features used in our models.

In Table 4, a comparison of several computer-aided methodologies for the prediction of clinical

Figure 2. Indicative rules (crisp) for prediction of clinical restenosis

```
IF (SVD = 1 and CP = 1 and VT = 1   and FH = 0 and HL = 1 and PTCA = 0)                  THEN      normal
IF (SVD = 1 and CP = 1 and VT = 1   and FH = 0 and HL = 1 and PTCA = 1)                  THEN    restenosis
IF (SVD = 1 and CP = 1 and VT = 1   and FH = 1 and ST = 1)                               THEN      normal
IF (SVD = 1 and CP = 1 and VT = 2)                                                       THEN      normal
IF (SVD = 1 and CP = 1 and VT = 3   and Age ≤ 66)                                        THEN      normal
IF (SVD = 1 and CP = 2 and CABG = 0 and HL = 0 and HT = 0)                               THEN      normal
IF (SVD = 1 and CP = 2 and CABG = 1)                                                     THEN    restenosis
IF (SVD = 1 and CP = 3)                                                                  THEN      normal
IF (SVD = 0 and CP = 1 and PTCA = 0 and VT = 1 and CABG = 0 and Age ≤ 51)                THEN      normal
IF (SVD = 0 and CP = 1 and PTCA = 0 and VT = 2 and Sm = 0   and HT = 0 and Age > 60)     THEN    restenosis
IF (SVD = 0 and CP = 1 and PTCA = 0 and VT = 3 and ST = 1   and FH = 0 and Age ≤ 58)     THEN    restenosis
IF (SVD = 0 and CP = 2 and Sex = 0  and VT = 3 and DM = 0   and ST = 2)                  THEN    restenosis
IF (SVD = 0 and CP = 2 and Sex = 0  and VT = 3 and DM = 1)                               THEN    restenosis
IF (SVD = 0 and CP = 2 and Sex = 1  and PTCA = 1)                                        THEN    restenosis
IF (SVD = 0 and CP = 3 and HT = 0   and FH = 0 and ST = 1   and Age ≤ 66)                THEN      normal
IF (SVD = 0 and CP = 3 and HT = 0   and FH = 0 and ST = 1   and Age > 66)                THEN    restenosis
IF (SVD = 0 and CP = 3 and HT = 1   and Sm = 0 and PTCA = 0 and Sex = 1 and DM = 0)      THEN      normal
IF (SVD = 0 and CP = 3 and HT = 1   and Sm = 0 and PTCA = 0 and Sex = 1 and DM = 1)      THEN    restenosis
```

Table 3. Features for prediction of clinical restenosis CDSS

#	Feature	Units
1	Stent Type (ST)	Balloon (0), Bare Metal Stent (1), Drug Eluting Stent (2)
2	Sex	male(1), female(0)
3	Age	Years
4	Diabetes Melitus (DM)	FBGC ≥ 126mg/dl (1) Else (0)
5	Hypertension (HT)	DBP>90mmHg and/or SBP>140mmHg (1) else (0)
6	Smoking (Sm)	smoker (1), non-smoker (0)
7	Hyperlipidemia (HL)	total cholesterol over 220mg/dl (1) else (0)
8	Family History (FH)	yes(1), no(0)
9	CAD History (CAD)	yes(1), no(0)
10	Prior PTCA (PTCA)	yes(1), no(0)
11	Prior CABG (CABG)	yes(1), no(0)
12	Single Vessel Disease (SVD)	yes(1), no(0)
13	Clinical Presentation (CP)	Unstable angina (1), Acute myocardial infarction (2), Stable angina (3)
14	Vessel Treated (VT)	Left anterior descending (1), Left circumflex (2), Right coronary artery (3), Left main (4), Bypass graft (5)
15	IIB/IIIA	yes(1), no(0)

Table 4. Comparison of several computer aided methodologies for prediction of restenosis after coronary angioplasty

Author - Year	Number of subjects	Data	Method	Accuracy (%)
Budde, 1999	2500	Risk factors for CAD	Rule based system	95
Resnic et al., 2000	2804	Demographic, clinical and angiographic data	Statistical analysis Risc score ANN	81 79 81
Maier et al., 2001	325 (lesions)	Clinical and angiographic data	Statistical analysis Rule based system	58 92
Tsipouras et al., 2006	1000	Demographic, history and clinical data	Data mining, fuzzy modelling	61

restenosis is presented. Different datasets were used in each method; therefore a direct comparison is not feasible. Some approaches (Budde, 1999; Tsipouras et al., 2006) are based on noninvasively acquired data, while others employ also data obtained from angiographies (Maier et al., 2001; Resnic et al., 2000), thus being invasive approaches. Data analysis is performed mainly using rule based systems (Budde, 1999, Maier et al., 2001, Tsipouras et al., 2006) or artificial neural networks (Resnic et al., 2000).

FUTURE TRENDS

Researchers have spent great efforts in the design and development of CDSSs for several domains in medicine and health care. Most of the CDSSs try to reduce the effort and time of the experts when performing diagnosis. However, a plethora of systems has been presented for staging, treatment, dose adjustment, and follow-up. An important requirement of this type of system is the transparency regarding the automated decisions and the interpretation they provide. Moreover, experts rely more on systems that their automated decisions coincides with established medical knowledge. Integration of knowledge provided by the experts and knowledge generated using data mining methods, for the creation of more sophisticated CDSSs, is the trend of the future. Established medical knowledge combined with data mining models is the key to increase the effectiveness of these systems and provide advanced tools for computer based clinical medicine.

CONCLUSION

CVDs are among the most life threatening diseases worldwide. A vast amount of patients suffering from CVDs are examined, hospitalized, and treaded every day; this has a major impact in national health care systems. The importance of CVDs has lead to the development of a large number of computer-based CDSSs that mainly focus in diagnosis, treatment, or follow-up. An important requirement of a CDSS is its ability to provide transparency regarding the generated decisions, thus providing a clear insight of their inner process for decision making; this is essential for physicians in order to incorporate such systems in their clinical practice. Another important requisite is an extensive evaluation of a CDSS by medical experts, in order to comment on the functionality of the system and fully exploit its potential. Furthermore, the employment of easily obtained and noninvasive features for decision support is considered an advantage since it facilitates the straightforward application of the system. Most of the CDSSs proposed in the literature do not meet these requirements, thus complicating their application in clinical practice. The CDSSs presented in this article fulfill these issues, making them suitable to be used in clinical practice.

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KEY TERMS

Artificial Neural Network: An interconnected group of artificial neurons that uses a mathematical or computational model for information processing based on a connectionist approach to computation.

Clinical Decision Support Systems (CDSS): Computer based methods that aim to assist clinicians in decision making. The core of CDSSs is an inference engine that can generate case specific advice based on medical data.

Clinical Restenosis: Death presumably from cardiac causes, myocardial infarction not attributable to another coronary artery than the target vessel, and target vessel revascularization either by repeat PTCA or CABG.

Coronary Artery Disease: The narrowing of the coronary arteries, sufficiently to prevent adequate blood supply to the heart muscle. It is usually caused by atherosclerosis and may progress to the damage of heart muscle.

Data Mining: The process of extracting previously unknown and potentially useful knowledge, hidden in large volumes of data.

Fuzzy Logic: A way of reasoning that can cope with uncertain or partial information.

Inference Engine: The part of a decision support system that performs the reasoning function.

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Chapter 4.22

Analysis and Intuition in Strategic Decision Making:

The Case of California

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INTRODUCTION

"The primary wisdom is intuition."
Ralph Waldo Emerson, American philosopher

Many management scholars believe that the process used to make strategic decisions affects the quality of those decisions. However, several authors have observed a lack of research on the strategic decision-making process. Empirical tests of factors that have been hypothesized to affect the way strategic decisions are made are notably absent (Fredrickson, 1985). This article reports the results of a study that attempts to assess the effects of decision-making circumstances, focusing mainly on the approaches applied and the managerial skills and capabilities the decision makers built on during concrete strategic decision-making procedures. The study was conducted in California between September 2005 and June 2006 and it was sponsored by a Fulbright research scholarship grant.

Strategic decisions are those that affect the direction of the firm. These major decisions concern areas such as new products and markets, product or service development, acquisitions and mergers, subsidiaries and affiliates, joint ventures, strategic alliances, finding a site for a new investment, reorganisation, and other important matters. Strategic decision making is usually conducted by the firm's top management, led by the CEO (chief executive officer) or president of the company. That is why in this research 20 top-level managers were targeted: 12 were CEOs, presidents, vice presidents, or chief financial officers (I will call them executives) while 8 were founders and majority owners of their own enterprises (they will be called entrepreneurs). Sixteen respondents were male, four were female. The average respondent has been working for 28.7 years in general, for 13.8 years for the actual company, and for 8.4 years in the current position. Sixty percent of the respondents have a graduate business degree, 60%

have an undergraduate degree, seven of them have an MBA or a PhD, and two out of these seven have both an MBA and a PhD. One respondent is working on his PhD right now.

The interviews took 2½ hours on the average, varying from 2 hours up to 5 hours. During the interviews, a preliminary structured list of questions was followed. With each respondent we investigated the circumstances of four different strategic-decision cases from his or her practice. The participants could choose the cases on their own. Using this technique, a database of 80 strategic decisions could be built.

BACKGROUND

Kathleen M. Eisenhardt (1998), professor of strategy and organisation at Stanford University, found that top managers at more effective firms were able to make quick and high-quality decisions that were highly supported throughout the firm. Her studies identified four areas in which effective decision makers outperformed counterparts at less effective firms:

- Building collective intuition
- Stimulating conflict
- Maintaining a pace or schedule for decision making
- Defusing political behaviour

In my research, I focused on the role of intuition in strategic decision making. As Ashley F. Fields (2000) stated, intuition is one of the more mysterious concepts associated with the study of human capital. Classical theoreticians, from Carl Jung (1934) to Chester Barnard (1938) and Abraham Maslow (1954) have commented on the existence and value of intuition in organisational settings. Carl Jung said, "Intuition does not denote something contrary to reason, but something outside of the province of reason." It is real but it is not in our heads, and our heads cannot control it. Harold Leavitt (1975) viewed intuition as a valuable weapon to be used against the heavily analytical practices, which gave rise to his derisive term "analysis paralysis." Fascination with the subject of intuition remains alive and well in recent years too.

Intuition is usually defined as knowing or sensing something without the use of rational processes. Alternatively, it has been described as a perception of reality not known to consciousness, in which the intuition knows, but does not know how it knows. Westcott (1968) redefined intuition as a rational process, stating that it is a process in which an individual reaches a conclusion on the basis of less explicit information than is ordinarily required to reach that decision. Weston Agor (1997) argued that intuition is a built-in capacity that some of us have and some do not. In my research, I basically relied on the definition given by Martha Sinclair and Neal Ashkanasy (2000). According to these authors, intuition is a non-sequential information processing mode, which comprises both cognitive and affective elements and results in direct knowing without any use of conscious reasoning. Practically, it is an unconscious process of making decisions on the basis of experience and accumulated judgment.

Isenberg (1984), who studied managers in Fortune 500 firms, found that they combine both rational and intuitive methods in decision making. Parikh (1994) studied more than 1,300 managers and found that intuition is cross-national. Catford's (1987) study of 57 business professionals demonstrated that intuition was used commonly as a business tool. These and many other researchers have demonstrated that intuition is used regularly in the conduct of business (Fields, 2000).

Interestingly, more than half of today's intuition books are authored by females. Psychologists debate whether the intuition gap is truly intrinsic to gender. Whatever the reason, Western tradition has historically viewed rational thinking as masculine and intuition as feminine. Women's way of thinking gives greater latitude to subjective knowledge. Some personality tests show that nearly 6 in 10 men score as "thinkers" (claiming to make decisions objectively, using logic) while 3 in 4 women score as "feelers" (claiming to make decisions subjectively, based on what they feel is right; Meyers, 2002).

In recent years instinct appears ascendant. Decision makers have good reasons to prefer instinct. In a study, executives said they use their intuition as much as their analytical skills, but credited 80% of their success to instinct (Buchanan & O'Connell, 2006). Mintzberg and Westley (2001) explain that strategic thinking calls for creativity and synthesis, and this is better served by intuition than analysis. Buchanan and O'Connell cited some famous statements related to intuition:

"Pragmatists act on evidence. Heroes act on guts."

"Intuition is one of the X-factors separating the men from the boys."

One feature common to all the authors cited above is an inability to articulate a coherent, consistent, and verifiable theory of what underlies the intuitive phenomenon. These researchers unanimously declare that something really exists, but they cannot agree on just what exists or why it works as it does (Fields, 2000). Recent advances in cognitive science and artificial intelligence suggest that there is nothing mystical or magical about intuitive processes, and that they are not paranormal or irrational. Rather, intuitive processes evolve from long experience and learning and consist of the mass of facts, patterns, concepts, abstractions, and generally what we call formal knowledge or beliefs, which are impressed in our minds (Isenberg, 1984; Simon, 1987). Intuition is not the opposite of rationality, nor is it a random process of guessing, as we very often think. It is a sophisticated form of reasoning based on chunking that an expert hones over years of job-specific experience. Consequently, intuition does not come easily; it requires years of experience in problem solving and is founded upon a solid and complete grasp of the details of the business. However, in some cases, it compresses experience and learning into seconds, as it was shown in some cases during my interviews.

RATIONAL/INTUITIVE ORIENTATION

The lack of field studies in strategic decision-making processes called for a research study to examine concrete real-life cases and to analyze the following:

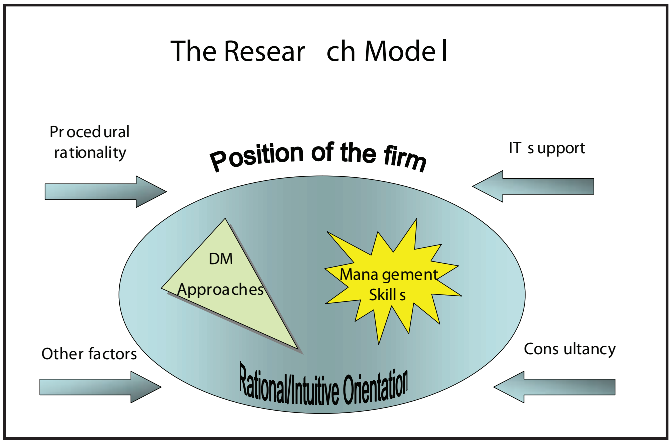
- How top-level managers really make strategic decisions.
- How entrepreneurs and executives differ, if at all, in their approach to strategic decision-making processes when they combine rational thinking with their intuition
- Similarities and differences, if any, in management skills between entrepreneurs and executives

The logic of the research model can be described as seen in Figure 1.

Rational/intuitive orientation is a concept that has yet to make a significant impact on mainstream decision-making research. Consequently, no well-established indicators of rational/intuitive orientation exist. Based on understanding the concept, however, two optional indicators (decision-making approaches and management skills) were identified in this study.

In the literature of decision theory, several models of organisational decision making can be found. These differ from each other in the sense that they use other prerequisites of decision makers and also refer to the organisational connections of decision makers. On the basis of the above dimensions, four different models and decision-making mechanisms were identified (analytical, political, bounded rationality, and intuitive). Eleven man-

Figure 1. The research model



agement skills were investigated and rated as to whether they support analytical or intuitive thinking. In this article, we will focus on the core of the above-mentioned research model, namely on rational/intuitive orientation.

The main hypotheses of the research can be summarized as follows:

H1: Intuition plays a key role in strategic decision making since strategic problems are ill structured and hence cannot be programmed. Decision makers at the top level combine analytical and intuitive approaches, but more heavily rely on their intuition.

H2: Intuitive decision making is more favoured by independent decision makers (entrepreneurs) who have extended control over their firms and are more often in the final decision maker's position. When they put the dot on the i, they are almost always intuitive.

H3: The level of management skills is high. The creative/intuitive skills are even more developed in the sample.

Herbert Simon (1982) was the first to distinguish between the two extreme types of decisions. He called recurring, routine-like, or ready-made ones programmed decisions, while those being unique and unstructured with long-term impacts were called nonprogrammed decisions. Programmed and nonprogrammed decisions naturally set the two extreme poles of one continuum, and the appearance of interim cases is much more probable. In the course of company operations, it happens very rarely that a decision situation clearly corresponds to the terminology of the programmed or nonprogrammed decisions. On the other hand, most managers develop some kind of practice for the handling of nonprogrammed decision situations that can be successfully applied if a ready-made solution can be fitted to an actual situation. Certain nonprogrammed decisions may become programmed in the course of time in a company's practice. It is rather meaningful that programmed and nonprogrammed decisions are sometimes referred to as well structured and ill structured as well.

A central part of this survey consisted of the examination of 20 plus 60 real strategic decisions. At the beginning of the interview, every respondent could mention a big case that was mainly ill structured. When I asked the respondents to quote three more decision cases, they mainly mentioned semistructured problems that could be positioned somewhere between the well-structured and ill-structured extremes. These cases were not as big as the previous 20 decision situations, but they still had long-term consequences and strategic importance. Practically, each participant could mention four cases, one big case and three semi-structured cases. This is how the database of the survey was built up based on the cases of the 20 contributors.

In the interest of comparability, the semistructured decision cases were classified into categories that are borrowed from the "Bradford Studies" (Hichson, Butler, Cray, Mallory, & Wilson, 1986). According to this, I distinguished the following types of decisions:

- Investment
- Reorganisation
- Acquisition
- Fundraising
- Marketing
- Service or product development
- Production
- Finding a site for investment
- Human resource management
- Quality management
- Other decisions

Decisions related to service or product development (10), investment (9), reorganisation (9), marketing (8), and finding a site for investment (7) were the most frequently mentioned cases. However, I also found at least a single case for each other category.

The respondents mixed the analytical and intuitive problem-solving approaches when they made these decisions. As they argued, they found it very difficult to use only the rational approach for these semiprogrammed decisions, therefore intuitive decision making was very often valuable and also applied. However, it was also typical that decision makers made their decisions and later developed rational-sounding reasons for the decision after the fact. It seemed that for some reason they like to be seen as rational. However, some of them were very proud of relying on their instinct in solving particular cases. Demonstrating the concept of bounded rationality, the respondents recognized that at least in part their decisions were based on intuition or a gut feeling. This was most typical in marketing cases, where the respondents needed more experience and judgment than sequential logic or explicit reasons to make those decisions. As they explained it, they made these decisions based upon what they believed to be right rather than upon what they could document with hard data. In the other categories, especially in cases of service or product development, investment, acquisition, and finding a site, they did not find it appropriate to apply this kind of logic.

When the respondents were given an extra opportunity to rethink their earlier answers concerning the analytical and intuitive approaches in their cases, they changed their minds only slightly. If they could repeat the same decisions, which will of course never happen, they would rely more on analysis in marketing decisions too, but in service and product development interestingly would give more room for intuition.

Clearly, there were major perceived differences between entrepreneurs' and executives' answers in terms of how their decisions were made. One of the main differences is that executives tend to exhibit more characteristics of analytical decision making than entrepreneurs do. Executives more heavily rely on the analytical approach. However, it is interesting to note that entrepreneurs are more careful in cases of investment decisions, where they insist on preliminary analytical investigation. A logical explanation could be that they risk their own money when investing and are therefore more careful about it.

The quality of the decision-making activity and the company's success is considerably influenced by the fact of who makes the decisions, what skills and capabilities they have, what their managerial style is, and also what techniques and methods they use in the course of decision making. Consequently, it is not only the applied decision-making approach and the managerial style that leave their mark on decision making, but equally important is the level of professional abilities, education, and experience the managers have.

What characteristics or individual skills must management have to be successful? The survey embraced the general abilities of management. What is more, in the in-depth interviews I encouraged respondents to make some self-evaluations. I asked them to define their strengths and weaknesses according to the investigated characteristics and skills by evaluating themselves on a five-point Likert scale. However, the first task was to rank the skills according to their importance. Considering the opinions of all respondents (N=20), the "image of the ideal manager" fulfilling all expectations of management appeared in decreasing order:

- Excellent communication skills
- Sense for business
- Problem-solving skills
- Practice-minded behaviour
- Ability to represent ideas
- Risk-taking nature
- Expertise
- Organising skills
- Executive skills
- Analytical skills
- Use of PC and computers

Some interesting features are revealed from this ranking. Naturally, the top and the bottom of the list are worth attention, since the skills there outline a manager image frequently mentioned during the interviews. The major task of a manager is to communicate inside and outside of the company (as they stated they do most of the marketing) while the use of computers at top level is not a must since they can get all necessary IT support whenever they need. The other skills could be divided into two subgroups. As one of the respondents stated, the skills that are more important, which you cannot buy, happen to be in the upper part of the list, while those that are available through different channels, for example, consultancy, like organising skills, analytical skills, or IT knowledge, are in the second half of the list.

If we compare these results to the actual self-assessments, we can see interesting evidence of cognitive dissonance. The respondents ranked less important their weaknesses and more important their strengths. They were far beyond the average performers (if we define this category on a five-point scale with the middle position indicated by 3) on all criteria except one, the use of computers, but as we saw earlier, they did not feel that fact was a disadvantage. They are very good communicators, which I can confirm based on my personal experiences. They quite heavily rely on their accumulated knowledge, experiences, and expertise, and are equipped with the necessary problem-solving skills. They named as a real strength their sense for business. We cannot forget that two fifths of them are the founders and majority owners of their enterprises in the sample. Two of them started totally new businesses when they recognized new business opportunities. They left behind their emerging and safe careers and chose unknown and challenging new fields. Both of them are very successful in their new businesses.

We know that some skills and capabilities support more the intuitive way of problem solving than the others. My research method also involved interviewing a dozen university professors in an effort to link the management skills involved in this research with the analytical or intuitive way of problem solving. A quick survey was designed and the professors were asked to evaluate the above-mentioned skills by indicating whether these skills supported analytical or intuitive thinking strongly. They could mark only one answer for each skill. All of the respondents had strong management background since they were teaching either in the field of organisational behaviour or decision sciences.

The skills were split into two groups depending on their role supporting intuitive or analytical problem solving. According to the opinion of the university professors with management background, intuitive thinking and problem solving are best supported by the following skills: a willingness to take risks, a sense for business, the ability to represent ideas, practice-minded behaviour, and excellent communication skills. On the other hand, different skills take precedence when problems require analytical solutions. The skills that most support this approach were determined to be analytical skills, computer skills, organising skills, professional expertise, and problem-solving skills. Not surprisingly, executive skills are somewhere between these two groups of skills since effective leadership requires a combination of analytical and intuitive approaches.

Subsequently, I revised this distinction at two points. Most of the authors (Csikszentmihalyi, 1996; Klein, 2004; Sinclair & Ashkanasy, 2005) agree that intuition is nothing else than experience put into practice. This demystified definition of intuition shows how one can become expert in one's profession through one's cumulative experience or knowledge. Klein argues that intuition is a developed sense helping to put experience into recognizable patterns for future use. As it is well known, good communication skills often go with good analytical skills since both are the functions of the left hemisphere of the brain (Browning, 2005).

Putting this split into practice, the chart of the managers shows a rather balanced picture of their analytical and intuitive skills. Problem-solving skills lead the rank of the analytical skills while business sense is the most important strength among the intuitive skills. Among the 80 analyzed decision cases, I found much that confirms the importance of business sense as the path toward success. The weaknesses are compensated by the high level of strengths. Lack of computer knowledge or organising skills does not seem to be a big problem because top-level managers can easily find someone to do these jobs.

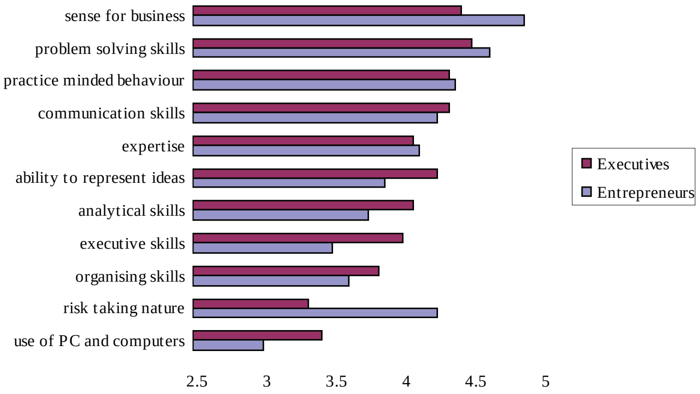
The largest gap could be recognized in the ability to represent ideas. Entrepreneurs do not have to sell their decisions because they are typically the final decision makers; consequently for them this skill is not a must. Their priorities are instead risk-taking nature, problem-solving skills, a sense for business, and communication skills. Executives consider the ability to represent ideas far more important than the entrepreneurs. Analytical and organising skills are ranked a little bit higher by them too.

Differences between groups that exceed 10% are considered to be very significant in survey research. There were relatively large differences in this research between the two responding groups according to the capabilities and skills based on their self-assessments (Figure 2). Entrepreneurs have better business sense and they are ready to take far more risks. They evaluated their problem-solving skills slightly higher than the executives. Executives' strengths are in the ability to represent ideas, analytical skills, and executive skills. The more balanced picture emerged when we compare practice-minded behaviour, communication skills, and expertise.

FUTURE TRENDS

When analyzing these findings, it must be remembered that these results were based on self-assessments. Rarely are self-assessments and independent (objective) assessments congruent. However, we do not have any techniques to measure the level of the different management skills and capabilities or decision-making approaches objectively yet. We feel that there might be a lack of agreement between the self-assessments and an imaginative objective assessment of these parameters. We call this gap "the coefficient of self–delusion." This coefficient can be positive (when the objective rating is higher than the self-assessment) or it can be negative (when the objective ratings are lower than the self-assessments). The

Figure 2. Differences in management skills of executives and entrepreneurs



positive coefficient of self-delusion occurs with people who either are genuinely humble or may be trying to avoid overinflating their self-ratings for a variety of reasons, for example, because of their cultural background. The negative coefficient of self-delusion usually occurs with people who are not conscious of the impact of their behaviours on others or they have an inflated sense of self. In either case, it is important to investigate why the assessment gap exists and reflect upon ways that it can be narrowed, perhaps even closed, which is a big research challenge.

There is a big debate at the present time whether the analytical or the intuitive way of thinking is more powerful in the business arena. Thomas Davenport (2006) argued that some companies have built their very businesses on their ability to collect, analyze, and act on data. Every company can learn from what these firms do. The popular "head vs. formula" controversy that is based mostly on laboratory studies in the past established the superiority of the rational-analytical approach over the soft judgmental or intuitive approach. The extension of this approach to strategic decision making is problematic, however. This is because strategic decisions are characterized by incomplete knowledge. Consequently, it may be impossible to identify quantitative equations among variables and find numeric values for parameters and initial states. That is why people still use their heads instead of formulas in strategic cases (Khatri & Alvin, 2000). As a conclusion of the very intensive debate, there is now an agreement that intuition is not an irrational process. It is based on a deep understanding of the situation. It is a complex phenomenon that draws from the store of knowledge in our subconscious and is rooted in past experience. It is quick, but not necessarily biased as presumed in previous research on rational decision making (Khatri & Alvin).

CONCLUSION

In everyday language, we tend to use the word intuitive with some connotation of irrational. This is probably due to Bergson (1911) who attached great importance to intuition but interpreted it as a mystic force that by definition could not be subject to rational means of inquiry (Wierzbicki, 1997). However, almost a hundred years of research in various fields of science now leads to a reversal of this interpretation. In the management literature of our days, we can read that intuition is not arbitrary or irrational because it is based on years of practice and hands-on experience, often stored in the subconscious. Managers started to accept that new interpretation and they believe that their intuition is part of their business knowledge. Decision support systems might help to strengthen this perception by providing user-friendly tools to obtain and sort the necessary knowledge for successful decisions. It will probably take time until this view is widely recognized.

This study showed that executives in a corporate setting tend to view decision making differently than entrepreneurs. Since they are typically given a fixed amount of budgeted resources to work with, they tend to define a problem in terms of what can be done with the resources on hand. Entrepreneurs, on the other hand, will likely pose the problem in terms of an objective. They usually state, “This is what I want to get done,” and then start to worry about finding the resources to accomplish that objective. As a result, entrepreneurial decision makers feel less constrained by the lack of resources. They are famous for making “seat-of-the-pants” decisions, which means they make quick decisions based on a good feeling or intuition. This kind of challenge requires different skills from the entrepreneurs than from the executives.

There was another interesting finding when I compared the decision-making practices of the executives and the entrepreneurs. Both groups relied quite heavily on analysis in the preparation phase of the decision-making process, which gave room for decision support applications. However, executives were ready to follow the decision support systems’ recommendations in the moment of choice while entrepreneurs preferred to follow their intuition. As a conclusion, we can state that entrepreneurs’ support must focus mainly on the preparation phase, and decisions should be made by them vs. support systems.

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KEY TERMS

Analytical Skills: The skills that most support the analytical approach in problem solving are determined as follows: analytical skills, computer skills, organising skills, professional expertise, problem-solving skills, and communication skills.

Intuition 1: Intuition is usually defined as knowing or sensing something without the use of rational processes.

Intuition 2: Intuition has been described as a perception of reality not known to consciousness, in which the intuition knows, but does not know how it knows.

Intuition 3: Intuition is a rational process in which an individual reaches a conclusion on the basis of less explicit information than is ordinarily required to reach that decision.

Intuition 4: Intuition is a nonsequential information processing mode, which comprises both cognitive and affective elements and results in direct knowing without any use of conscious reasoning.

Intuitive Skills: Intuitive thinking and problem solving are best supported by the following skills: the willingness to take risks, a sense for business, the ability to represent ideas, and practice-minded behaviour and expertise.

Nonprogrammed or Ill-Structured Decisions: Unique and unstructured decisions with long-term impacts are nonprogrammed decisions. Programmed and nonprogrammed decisions naturally set the two extreme poles of one continuum and the appearance of interim cases is much more probable. In the course of company operations, it happens very rarely that a decision situation clearly corresponds to the terminology of the programmed or nonprogrammed decisions. On the other hand, most managers develop some kind of practice for the handling of nonprogrammed-decision situations that can be successfully applied if a ready-made solution can be fitted to an actual situation. Certain nonprogrammed decisions may become programmed in the course of time in a company's practice. It is rather meaningful that programmed and nonprogrammed decisions are sometimes referred to as well-structured and ill-structured decisions as well.

Programmed or Well-Structured Decisions: Herbert Simon was the first to distinguish between the two extreme types of decisions. He called recurring, routine-like, or ready-made ones programmed decisions.

Strategic Decisions: Strategic decisions are those that affect the direction of the firm. These major decisions concern areas such as new products and markets, product or service developments, acquisitions and mergers, subsidiaries and affiliates, joint ventures, strategic alliances, finding a site for a new investment, reorganisation, and other important matters. Strategic decision making is usually conducted by the firm's top management, led by the CEO or president of the company.

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Section V

Organizational and Social Implications

This section includes a wide range of research pertaining to the social and organizational impact of strategic information systems around the world. Chapters included in this section analyze organizational knowledge management, e-collaboration, and group decision support systems. The inquiries and methods presented in this section offer insight into the implications of strategic information systems at both a personal and organizational level, while also emphasizing potential areas of study within the discipline.

Chapter 5.1

Group Decision Support Systems

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INTRODUCTION

Group decision support systems (GDSSs) which aim at increasing some of the benefits of collaboration and reducing the inherent losses are interactive information technology-based environments that support concerted and coordinated group efforts toward completion of joint tasks (Dennis, George, Jessup, Nunamaker, & Vogel, 1998). The term *group support systems* (GSSs) was coined at the start of the 1990's to replace the term GDSS. The reason for this is that the role of collaborative computing was expanded to more than just supporting decision making (Patrick & Garrick, 2006). For the avoidance of any ambiguities, the latter term shall be used in the discussion throughout this paper.

If we trace back, GDSSs are specialized model-oriented *decision support systems* (DSSs) or management decision systems that were born in the late 1960s. By the late 1970s, a number of researchers and companies had developed interactive information systems that used data and models to help managers analyze semi-structured problems. From those early days, it was recognized that DSSs could be designed to support decision makers at any level in an organization. DSSs could support operations, financial management, and strategic decision making.

BACKGROUND

In the early 1980s, academic researchers developed a new category of software to support group decision making. Execucom Systems developed *Mindsight*, the University of Arizona developed *GroupSystems*, and researchers at the University of Minnesota developed the *SAMM system (Power, 2003).* These are all examples of early GDSSs. The increased need for GDSSs arises from the fact that decision making is often a group phenomenon, and therefore computer support for communication and the integration of multiple inputs in DSSs is required. The desire to use GDSSs therefore comes from the need of technological support for groups.

GDSSs are designed to remedy the dysfunctional properties of *decision*-making *groups*. These systems are becoming popular in aiding *decision* making in many organizational settings by combining the computer, communication, and *decision* technologies to improve the *decision*-making process. These systems use a key tool to improve the quality of *decisions made by a group*. This key tool is the anonymity of members of a *decision*-making *group*. The purpose of GDSSs is to maximize the benefits of group work, while minimizing the dysfunctions of group work. This maximization and minimization can be made possible by GDSSs mainly by two factors: anonymity and parallelism.

MAIN FOCUS

Strengths and Weaknesses of GDSSs

GDSSs provide a lot of support for communication, deliberation, and information flow especially for group activities that may be distributed geographically and temporarily. Group work has numerous benefits and advantages. First, groups are better at understanding problems and catching errors than individuals. Second, a group has more information than any one member which when combined can create new knowledge. Third, working in a group stimulates creativity and synergy. Finally, groups balance out the risk-tolerant and risk-averse. GDSSs offer many benefits. First, GDSSs support parallel information processing, parallel computer discussion, and generation of ideas. Second, they promote anonymity, which allows shy people to contribute and helps prevent aggressive individuals from driving the meeting. Finally, these systems help keep the group on track and show the big picture. The two keywords here are parallelism and anonymity (Turban, Aronson, & Liang, 2005).

Some of the potential dysfunctions of group work are not automatically eliminated by GDSSs. First, as mentioned earlier, groupthink is where people begin to think alike and not tolerate new ideas. We can also include inappropriate influences, and free-riding. Second are the lack of coordination, excess time consumption, poor quality solutions, and nonproductive time. Third are the duplication of efforts, and high cost of meetings, including travel. Finally, information overload, concentration blocking, and group misrepresentation add to the potential dysfunctions of group work. Process dysfunctions are caused by structural characteristics of the group setting that could hinder a group from reaching its full potential. Process dysfunctions hinder productivity because of unequal participation or unequal air time; this happens in a setting where only one person can take control of the floor. This sort of dysfunction can be countered by the use of computerized exchanges because people may enter their comments and thoughts simultaneously. Power (2003) states that simultaneous expression of ideas may be beneficial for the quantity of ideas generated because of the computer's capacity for concurrency. Finally, process dysfunctions are usually caused by limitations in the structure and form of meetings.

Social dysfunctions, as Power (2003) describes, can hinder group productivity through undesirable social processes that occur in the group. For example, a group may limit the quality and quantity of input from any of its members by social processes such as evaluation apprehension, conformity pressures, free riding, social loafing, cognitive inertia, socializing, and domination due to status imbalance, groupthink, and incomplete analysis. These problems arise from processes present in all groups and are rooted in the ways in which group members change their behavior to adapt to the group. Finally, the prevalent analysis of group decision making is that social influences within the group lead the rational individual astray.

The view of GDSSs portrayed by Power (2003) is that they are text-based tools made with the purpose of remedying some problems of *decision* making in co-present *groups*. These *systems* claim to remove the social obstacles that prevent individuals from attaining their full potential in the *group*. Anonymity is central to achieving this full potential of individuals in a group.

Recent GDSSs Research Findings

Decision-making in an organization today has become more the work of some form of group. Whether this group is a board, team, or a unit, important issues can be at stake. It is fair to ask, given the possible problems that occur in a group setting: Would the group setting have a negative effect on the quality of decisions that have to be made by the group? Current research in this area suggests that GDSSs, if implemented and used correctly, can improve the quality of group decision making significantly by minimizing the negative effects of group decision making and by maximizing the benefits of group collaboration and decision making. Having come a long way since their inception, current and previous research efforts have made significant findings on the effects of the numerous criteria that affect the decision-making process in a group setting while using GDSSs. The results show that while the Internet has made it easier and less costly to use GDSSs than ever before, the social effects of group decision making can have a significant effect on the quality of decisions made in a group setting using GDSSs. By manipulating things such as visual cues, group versus individual-based incentives, anonymity, group size, feedback, leadership role, communication mode, type of tool used, social presence, face-to-face versus distant, shift work or non-shift work, the fit between facilitation style and agenda structure, and finally, a relationship versus a task focus, it is possible to significantly impact the quality off decisions made by a group using GDSSs.

According to Barkhi, Jacob, and Pirkul (2004), GDSSs are divided into two groups: distributed GDSS (DGDSS) and face-to-face GDSS (FGDSS). DGDSS groups consist of members who use a GDSS at the same time but at different places. On the other hand, FGDSS groups consist of members who use a GDSS at the same time and same place. The authors studied and compared the decision process and outcomes of groups that use FGDSS to those that use DGDSS. The results indicate communication mode, and incentive structure can influence the effects of each other. Therefore, the appropriate design of incentive structures may be important to the success of virtual organizations.

The *Web-based multi-criteria group support system* (MCGSS) according to Zahir and Dobing (2002) is designed so that users can enter their preferences in an easily understood and user-friendly interface through a Web browser. They state that easy-to-learn and user-friendly interfaces are essential if GDSSs are to become more commonly used in organizational decision making and that MCGSS uses a new visual mode of preference entry. The relative importance of any two objects is expressed through a pair of side-by-side bars drawn in a graphical window. The ratio of the heights of two bars represents the user's relative preference for the two objects. Bar heights can be adjusted dynamically by dragging the mouse or utilizing some other device. Their article presents the design of a Web-based MCGSS that can be used by a group of geographically dispersed decision makers. This system takes advantage of Internet technology and enables a novel procedure to aggregate intensities of preferences.

In line with Kim (2006), the role of leadership facilitates group processes by adding structure to group interaction. The effects of leadership on group performance in GDSSs settings still remains one of the least studied areas of GDSSs research. An analysis of comments by group leaders show that they are more efficient when making comments on group objectives and interaction structure, but this is only true in the early stages of group interaction. In the later stages, it is of increasing importance that group leaders make comments that encourage interaction and maintain cohesion between members of the group. Dennis and Wixom (2001/2002) presented a meta-analysis investigating five moderators. These moderators are as follows: tool, the type of group, task, the size of the group, and facilitation. The authors studied their effects on GDSSs. Results of the study draw multiple conclusions. First, process satisfaction is less for decision-making tasks than it is for the idea-generation tasks. Second, the GDSSs tool itself influences decision quality. Finally, the authors conclude that group size is an important moderator when it comes to measuring satisfaction with the process and decision time.

Rutkowski, Fairchild, and Rijsman (2004) demonstrated experimentally that in the context of dyadic conflict, patterns of interpersonal communication, supported by a particular GDSS technology, affect the quality of decision making. The authors find that GDSSs are efficient tools that support inter-group communication and relations. The authors also delve further into this topic and discuss the implications of their research on the study of intercultural negotiation and conflict resolution. Groups are becoming increasingly important in organizations, and that they use electronic groupware to facilitate communication and workflow. Barkhi (2005) compared the performance and information exchange truthfulness of groups under these various experimental conditions. The author utilizes a game theory perspective to study the behavior of members in these groups. The results indicate that communication channel and incentive structure mitigate strategies that lead to decision choices and information exchange truthfulness among members in a group.

GDSSs can improve communication and learning as demonstrated by Bandy and Young (2002). Their study examined the impact of two collaborative technologies and a priming agent upon communication complexity and learning style in a group decision-making context. Findings revealed that communication complexity was significantly greater in groups using a GDSS compared to groups using a simple chat system, suggesting that characteristics of the GDSS served to structure discourse among group members. Burke (2001) examined how GDSS learning environments (face-to-face vs. distant) and task difficulty level (simple vs. difficult) influenced participation levels and social presence among accounting students working collaboratively on an accounting task.

Hostager, Lester, Ready, and Bergmann (2003) examined the effects of agenda structure and facilitator style on participant satisfaction and output quality in meetings employing GDSSs. This study indicates that GDSSs facilitators should try to find a fit between their facilitation style and the agenda structure, while not forgetting to adopt either a relationship or a task focus and ensuring that they are consistent with their choice. A GDSS is designed as an analysis tool to support the decision processes of a group. Inherent in the design is the developer's desire to make the basic meeting process better either by increasing process gains or reducing process losses. Further, it is suggested by Martz and Sheperd (2003) that one way that GDSSs attack these losses is by providing immediate feedback.

GDSSs in the Real World

There are options for setting up GDSSs technologies. One of them is in a special-purpose decision room, another is at a multiple-use facility, and the third is a Web-based groupware with clients running wherever the group members are.

Facilitating Meetings

One example of the use of GDSSs is the system developed by a group of researchers from the University of Arizona to facilitate the organization of meetings. A typical meeting room consisted of a microcomputer for each participant, as well as a large projector for the display of either individuals' work or the combined results off the group efforts. A typical meeting consisted of a three-tier process consisting of electronic brainstorming, idea generation, as well as voting. Under the electronic brainstorming phase, all group members typed at separate terminals using electronic brainstorming software, and recorded their ideas regarding questions posed for the day. Even though these sessions were anonymous, everyone could see the abundance of ideas. Additionally, an issue analyzer assisted the group in identifying and consolidating key ideas generated from the idea generation. Finally, a voting tool provided various methods for prioritizing key terms. Here, even though voting is anonymous, the results are readily displayed for all to view. This GDSS by Nunamaker, Briggs, Mittleman, Vogel, and Balthazard (1996/1997) was used at an IBM site. It was found that process structure helps focus the group on key issues and discourages irrelevant digressions and unproductive behaviors.

Web-Based GDSSs

A Web-based GDSS is a GDSS built with Web technologies so that the users access with Eeb browsers through Internet connections (Chen et al., 2005). In addition, Web-based GDSSs applications that are developed by companies may be deployed on company intranets to support internal business processes or can be integrated into public corporate Web sites to enhance services to trading partners (Power & Kaparti, 2002).

Most Web-based GDSSs are currently individual DSS systems (Bharati & Chaudhury, 2004). On the contrary, Web-based *GDSSs* provide a broader approach to solving complex problems that are less structured. As noted earlier, there are a few Web-based GDSSs and one of them, *GroupSystems*, is a local area network-based client-server that exists for online collaboration (Chen et al., 2005). Several commercially available Web-based GDSS products also contain decision-making tools. One such product is *FacilitatePro 9.0*, which provides support to the group decision-making process with tools that facilitate brainstorming, idea generation, organization, prioritization, and consensus development (Facilitate.com, 2006).

Distance Learning

Several courseware packages facilitate distance learning. They range from such tools like *Blackboard*, through *Microsoft NetMeeting*, to *PlaceWare Virtual Classroom*. Distance learning can be an effective learning tool, and many corporations have taken advantage of it mostly through Web-based streaming and other private company intranets. Distance learning therefore acts as a strong collaborative and knowledge management tool and is accessible every hour of the day.

GSS for Political Events

The multi-faceted use of GDSS is reflected in the dynamism inherent in organizational structures. For instance, political risk associated with corporations' decisions to expand internationally could be alleviated using GDSS. This is because the key to analyzing political events is obtaining good information about these events. GDSS thus provides higher reliability in accessing this needed information, through anonymity, simultaneity, and documentation features that are lacking in face-to-face interactions. Among other advantages, anonymity offers participants a greater degree of freedom in expressing their thoughts, and presents them with a greater sense of confidence to be more critical. Blanning &

Reinig (2005) suggest a two-characteristic framework depending on whether analysis of the event under consideration is static or dynamic, as well as whether the analysis is one-dimensional or multi-dimensional.

FUTURE TRENDS

GDSSs are transforming into GSSs and the same ideology used for enhancing group meetings is being used in other areas as well. The idea is not just to increase the effectiveness of decision making, but to incorporate the current improvements in communication technology to redefine collaboration. Anonymity is also becoming more and more widespread in this new Internet culture; its effects on collaboration are very interesting as shown. The findings presented in this paper uncover the social effects that might affect group work. These findings can also be applied to other fields in which collaboration is experiencing growth as in education and social networking. By combing the Internet, emerging technologies, and the findings in social behavior as they relate to group work, with the exploding growth currently being experienced in communication, the results and the rate of introduction of new ways of collaborating will be absolutely amazing.

CONCLUSION

GDSSs, if implemented and used correctly, can improve the quality of group decision making significantly by minimizing the negative effects of group decision making and by maximizing the benefits of group collaboration and decision making. GDSSs have come a long way since their inception. Current and previous research efforts have made significant findings on the effects of the numerous criteria that affect the decision-making process in a group setting while using GDSSs. The results show that while the Internet has made it easier and less costly to use GDSSs than ever before, the social effects of group decision making can have a significant effect on the quality of decisions made in a group setting using GDSSs. By manipulating things such as visual cues, group versus individual-based incentives, anonymity, group size, feedback, leadership role, communication mode, type of tool used, social presence, face-to-face versus distant, shift work or non-shift work, the fit between facilitation style and agenda structure, and finally, a relationship versus a task focus, it is possible to significantly improve the quality of decisions made by a group using GDSSs.

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KEY TERMS

Distributed Group Decision Support Systems (DGDSS): Groups consisting of members who use a GDSS at the same time but at different places.

Face-to-Face Group Decision Support Systems (FGDSS): Groups consisting of members who use a GDSS at the same time and same place.

Group Decision Support System (GDSS): Can also be referred to as a GSS or an electronic meeting system. A GDSS is characterized by being used by a group of people at the same time to support decision making

Group Polarization: The tendency of people to become more alike or extreme in their thinking following group discussion. It is also the phenomenon that is generally considered decision bias.

Group Support Systems (GSS): Any combination of hardware and software that enhances group work. GSS is a generic term that includes all forms of collaborative computing.

Multi-Criteria Group Support Systems (MCGSS): GSS designed so that users can enter their preferences in an easily understood and user-friendly interface through a Web browser.

Social Presence: The degree to which people establish warm and personal connection with each other in a communication setting. Changes in the level of social presence can affect group communication.

Time/Place Framework: A framework for classifying IT communication support technologies. The matrix consists of four possibilities: same time/same place systems, same time/different place systems, different time/different place systems, and different time/same place systems.

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Chapter 5.2

Cooperative Decision Support Systems

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INTRODUCTION

The subject of our research aims to support in the most suitable way the collaborative decision-making process. Several scientific approaches deal with collaborative decision-making: decision analysis (Carlsson & Turban, 2002; Doyle & Thomason, 1999; Keeney & Raiffa, 1976) developing different analytical tools for optimal decision-making; in management sciences the observation of decision-making styles activity (Nuut, 2005; Fong, Wyer, & Robert 2003); decision-making as a group work (Esser, 1998; Matta & Corby, 1997); studies concerning different types of decisions focalised on number of actors: individual (Keeney & Raiffa, 1976), group (Shim, Warkentin, Courtney, Power, Sharda, & Carlsson, 2002), cooperative (Zaraté, 2005), and collaborative (Karacapilidis & Papadias, 2001). For the collaborative decision-making field, the situation is clear. In most of research studies, the concept of collaborative decision-making is used as a synonym for cooperative decision-making. Hence, the collaborative decision-making process is considered to be distributed and asynchronous (Chim, Anumba, & Carillo, 2004; Cil, Alpturk, & Yazgan, 2005). However, we can stand out several works, having different research approaches, considering collaborative decision-making process as multi-actor decision-making process, where actors have different goals. Considering (Panzarasa, Jennings, & Norman, 2002) the collaborative decision-making process is seen as “a group of logically decentralised agents that cooperate to achieve objectives that are typically beyond the capacities of an individual agent. In short, the collaborative decision-making has generally been viewed and modelled as a kind of distributed reasoning and search, whereby a collection of agents collaboratively go throughout the search space of the problem in order to find a solution." The main interrogation of this article is to study the best way to support collaborative decision-making process.

BACKGROUND

Many studies are based upon the work of Simon (Simon, 1977). Le Moigne (1990) develops the canonical model of decision-resolution process based upon the Simon's definition of the process. The working hypothesis adopted in this study is that "the decision can be represented as a work of symbolic computation," as Simon's model. The decision-making process, considered as a cognitive process of problem solving, is constituted of four main phases: intelligence, conception, selection, and review.

We notice that there have been changes influencing decision-making process (Teulier-Bourgine & Zaraté, 2001). Decision-making in organisation is becoming more and more multi-actor and complex. We could cite the work of Gorry and Scott Morton (1971) stating that the more one organisation is complex, the less are the chances that the decision will be taken by one single actor. Therefore, participants of one decision-making process have to integrate multiples points of view that are not necessarily in harmony. Due to the rapidly changing environment, every actor involved in a decision-making process has to augment his or her own vigilance and information research. Therefore, based upon the work of Simon, we propose a revisited decision-making process. The intelligence phase is becoming more complex and more active because of the environment to be taken into account. These changes have also influenced the decision-making progress. The actors have a prominent role of research of pertinence. Before these changes, the decision-makers have to search for efficient information in order to not forget important information; they must very rapidly sort out information that is very numerous. The conception step is also more frequent because every time the context is changing, every time the decision-maker must redesign a new solution.

The step of choice seems to stay the same because the very rapid sorting out process does not imply an alternatives generation and a systematic comparison among them and finally the choice of one of them.

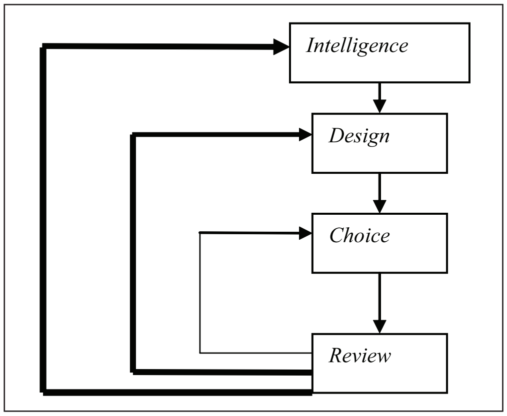
The review process is then modified. As shown in Figure 1, the two first steps are visited more often than the third one. Several iterations are necessary for decision-makers before the choice by itself.

Summarising, the revisited cognitive decision making process is composed by four steps: intelligence, design, choice, and review and the two forts steps are visited very often, the decision makers must sort out the information in a very efficient may.

This process being modified, the need of new kind of decision support systems is obvious.

We present a study developing different situations of collaborative decision-making process and give an overview of different support adequate in each case. We develop a matrix of collective decision-making process taking into account two criteria: time and space.

Figure 1. The revisited decision-making process of Simon (1977)



Our purpose is to define what a collective decision making process is.

Authors consider collaborative decision-making process as a multi-agent socio-cognitive process. Thus, they incorporate beliefs, goals, desires, intentions, and preferences in what they call mental modeling. Panzarasa, Jennings et al. (2002) formalise a model giving the insight in: a) the agent's mental states and processes and b) a range of social behaviours that lead them to solicit and take part in decision-making process.

The authors also adopt a prescriptive approach in order to give a set of possible actions in every step of collaborative decision-making. The model is developed using social mental shaping, the process by which the mere social nature of agents may impact upon their mental states and motivate their behaviour. Their collaborative decision-making model consists of four phases:

1. The practical starting-point
2. Group ideas generation
3. Social practical reasoning
4. Negotiation.

This developed model, as the authors state, "aims at developing the theoretical foundation of collaborative decision-making by using a formal language." The authors do not propose a concrete help for decision makers in this process. Moreover, they consider the collaborative decision-making process in an idealised world and not to be iterative. The process is socially oriented and "captures underpinning motivations and social processes of each stage."

In order to clarify this collective decision making process, we intend to propose a typology of it according to the different situations. Decision makers could work:

- In one hand at different places or not, and
- In another hand at different times or not.

We then can find different types of collective decision making process (see Figure 2).

Collective decision making situations and the corresponding supports are defined as follows:

1. Face to face decision making: different decision makers are implied in the decisional process and meet them around a table. This is a very classical situation and it could be supported by every kind of group decision support systems (GDSSs) as well as GDSSs rooms.
2. Distributed synchronous decision making: different decision makers are implied in the decisional process and are not located in the same room but work together at the same time. This kind of situation is enough known and common in organizations and it could be supported by every kind of electronic meeting systems (EMS), videoconferences, telephone meetings, and so forth.
3. Asynchronous decision making: different decision makers are implied in the decisional process and they come in a specific room to make decisions but not at the same time. The specific room could play a role of memory for the whole process and also a

Figure 2. Collective decision making situations

	Same time	Different times
Same place	Face to face decision making	Asynchronous decision making
Different places	Distributed synchronous decision making	Distributed asynchronous decision making

virtual meeting point. This kind of situation is well known in the CSCW field and some real cases correspond to it, but for decision making it have no intrinsic meaning for a physical point of view, we cannot imagine decision made in organisation in this way: it is the reason why this case has a grey bottom in Figure 2.

4. Distributed asynchronous decision making: different decision makers are implied in the decisional process and they do not necessarily work together at the same time and in the same place; each of them give a contribution to the whole decisional process. This is a new kind of situation and decision-makers must cooperate. For this purpose cooperative decision support systems must be designed.

Summarising, for us a collective decision making process is defined as a decision making process in which several decision makers are involved that could happen in three kinds of situations: face to face, distributed synchronous, and distributed asynchronous situations.

COOPERATIVE DECISION SUPPORT SYSTEMS

Several systems have been designed for this purpose. One of them is designed by Karacapidilis and Papadias (2001) and is called the Hermes. Therefore, they develop the Hermes system as a "generic active system that efficiently captures users' rationale, stimulates knowledge elicitation, and argumentation on the issues under consideration, while it constantly (and automatically) checks for inconsistencies among users preferences and considers the whole set of argumentation items asserted to update the discourse status." In this argumentation process, Karacapilidis and Papadias (2001) present the argumentation basic elements: issues, alternatives, positions, and constraints representing preference relations.

The field of cooperative decision-making processes is mostly addressing distributed and asynchronous situation. When addressing likewise defined cooperative decision-making processes, we can state several research approaches, mostly support oriented:

- Multi-agent support systems and
- Cooperative decision support systems.

Multi-agent systems are systems constituted of different information processes that are realised at the time, that is, of different living agents, using the common resources and communicating between them.

In his work Bui and Lee (1999) defines a software agent as "a program that performs a specific task on behalf of a user, independently or with little guidance. An intelligent agent performs, reactively and/or pro-actively, interactive tasks tailored to a user's needs without humans or other agents telling it what to do." Researches in the field of multi-agent systems supporting decision-making processes can be illustrated by several studies:

- Bui and Lee (1999) propose a framework for building decision support systems using agent technology. They propose taxonomy of agents' characteristics that can be used to help identify agent necessary to support different decision tasks. The authors propose a life-cycle for cooperative decision support building.
- Pinson, Louca, and Moraitis (1997) develop a general framework for building distributed decision support systems (DSDSS). The application is developed for strategic planning where "users intervene as human agents in the solution formation, and strategic knowledge and domain knowledge are distributed in different agents who communicate through various blackboards and message passing."

- Vahidov and Fazlollahi (2004) use agent technology for developing pluralistic multi-agent DSS. They develop a framework where agents are organised in groups according to the phases of the problem-solving.

As pointed out in the previous section and also by many other authors (Gachet & Haettenschwiler, 2001), the decision-making environment has changed. In order to support decision-making, the tools have to be able to support decisions in a dynamic environment that is rapidly changing and often distributed. Therefore, distributed decision support systems are defined by Gachet and Haettenschwiler (2001) as "a collection of services that are organised in a dynamic, self-managed, and self-healing federation of hard and software entities working cooperatively for supporting the solutions of semi-structured problems involving the contributions of several actors, for improved decision-making." This definition is based on several assertions:

1. A distributed DSS is not necessarily data intensive.
2. In a distributed DSS, two data units, which are not semantically related can always be physically stored in different storage devices.
3. A distributed DSS takes advantage of decentralized architectures.
4. A distributed DSS can survive on an unreliable network.
5. A distributed DSS enhances mobility.
6. A distributed DSS does not replace face-to-face meetings, it promotes and enhances them.

Other author defines collaborative decision support system (CDSS) as follows: "Collaborative decision support systems (CDSSs) are interactive computer-based systems, which facilitate the solution of ill-structured problems by a set of decision makers working together as a team." (Kreamer & King, 1998)

We find this definition very large and find it necessary to define the following architecture for these systems. Therefore, we propose a cooperative decision support framework. This framework is composed by several packages:

1. An interpersonal communication management system.
2. A task management system.
3. A knowledge management tool.
4. A dynamical man/machine interactions management tool.

This framework is described in Figure 3.

The interpersonal communication management tool is able, as in every kind of CSCW tool, to help users and decision-makers to very easily interact among themselves.

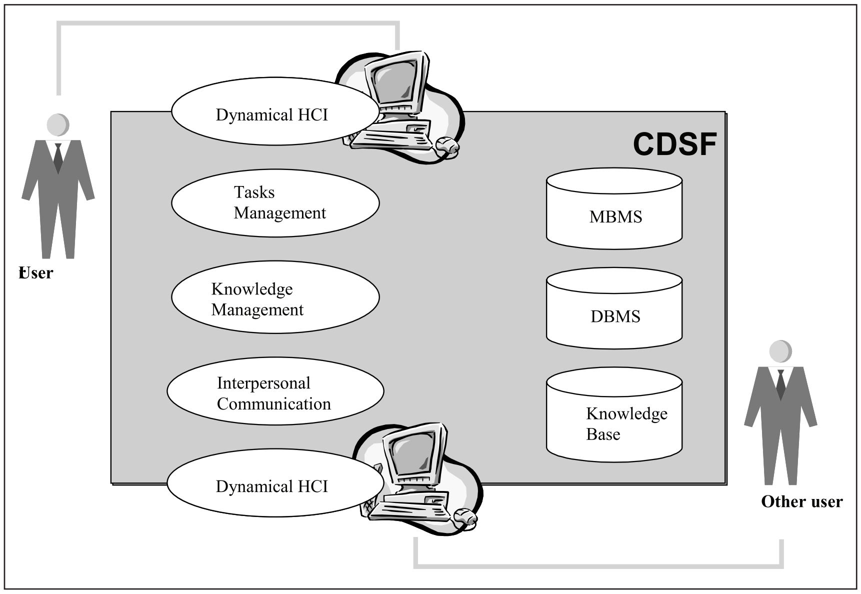
The dynamical man/machine interactions management tool guides the users in their processes of solving problems in order to solve the misunderstanding problems.

The knowledge management tool storages the previous decision made by the group or by other groups. The system proposes solutions or part of solutions to the group in very similar situations. In the case of a different situation, the system must be able to propose the solution the most appropriated and the users could accept it or not. This tool is based on a knowledge management tool and based reasoning tools.

Based on the DSSs' architecture defined by Sprague and Carlson (1982), the system includes also a data base management system, a model base management system. Nevertheless, this system is based on the development of knowledge based system and more particularly cooperative knowledge based system. Thus, the proposed system includes a knowledge base.

This tool is based on cooperative knowledge based system architecture. This cooperative knowledge based architecture is based on libraries of models: users' models, domain models (or problems models), and contextual models. The

Figure 3. Cooperative decision support framework architecture



calculation of the proposed solutions is based on several techniques: planning tools (Camilleri, 2000), linear programming (Dargam, Gachet, Zaraté, & Barnhart, 2004). The main usage principle of this kind of tool is based on the interaction between the system and the users. The system proposes a solution to the group, the group takes in charge some tasks and then the system recalculates a new solution and proposes the new one to the group and so forth. The problem or the decision to make is solved step by step, each actor (system and users) solving parts of the problem.

The part of the system for which the development is deeper is the task management system. This tool has for objective to propose solutions or part of solutions to users. It calculates the scheduling of tasks and sub-tasks and each role that is assigned to each task. It also proposes an assignment of tasks to users or to the system itself.

FUTURE TRENDS

The cooperative decision support system is a proposal of architecture rather than a complete software package. The fundamental principle of this proposal is to support the users in an integrated approach. The main contribution of this kind of tool is the possibility given to the user to solve a part of the problem. The system must be able to dynamically react, that is, taking into account the users' answers, it must recalculate and propose a new assignment of the tasks to solve, to the different users. This is possible thanks to the interactive planning of decisions to make or tasks to realise. Nevertheless, the human confrontation stays essential for decision-making. This confrontation is possible through a solid argumentation among the decision-makers. Thus, we underline the fact that the use of this kind of tool will be efficient only if it is going with a methodology of the cooperative decision-making process management.

CONCLUSION

We have shown that the collaborative decision-making is a complex process. In order to support it, several kinds of tools are necessary depending of the king of collective situations. New kinds of systems are necessary: cooperative decision support systems. These systems are generally defined by several authors as frameworks integrating several tools. The main point of these frameworks is that the system must be able to support dynamically, decision-makers by proposing an "intelligent" assignment of tasks among the involved actors: decision-makers and software seen as agents.

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KEY TERMS

Collective Decision-Making Process: Collective decision making process is defined as a decision making process in which several decision makers are involved that could happen in three kinds of situations: face to face, distributed synchronous, and distributed asynchronous situations.

Cooperative Decision Support Systems: Is seen as a framework in which several packages are necessary for supporting in an efficient way, decision makers involved in cooperative decision making process. This framework is composed by: an interpersonal communication management system, a task management system, a knowledge management tool, and a dynamical man/machine interactions management tool.

Revisited Cognitive Decision-Making Process: Is composed by four steps: intelligence, design, choice, and review and the two forts steps are visited very often, the decision makers must sort out the information in a very efficient way.

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Chapter 5.3

Supporting Distributed Groups with Group Support Systems:

A Study of the Effect of Group Leaders and Communication Modes on Group Performance

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ABSTRACT

The leadership role facilitates group process by structuring group interaction. How leadership affects group performance in GSS settings remains one of the least investigated areas of GSS research. In this study, the presence of a group leader is found to make a significant difference in objective decision quality and satisfaction with the decision process. At the same time, perceived decision quality and consensus are not significantly different in groups with a leader and those without one. A content analysis of comments by group leaders shows that group leaders are effective when making comments on clear group objectives and interaction structure in the early stages of group interaction. In the later stages, however, it becomes more important for group leaders to offer comments encouraging interaction and maintaining group cohesion.

INTRODUCTION

Group support systems (GSS) are information technology-based environments to support group activities that may be distributed geographically and temporally (Dennis, George, Jessup, Nunamaker, & Vogel, 1988). The objective of GSS is to increase the effectiveness and efficiency of group interaction by facilitating the interactive sharing of information among group members (Nunamaker, Dennis, Valacich, Vogel, & George, 1991). These objectives are accomplished by augmenting the group's information-processing capability, increasing participation, and improving communication by structuring the interaction with technology (Ho & Raman, 1991). In this respect, there are clear parallels between GSS studies and structured group interaction techniques, such as the nominal group technique and the Delphi method (Turoff, Hiltz, Baghat, & Rana, 1993), in which leadership and structured communication have been found to exert a significant influence on group outcomes. In fact, GSS research has a strong tradition of studying the effects of structuring group communication (Fjermestad & Hiltz, 1998-1999). Investigation into the impact of leadership on group performance, however, is seldom part of GSS studies (Briggs, Nunamaker, & Sprague, 1997-1998; Parent & Gallupe, 2001). Out of about 230 published papers on GSS, only 6% investigated the effect of leadership in GSS environments (Fjermestad & Hiltz, 1999).

Another little-explored area is the effect of distributed group support systems (DGSS) on dispersed groups, where all group members are geographically and/or temporally dispersed and interact asynchronously through computer-mediated communication systems (CMCS) (Turoff et al., 1993). Although there has been considerable research on communication behavior in face-to-face groups with GSS, there have been few efforts to verify the generalizability of face-to-face communication behaviors in distributed group settings or to investigate factors of computer-mediated communication that uniquely affect the performance of distributed groups (Fjermestad, 2004).

Synthesizing previous studies, Bordia (1997) reports several behavioral differences between groups with CMCS and those with face-to-face communication. The main reason for these differences is that in computer-mediated communication, the lack of social presences (Short, Williams, & Christie, 1976) affects the perception and interpretation of the meaning of the messages exchanged (Rice, 1984), making exchange of information among dispersed group members difficult (Hightower & Sayeed, 1996). This implies that communication support for distributed groups is necessary to overcome the potential problems with limited bandwidth and lack of social presences in CMCS (Hiltz & Johnson, 1990). In addition, the support for asynchronous communication with CMCS should include ways to support larger decision groups, improve the participation of uncooperative subgroups, and deal with critical mass activity phenomena (Turoff et al., 1993). To this end, this study was designed to look into the effects of leadership and communication structuring on group performance in asynchronously interacting distributed groups with CMCS. In the following sections, the literature on leadership and GSS is briefly reviewed, research design and methodology are explained, and research findings are discussed.

LEADERSHIP AND GROUP SUPPORT SYSTEMS

Leadership, by its very nature, is the process of directing and coordinating group interaction (Jago, 1982). According to path-goal theory (House, 1971), a leader affects group performance by clarifying the path to the group's goals, reducing obstacles that prevent the group from reaching these goals, and trying to increase the group's satisfaction as it works toward achieving its goals. In doing so, a leader may define objectives, maintain goal direction, provide the means for goal attainment, provide and maintain group structure, facilitate group action and interaction, maintain group cohesiveness and member satisfaction, and facilitate group task performance (Roby, 1961; Schutz, 1961). Leaders also establish and maintain the link between satisfaction and group performance by employing different leadership styles whose effectiveness can be moderated by the nature of the task, which may account for variance in group performance of more than 50% (Hirokawa & Poole, 1986).

The study of leadership in GSS research also sees leadership as the process of directing and coordinating group interaction. In this research, leadership is considered to be another layer of the group interaction structure (George, Easton, Nunamaker, & Northcraft, 1990; Hiltz, Johnson, & Turoff, 1991) that uses GSS tools to dictate who can say what and when. But the effect of leadership in GSS still remains largely unexplored (Ho & Raman, 1991; Briggs et al., 1997-1998; Parent & Gallupe, 2001), particularly in DGSS settings. In fact, leadership effects have been investigated in just under 10% of the GSS studies (Fjemestad & Hiltz, 1998-1999). One reason is the lack of GSS software tools to support leadership functions. Since GSS research depends on software tools, as Turoff, et al. (1993) argue, there should be more efforts to develop GSS software tools to support the roles of leaders in GSS-supported groups. However, it is difficult to develop software tools that may replace/support the leadership role without understanding the behavior of leaders in GSS settings.

The majority of GSS leadership studies argue that leadership alone rarely affects group outcomes, although it may do so in group performance in interaction with other variables. This is probably the case, because the effect of a group leader is offset by the GSS tools used, where leadership itself is another GSS tool for interaction facilitation (Hiltz et al., 1991; Briggs et al., 1997-1998). This means that leadership alone does not have a significant impact on group performance. Rather, leadership in GSS settings is a moderating variable that affects group outcomes in conjunction with other variables such as anonymity (George et al., 1990; Sosik, Avolio & Kahai, 1997), communication channel (Barkhi, Jacob, Pipino, & Pirkul, 1998), and other GSS tools used (Ho & Raman, 1991; Lim, Raman, & Wei, 1994). Therefore, caution should be exercised when adopting leadership as a complement to GSS tools in GSS-supported groups. When care is not taken, it could negatively affect group performance by creating too restrictive of an interaction structure (Kim, Hiltz, & Turoff, 2002). One case study, in fact, does report the failure of the use of GSS when the leadership style collides with the GSS arrangement (Parent & Gallupe, 2001). A few other studies demonstrate the mediating effect of leadership in a GSS environment. Hiltz, et al. (1991) find that when statistical feedback is given by the system, groups without leaders perform better, while groups with leaders are less able to reach consensus. Ho and Raman (1991) corroborate that a leader in GSS settings may be effective only when a group needs to establish an interaction structure, because this structure is already available as a GSS tool. George, et al. (1990) observe that anonymous groups with leaders are significantly more satisfied with the decision process. Equal participation and consensus are more likely to be achieved, since leaders are highly influential and dominant over group members and their interaction (Ho & Raman, 1991; Lim et al., 1994).

What do these findings mean to asynchronously interacting groups through CMCS? Can these findings be extended to distributed groups in order to improve their performance? The answer may be no. All these findings are context-specific, not replicated in other studies, and found mostly with face-to-face groups. Still, the way leaders work in CMC settings remains unstudied (George & Sleeth, 2000). To date, Kim, et al. (2002) is the only GSS leadership study with fully distributed groups with CMCS. Although Hiltz, et al. (1991) and Barkhi, et al. (1998) investigated the leadership effect with distributed groups, the group distribution was limited to groups meeting at the same time but in different places. In this regard, a study was designed, as in Figure 1, to investigate how leadership would affect the performance of distributed groups in conjunction with communication modes.

HYPOTHESES DEVELOPMENT

Decision Quality

GSS research has shown clearly that the communication mode has a positive impact on a group's decision quality. The impact of leadership in previous GSS studies, however, is inconsistent. The

Figure 1. Research design

impact either was not measured (Ho & Raman, 1991; Lim et al., 1994), tested insignificant (George et al., 1990), or reported significant (Hiltz et al., 1991; Tan, Wei, & Lee-Partridge, 1999). In GSS research, because most tasks chosen for studies are preference tasks, decision quality generally is measured using either the perceptions of a panel of experts or the responses to a questionnaire. Perceived decision quality, however, rarely measures decision quality itself. Tan, et al. (1999) assert that perceived decision quality measures decision confidence, which is the degree to which group members are sure that they have arrived at an appropriate group decision. The nature of the experimental task in this study, however, allows objective decision quality as well as perceived decision quality to be measured.

Objective Decision Quality

H1a: Groups with a leader will make better decisions than groups without a leader.

H1b. Parallel communication groups will make better decisions than sequential communication groups.

Perceived Decision Quality

H2a: Groups with a leader will perceive that their decisions are better than groups without a leader.

H2b. Parallel communication groups will perceive that their decisions are better than sequential communication groups.

Consensus

Consensus refers to the degree of support among group members in synthesizing divergent and mutually conflicting ideas during interaction. The level of consensus indicates what happens during group interaction. Consensus also measures the degree of the acceptance of a decision and the commitment to it (Dess & Orieger, 1987; McGrath, 1984) and the level of effective completion of preferred tasks (Tan et al., 1999). Thus, when implementing a decision is more important than reaching a correct decision, consensus as the measure of the acceptance of a decision should take precedence over objective decision quality (Dickson, Lee-Partridge, & Robinson, 1993).

Leadership in GSS settings generally shows no significant impact on consensus. Ho and Raman (1991) indicate that a leader in an unsupported or unstructured group has more influence on consensus, but the leader's effectiveness may be canceled out when another process structuring mechanism is present (Hiltz et al., 1991). These findings suggest that leadership may be more important when a group needs to establish a structure for interaction. Hiltz, et al. (1991) also found that asynchronously interacting groups through CMCS tend to be more task-oriented and, therefore, generate a lower level of consensus than face-to-face communication groups. This suggests that the influence of leadership on consensus in dispersed groups should be significant, because asynchronous interaction through CMCS requires more structure in order to coordinate its activities (Turoff et al., 1993).

With regard to the communication mode, the sequential communication mode is likely to show a higher level of consensus, because it provides a more focused interaction than the parallel communication mode. In interacting through CMCS, where social presences already are missing, groups interacting in the parallel communication mode, by allowing discussion on all topics, may have difficulty maintaining group cohesion (Turoff et al., 1993), which easily could lead to a low level of consensus.

H3a: Groups with a leader will show a higher level of consensus than groups without a group leader.
H3b: Sequential communication groups will show a higher level of consensus than parallel communication groups.

Participation

One or a small number of individuals generally dominate a discussion when there is unsupported group interaction. This may lead to lower decision quality and less effective group performance (Hiltz et al., 1991; Tan et al., 1999). GSS generally can ensure equal participation (Fjermestad, 2004). This is because GSSs diminish the potential for dominance by an informal leader by filtering out certain interpersonal cues and regulating the frequency and duration of speaking, which is linked empirically to the emergence of an informal leader (Culnan & Markus, 1987). Therefore, group leadership in GSS is likely to have a positive influence on equal participation. At the same time, participation is expected to be less equal with the parallel communication mode, because when group members are allowed to discuss any of the topics when they see them, individuals may speak with greater frequency and for longer periods of time.

H4a. Participation will be more equal in groups with a leader than in groups without a leader.
H4b. Participation will be more equal in sequential communication groups than in parallel communication groups.

Satisfaction with the Decision Process

Satisfaction refers to morale, loyalty, or any other manifestation of individual contentment with group outcomes and processes. It is important to measure the level of satisfaction, because it clearly is related to group consensus, productivity, general performance, and effectiveness. Satisfaction also includes attitudinal changes, either positive or negative, toward GSS and the willingness of members to work again.

Findings on satisfaction with the decision process in GSS-supported groups are mixed. Some research results report higher satisfaction with the decision processes in GSS-supported groups (Easton, George, Nunamaker, & Pendergast, 1990). In other studies, however, either no difference or lower satisfaction is found in GSS-supported groups (Chidambaram & Jones, 1993). Findings on the impact of a group leader on satisfaction with the decision process also are inconsistent. While George, et al. (1990) find no impact, Hiltz, et al. (1991) and Tan, et al. (1999) observe that satisfaction with the decision process is significantly higher in groups with leaders.

H5a: Satisfaction with the decision process will be higher in groups with a leader than in groups without a leader.
H5b. Satisfaction with the decision process will be higher in parallel communication groups than in sequential communication groups.

RESEARCH METHODOLOGY: CONTROLLED EXPERIMENT WITH 2 X 2 FACTORIAL DESIGN

Operationalization of Independent Variables

A group leader selected by group members during a training session is given the flexibility to change any interaction rules or structure, as necessary. In groups with a group leader, these rules and structure thus are not adhered to strictly during the experiment. Groups without a leader, however, are asked simply to adhere to the given interaction rules and structure; they do not have flexibility to modify them.

Communication structuring is arranged in two different modes: parallel and sequential. Generally, research on the impact of communication structuring compares the parallel communication mode through CMCS in GSS-supported groups and the sequential communication mode of turn-taking in face-to-face groups. What is different in this study is the control of human parallel processing (Gray, 1988). With human parallel processing, all group members contribute at the same time in an effort to eliminate communication inefficiencies, such as airtime fragmentation or production blocking (Nunamaker et al., 1991) of sequential face-to-face communication. In both the parallel and sequential communication modes in this study, human parallel processing always is allowed, because all communication takes place through CMCS. The difference between the parallel and sequential communication mode, as operationalized for the experiment, is the difference in the number of discussion items open for group discussion at a time. In the parallel communication mode, all discussion items are open concurrently to the group from the very beginning, until the experiment is completed. All group members concurrently discuss any topic at any time in any order throughout the experiment. In the sequential communication, when the experiment begins, groups are informed of all of the topics to discuss during the experiment. However, groups discuss one topic at a time sequentially. Once a group moves to the next discussion topic, it may not revisit previously discussed topics. This step-by-step communication leaves no freedom to deviate from a system-defined linear interaction procedure.

Experimental Task

The task developed for the study is the Investment Club Task (Kim et al., 2002). In performing this task, participants attempt to maximize their portfolio value by agreeing to invest in at least one but no more than three stocks out of 15 candidate stocks to be held for at least six months. Basic information about each stock is provided, and group members are free to gather additional information from any source. The task in a GSS experiment study is usually one of McGrath's Circumplex Task Types (McGrath, 1984). The problem with this task classification is its insistence upon the mutually exclusive categorization of tasks based on performance processes (Rana et al., 1997). The investment club task, however, has characteristics of both Intellective and decision-making task types (McGrath, 1984). It has the characteristics of a decision-making task, because when a decision is made at the end of the experiment, there is no way to have objective knowledge of the decision quality. On the other hand, after the decision horizon is reached (at least six months after the experiment), objective decision quality can be evaluated by measuring actual changes in stock prices.

Subjects

There were 212 subjects in 47 groups in this experiment. The subjects were recruited from universities in the New York area. All subjects were enrolled in undergraduate or graduate-level MIS classes. During the recruiting session, the subjects filled out preexperiment questionnaires; were assigned to groups of five; and were scheduled for a one-hour, face-to-face training session. After the training session, groups were assigned randomly to experimental conditions. In a few groups, however, the experiment was conducted with three or four subjects due to dropouts during the training session. The subjects' backgrounds are summarized in Table 1.

Nunamaker, Briggs, Mittleman, Vogel, and Balthazard (1996-1997) argue that established groups of managers perform far better than the student subjects used in most GSS experiment studies. An advantage of using student groups, however, is the accessibility to a larger pool of subjects with little variances in their ages, education, or business experience that would enhance the statistical power in testing hypotheses. The use of student subjects can be justified, because when training is given to ad hoc groups before an experiment, ad hoc groups seem to perform as well as established groups (Mennecke, Hoffer, & Wayne, 1992).

Technology and Training

Electronic Information Exchange System 2 (EIES 2) was used for this experiment and modified to add experiment-specific procedures and rules. EIES 2 is one of the major GSS research tools (Fjermestad & Hiltz, 1998-1999) and is used frequently in conducting asynchronous experiments for DGSS research. It is similar to many group communication support systems now available for use through the Internet. To minimize the problems associated with student subjects, a week-long asynchronous online training session with EIES 2 was given to all subjects, beginning with a one-hour, face-to-face session. All the subjects in a training group were assigned to the same experimental group. During training, all subjects were introduced to the system's features and experimental formats. Each group then selected a group leader, who would serve as the group leader if the group were assigned to the with-a-group-leader condition in the experiment.

Administration of the Experimental Procedure

The experiment continued for two weeks. The experimental procedures were constructed by arranging discussion items, and the details are summarized in Table 2. There was no face-to-face session during the experiment. Each group member had to respond to each topic before seeing the responses of others or joining the discussion on the topic. All interactions took place asynchronously through EIES 2.

Table 1. Subjects' backgrounds

Number of Subjects: 212			
Majors:		**Experience with EIES:**	
Information Systems	43%	Frequent Users	52%
Management	54%	Occasional Users	28%
Others	3%	Never Used	20%
Degree Enrolled:		**Investment Experience:**	
BA/BS	30%	Yes	43%
MS/MBA	68%	No	57%
Ph.D.	2%		

FINDINGS AND DISCUSSION

Statistical Measures

Except for the objective decision quality, all other dependent variables were measured by composite variables of multiple questionnaire items. A composite variable was used to test a hypothesis only when Cronbach's Coefficient Alpha was higher than 0.8. Because of the unequal number of subjects and groups for each experimental condition, the General Linear Model procedure was used instead of ANOVA for hypothesis testing. Whenever an interaction effect was significant, Fisher's Least Significant Difference Test (LSD) was used for pair-wise comparison of means among all experimental conditions. The results of the statistical analysis are summarized in Table

Table 2. Summary of administration of experimental conditions

		Communication Mode	
		Sequential	**Parallel**
Presence of Group Leader	**With Leader**	• **Discussion Items Presentation:** Sequential • **Transition:** Sequentially as decided by leader's one item at a time • **Leader:** Allowed to modify procedures • **Revisit:** Not allowed for previously discussed items	• **Discussion Items Presentation:** Parallel • **Transition:** No transition required; all items open throughout the experiment • **Leader:** Allowed to modify procedures • **Revisit:** Allowed for all items at any time
	Without Leader	• **Discussion Items Presentation:** Sequential • **Transition:** Sequentially by time table, one item at a time • **Leader:** No group leader • **Revisit:** Not allowed for previously discussed items	• **Discussion Items Presentation:** Parallel • **Transition:** No transition required; all items are open throughout the experiment • **Leader:** No group leader • **Revisit:** Allowed for all items at any time

Table 3. The results of the statistical analysis

Independent Variable: Group Leader

	Means				
Dependent Variables	**With**	**Without**	**SS**	**F**	**Pr > F**
Objective Decision Quality (H1)					
*After Six Months **	27,992	25,580	66,330,15	4.690	0.0360
*After One Year ***	31,702	29,515	55,524,8	3.240	0.0789
Perceived Decision Quality (H2)	27.32	26.84	2.766	0.400	0.5293
Consensus (H3)	11.57	10.90	4.727	2.19	0.1463
Satisfaction with Decision Process (H6) *	6.62	7.70	12.367	6.400	0.0152

Independent Variable: Communication Structuring

	Means				
Dependent Variables	**Parallel**	**Sequential**	**SS**	**F**	**Pr > F**
Objective Decision Quality (H1)					
After Six Months	26,994	26,638	1,290,644	0.094	0.7461
After One Year	30,818	30,454	1,290,661	0.070	0.7918
Perceived Decision Quality (H2) *	27.94	26.29	36.160	5.260	0.0268
Consensus (H3)	11.66	10.85	7.716	3.57	0.0655
Satisfaction with Decision Process (H6) *	6.67	7.61	10.368	5.350	0.0255

** Significant at α= 0.05; ** Marginally significant at α= 0.10 Degree of Freedom: Model = 1; Error = 43*

3, and a summary of the hypothesis testing is in Table 4.

Discussion

Objective decision quality was measured twice by comparing the dollar values of portfolios in six months and one year after the experiment, and perceived decision quality at the end of the experiment with the questionnaire. Although it did not play any significant role in perceived decision quality, the presence of a group leader significantly improves the objective decision quality after six months and after one year. The leadership variable was expected to have an impact on group performance in interaction with another variable (George et al., 1990; Hiltz et al., 1991; Ho & Raman, 1991)—communication mode in this study. However, there was no interaction effect with the communication mode on objective decision quality.

Although it made no significant difference in objective decision quality, the communication mode had a significant impact on perceived decision quality. Parallel communication groups felt that they made significantly better decisions than sequential communication mode groups (F=5.26 and p=0.0268). This finding can be explained by the preference for procedural order construct (Putnam, 1979), which states that individuals enter groups with a predisposition for particular work habits, ranging from tightly organized procedures to loosely structured ones. In making a decision in a group, all group members have implicit cognitive maps for structuring group activity that interacts with the group's contingency factors that influence group performance. These cognitive maps are relatively inflexible, regardless of their previous success or failure. Satisfaction with the decision process may have resulted from the fact that in the parallel communication mode, group members were able to rearrange the sequence of topics in a way that was compatible with their cognitive maps. Hence, they gave a high rating to perceived decision quality, which is correlated highly with satisfaction with the decision process. Indeed, perceived decision quality was found to correlate highly with satisfaction with the decision process ($\rho=0.7718$). On the other hand, group members with the sequential communication mode might have had a conflict with a GSS-enforced decision procedure, if it was not their preference. This preference for procedural order also was confirmed in the study of how group members appropriate and react to GSS technology and structured heuristics (Wheeler & Mennecke, 1992).

Another finding on decision quality is the relationship between objective and perceived decision quality. Although objective and perceived decision qualities were not expected to be

Table 4. Summary of hypotheses testing

	Group Leader	**Communication Mode**	**Interaction**
Objective Decision Quality	W > O (6 months) W > O (1 year)	–	–
Perceived Decision Quality	–	P > S	PO > SO^M
Consensus	–	P > S^M	–
Participation	W > O	–	PW >SW > SO > PO^M
Satisfaction	W > O	P > S	SW > SO

Communication Structuring: P: *Parallel*, S: *Sequential*
Group Leader: W: *With a Leader*, O: *Without a Leader*
^{M}: *Marginally Significant*

different (Gopal, Bostrom, & Chin, 1992-1993), Pearson's Correlation Coefficient Rho between perceived and objective decision qualities was –0.0604. This simply indicates no correlation between them. The significance of this finding is that perceived decision quality cannot be used as a surrogate measure for objective decision quality in all situations. It must be used with caution. Any study that measures only perceived decision quality must make clear why objective decision quality cannot be measured. It also should state how perceived decision quality can be used as a surrogate measure for objective decision quality. Otherwise, the findings of studies will be misleading. Failure to distinguish clearly between perceived and objective decision quality may have contributed to inconsistent findings on decision quality in previous GSS research.

With regard to satisfaction with the decision process, there are significant differences in the communication mode and the presence of a group leader. Parallel communication mode groups reported a higher level of satisfaction with decision process than sequential communication groups, while groups with a leader reported a higher level of satisfaction with decision process than groups without a leader. Further analysis with Fisher's LSD indicates that sequential communication groups with a leader report a higher level of satisfaction with the decision process than sequential communication groups without a leader.

One important finding in satisfaction measure is that parallel communication groups generally indicate a higher level of satisfaction than sequential communication groups. The results of satisfaction with the decision process are particularly interesting. Because of novelty effect (Watson, DeSanctis, & Poole, 1988), parallel communication groups were expected to show a lower level of satisfaction with the decision process. These groups, however, reported higher satisfaction than sequential communication groups with more commonly used face-to-face interaction. It appears that as the use of multiple topics and multiple-participant CMCS such as e-mail or instant messengers becomes pervasive, sequential communication no longer may be the preferred mode of communication, thereby dissipating the novelty effect. This opens up a new avenue for the use of GSS in different settings where it may be used as a knowledge management tool or organizational memory and not be limited to task-oriented groups or decision-making groups.

The equality of participation was measured objectively, by counting the number of groups in which an informal leader emerged, and subjectively with a questionnaire. The emergence of an informal leader was used as a surrogate measure for equal participation because it is linked to participation rate (Mullen, Sales, & Drisekll, 1987), and the rule of 50% or more comments than the group's average was used to determine the emergence of an informal leader (Hiltz, Johnson, & Turoff, 1982). The communication mode made no significant difference in either case. However, the number of groups where informal leaders emerged was significantly lower in groups with a leader than in groups without a leader. Ho and Raman (1991) and Lim et al. (1994) argue that the emergence of informal leaders is low in groups with a formal leader who tends to dominate the group process. This may impede a group member from accumulating idiosyncrasy credits that eventually can confer leadership status (Hollander, 1974). For the subjective measure of equal participation, neither the communication mode nor the presence of a group leader made any difference. All groups felt that participation was equal. This finding is in line with previous findings that CMCS increases the level of equal participation by reducing or eliminating the social influence of communication (Steiner, 1972).

The simple presence of a leader, however, did not make much difference. What was more important was whether leaders properly performed their leadership roles. To investigate the group leaders' performances, the contents of the group leaders' comments were analyzed to determine

Table 5. Average number of comments by group leader by content

Condition	Content Category				N. Items	N. CMT.	T.CMT	Percent
	DFN	*SRT*	*FCT*	*MTN*				
Sequential	1.3	3.8	6.1	2.3	11.6	10.8	25.3	41.7%
Parallel	3.3	5.2	6.3	3.2	13.6	12.3	24.8	51.1%

Content Category:
DFN: the number of comments on defining objectives
SRT: the number of comments on providing structure
FCT: the number of comments on facilitating interaction
MTN: the number of comments on maintaining the group
N.Items: the sum of the number of DFN, SRT, FCT, and MTN
N.NMT: the number of comments where content category appeared
T.CMT: the total number of comments generated by a group leader
Percent: the percentage of N.HMT over T.CMT

whether they were task-related or leadership-related, as summarized in Table 5. In doing so, all leadership-related comments were classified as being in one of the content categories based on previous studies of leadership functions (Roby, 1961; Schutz, 1961): defining objectives, providing interaction structures, facilitating interaction, or maintaining group cohesion.

Of these, the category *providing interaction structure* shows the greatest difference in terms of the average number of comments between group leaders in parallel communication groups (5.2 comments) and those in sequential communication groups (3.8 comments). It appears that for groups interacting through CMCS, there is a need to provide a certain number of interaction requirements. In parallel communication groups, group leaders were effective in dealing with what could have been chaotic interaction due to the lack of social presences and concurrent discussion. They did so by providing more interaction structure, such as initiating further discussion on some topics or summarizing and pointing out explicit differences in the underlying assumptions of group members. Indeed, Ho, and Raman (1991) found that leadership in GSS settings appears more effective when there is a need to bring structure into group interaction. In sequential communication groups, where the interaction structure of what to discuss and when was known throughout the experiment, additional leader-initiated interaction requirements might have created too restrictive of an interaction structure, which negatively affects group performance (Kim et al., 2002).

The timing of each content category is also worth mentioning. In both sequential and parallel communication groups, group leaders tended to generate more comments on defining group objectives and providing interaction structure in the early stages of the experiment. The frequency of these comments diminished toward the middle of the experiment. On the other hand, group leaders started making comments on facilitating interaction and on maintaining a group shortly before the middle of the experiment and continued through the later stages of the experiment. It seems that in asynchronous interaction through CMCS, the role of a group leader in the early stages is to make clear the decision strategy by which group interaction is coordinated. As all group members come to understand the interaction requirements of the decision strategy, however, the role of a group leader tends to change to that of a facilitator. This facilitation encourages uncooperative members to improve their participation in order to increase group cohesiveness and to deal with the critical mass activity phenomenon associated with negative feedback, if the participation rate is too low (Turoff et al., 1993).

LIMITATION AND FUTURE RESEARCH

One limitation of the study was the training of groups before the experiment. The task given to all the training groups was the selection of a group leader to serve as a leader in the experiment. The selected leader was announced to groups in *with-a-leader* conditions at the beginning of the experiment. In groups in *without-a-leader* conditions, the selected leader was never announced. However, it is suspected that by selecting a group leader during the training session, the subjects in without-a-leader conditions may have participated in the experiment, subconsciously feeling the presence of a group leader. A different training task could have prevented this feeling in groups in without-a-leader conditions. Fortunately, however, not many of the leaders selected in training sessions emerged as informal leaders in groups in without-a-leader conditions.

This study can be extended further to examine the impact of different leadership styles in GSS settings. Leadership is a very complex construct for which a stronger theoretical basis is needed to develop software support for leadership and facilitation roles in DGSS and GSS, in general. Leadership might not be affected by GSS; however, the use of GSS may be affected by a leader, particularly by leadership style (Parent & Gallupe, 2001). For example, one study found that while interaction-oriented transformational leadership positively has amplified the effect of GSS anonymity on group potency and effectiveness, outcome-oriented transactional leadership did not (Sosik et al., 1997). Unfortunately, in this study, leadership styles were not controlled. Groups in the same experimental condition could have had different interaction environments because of the different leadership styles used by group leaders. In a future study with the group leader variable, it may be necessary to control different leadership styles rather than simply to adopt the with-and-without-a-group-leader conditions.

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ENDNOTE

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Chapter 5.4

Supporting Structured Group Decision Making Through System-Directed User Guidance:

An Experimental Study

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ABSTRACT

This article addresses an area which holds considerable promise for enhancing the effective utilization of advanced information technologies: the feasibility of using system-directed multi-modal user support for facilitating users of advanced information technologies. An application for automating the information technology facilitation process is used to compare group decision-making effectiveness of human-facilitated groups with groups using virtual facilitation in an experiment employing auditors, accountants, and IT security professionals as participants. The results of the experiment are presented and possible avenues for future research studies are suggested.

INTRODUCTION

Intelligent information technologies have demonstrated considerable potential in helping users more effectively utilize advanced IT applications. Indeed, their widespread use as components of help functions in software applications has made the appropriation process for such software considerably less taxing. On a more complex level, expert systems and other “advice-giving intelligent systems” have proven to be effective in such diverse fields as medicine and finance. Their potential as “explanation facilities” for assisting users in meaningful ways is well documented (Berry & Broadbent 1987; Shortliffe, 1976).

Several researchers have argued that intelligent systems may be the most significant technical contribution to the effective utilization of information technology (Crowston & Malone 1988, Johansen 1988). In the context of group decision making, a number of researchers have claimed that expert systems may hold the potential of transforming group decision support systems (GDSS) from merely "passive agents" that process and present group decision-making information, into "active agents" that enhance group interaction (Aiken, Liu Sheng, & Vogel, 1991, Ellis et al. 1988, Liu Sheng et al. 1989). Aiken, Liu Sheng and Vogel (1991) have asserted that the goal of integrating expert systems with group decision support systems should be in designing systems that facilitate simplified and enhanced group decision-making.

A number of research studies have demonstrated that system-directed user guidance holds the potential of replacing human facilitation for supporting group decision making. Limayem and DeSanctis (2000) found that automated facilitation could result in higher levels of understanding and improved perceptions of the group decision making process. In a follow-up study, Limayem (2003) compared human facilitation with automated facilitation and found that the latter was as effective as human facilitation in improving faithfulness of appropriation.

Wong and Aiken (2003) likewise demonstrated that automated facilitation could be as effective as expert facilitators—and better than novice-human facilitators—for idea generation and ranking tasks. However, their study did not consider the effect of using automated facilitation for providing structured decision-making support, or for affecting satisfaction levels of participants. Likewise, Ho and Antunes (1999) examined the effectiveness of an automated tool for meeting planning, but their results were inconclusive. Chalidabhongse et al. (2002) similarly studied the effects of an intelligent facilitation agent and found that their automated system resulted in greater group participation, more ideas generated, and less group distraction. However, the effects of automated facilitation on intellective tasks were not considered.

Still other studies have proposed integrating expert systems with group support systems but have not empirically tested the effectiveness of such systems. Aiken, Liu Sheng and Vogel (1991) examined potential synergies between intelligent systems and GSS and described a system which would effectively integrate the two technologies, but they did not empirically evaluate their system. Lopez et al. (2002) proposed the possibility of embedding facilitation features in group support systems, but likewise, no empirical study was conducted. Recently, Briggs, DeVreede and Nunamaker (2003) introduced their "thinkLets" concept designed to help systemize the GSS facilitation process, but did not empirically test it.

Because qualified facilitators are not always available or affordable, the need for automated systems that are capable of effectively replicating the human facilitator function is apparent. Moreover, by systemizing the facilitation process and ensuring its consistent replication, the benefits from advanced information technology use can be more predictable (Briggs et al. 2003).

This research addresses an area which holds considerable promise for enhancing the effective utilization of advanced information technologies: the feasibility of using system-directed guidance for facilitating users of advanced information technologies. An application for automating the information technology facilitation process is used to compare decision-making effectiveness of human-facilitated groups with groups using system-directed facilitation in an experiment employing auditors, accountants, and IT security professionals as participants. Comparisons of the two methods of facilitation are made on the basis of brainstorming effectiveness and user satisfaction.

DECISIONAL GUIDANCE

Directly related to the idea of system-directed facilitation is the concept of decisional guidance, or how decision support systems "enlighten or sway users as they structure and execute their decision-making processes" (Silver 1991). As such, decisional guidance can be thought of as one way in which the technology appropriation process is expedited to fully exploit a decision support system's functional capabilities: "Just as a DSS (decision support system) supports the judgments required enroute to making decisions, decisional guidance can support the judgments required in the course of operating the DSS" (Silver 1991, p.106).

The concept of decisional guidance for computer-based decision support was first advanced by Silver (1991) in his explanation of *when and why* decisional guidance should be provided, *how* system designers can build decisional guidance into DSS, and what the *effects* of providing it are. Limayem (1992) defined guidance in a GSS context as "the enrichment of decision models with cues that direct decision makers toward successful structuring and execution of model components." As such, guidance can inform groups as to what to do next (forward guidance), help groups resolve problems from prior activities (backward guidance), or in the case of preventive guidance, prevent disruptions that obstruct progress in group decision-making (Limayem 1992).

Silver asserts that decisional guidance should be provided when users need to make *discretionary judgments*, which is dependent upon how much discretion the system allows its user. Likewise, the decision to provide decisional guidance is primarily based on a desire to create a DSS that is more supportive and that assists users in exercising their judgment as they interact with the decision support system. Thus, the need for decisional guidance is dependent upon both the complexity of the DSS system, as well as the users' perceptions of the decision-making task.

The decision to provide user guidance, however, must be weighed against the possibility of overloading users with information, or in fact making the system more complex with an excessive amount of guidance mechanisms. Moreover, the guidance system should avoid directing users to a specific decision, but should instead attempt to influence how users reach a decision (Silver, 1991, pp. 108-109)

DSS design features can be structured to either directly influence how decisions should be made (directed change) or to provide users with a number of alternative capabilities from which to choose in their decision-making activities (non-directed change). A number of design strategies exist for doing so, ranging from highly restrictive DSS, to minimally restrictive DSS. In his earlier study on directed and non-directed change, Silver (1991) presents a broad set of objectives for determining the appropriate level of system restrictiveness.

While Silver established the primary framework for assessing the effectiveness of decisional guidance, he did not empirically examine the efficacy of providing it. Parikh, Fazlollahi, and Verma (2001) conducted an empirical evaluation of the effectiveness of various forms of decisional guidance in four areas: decision quality, user satisfaction, user learning, and decision-making efficiency. The study found that deliberate decisional guidance was more effective in all four areas. Suggestive guidance was found to be more effective in improving decision quality as well as user satisfaction, while informative guidance was determined to be more effective in improving user learning.

EXPERT SYSTEMS

Broadly related to the concept of decisional guidance is the functionality of expert systems, in that each is designed to guide IT users in some fashion. However, while decisional guidance relates to how systems "enlighten or sway" users as they utilize decision support systems (Silver, 1991), expert systems are designed to simulate human experts within a specific domain. As such, expert systems are artificial intelligence tools that support decision making by using a knowledge base and inference techniques. While decisional guidance can provide procedures explaining how to solve problems and why a certain solution is recommended in order to assist groups in their decision-making processes, expert systems attempt to replicate a human adviser (e.g., a group facilitator) and, if effective, can potentially replace them.

Turban and Watson (1986) examined various issues relating to integrating decision support systems and expert systems (ES), and presented two frameworks for integrating DSS and expert systems: ES integration into DSS components; and ES as an additional component of a decision support system. Among the benefits resulting from combining expert systems and decision support systems, are the following, as summarized by Turban and Watson:

- Assistance in selecting decision models
- Providing judgmental elements to models
- Providing heuristics
- Providing explanations
- Providing terms familiar to user
- Acting as a tutor
- Providing intelligent advice
- Adding explanation capabilities
- Expanding computerization of the decision-making process (Turban and Watson. p.124)

By replicating the manager-consultant-computer process, as advocated by Goul and Tonge (1987), an integrated DSS/ES can be designed to query users to determine the general category of a problem, the exact nature of a problem, and finally, suggest an appropriate model for solving the problem. By using expert systems as "consultants" to determine what to do in specific problem-solving situations, the complexity of using GDSS for group decision-making activities can be significantly reduced. Similar applications of integrating DSS and expert systems can include the provision of explanation capabilities to the DSS that allow users to follow the reasoning behind specific recommendations. By using terms that are familiar to the user as well as by providing tutoring to users, such integrated systems can significantly reduce the cognitive load placed on users of GDSS.

Also related to the concept of decisional guidance and expert systems is the concept of cognitive feedback, or feedback about an individual or collective decision-making process which is "provided interactively as an integral part of the individual and group processes" (Sengupta & Te'eni, 1993). In their study investigating cognitive feedback for improving control and convergence in computer supported group decision-making, cognitive feedback was found to increase cognitive control, resulting in uniformly high levels of cognitive control over time. Additionally, cognitive feedback was found to result in increased levels and degrees of collective control for group decision making. As hypothesized, groups receiving cognitive feedback were found to formulate group decision rules more frequently than groups not receiving cognitive feedback.

Dhaliwal and Benbasat (1996) proposed a model based on cognitive learning theories explaining the reasons and theoretical basis for providing system explanations for facilitating user learning, and a two-part framework and for examining the use of knowledge-based system (KBS) explanations.

Hayes and Reddy (1983) assert that explanations are needed for three principal reasons: explanations *clarify* particular intentions; explanations are intended to *teach*; and explanations are used to *convince*. Although clarifying, teaching and convincing can indeed increase the understanding of information systems users receiving the explanations, the question of whether such explanations actually result in better decision-making remains unclear (Dhaliwal & Benbasat, 1996, p.345).

Dhaliwal and Benbasat contend that only *task information* is effective in promoting learning, and, as such, it forms the "coherent theoretical basis" for the various types of explanations that KBS should provide, including the "explanations provision model" they propose. Moreover, the authors contend that three possible *explanation provision strategies* exist for designing knowledge-based systems: feedforward only, feedback only, or both feedforward and feedback.

Dhaliwal and Benbasat used MYCIN, one of the earliest expert systems developed in the early 1970s at Stanford University, to illustrate the use of feedforward and feedback explanations. For example, "why" explanations in MYCIN were feedforward and presented information explaining why a particular question was being asked of a user. "How" explanations provided information regarding the basis on which a specific conclusion was reached. Although no strategic explanations were provided by MYCIN, later versions (NEOMYCIN) provided such explanations using a combination of feedforward and feedback (Dhaliwal & Benbasat, 1996, p.352).

The automated facilitation application used in the present research provides various feedforward and feedback explanations designed to explain *why* a group decision-making procedure and/or GSS tool is being used and *how* the previous decision-making activity has influenced the current activity and/or GSS tool. As predicted in the system-directed facilitation model presented in the following, the provision of such explanations should lead to improved user understanding of the decision-making process, resulting in improved user satisfaction, in comparison to groups not receiving such explanations.

As discussed more fully later, the system-directed facilitation application provides explanations to participants who lack significant knowledge regarding the GSS system and the group decision-making processes employed in the experiment. Likewise, by virtue of their audio-based delivery, provision of the explanations is designed to require minimum cognitive effort to assess and assimilate.

FACILITATION

Also broadly related to the concept of decisional guidance is what Dickson, Partridge, and Robinson (1993) originally termed facilitative support, or "the manner in which GDSS users are supported in their utilization of group decision support systems." While decisional guidance is primarily related to how inanimate decision support systems (DSS) advise users as they execute the decision-making processes, facilitative support, and the more general term "facilitation," generally refers to the use of "facilitators" whose function is to direct group members regarding which GDSS features to use, as well as when to use them (Dickson et al., p.173).

Keltner (1990) proposed that the facilitator function is to ensure that all group members are able to fully participate in the decision-making process, and that the process is not dominated by a minority of group members. Ackermann (1990) asserted that external facilitators could help support cognitive processing by providing the group a structure in which to operate. As such, he believed that facilitators could enable the group to match specific modeling techniques to assigned group tasks more easily. Eden, Jones, and Sims (1983) believed that external facilitators could be used to improve a group's cognitive judgment by encouraging discussion of differences in group members' perspectives, reviewing the objectives of a particular task, and identifying inconsistencies among group members' perspectives. Kayser (1990) proposed that facilitators could help the group "free itself from internal obstacles or difficulties so that they more efficiently the effectively pursue the achievement of its desired outcomes (p.12-13).

In an early study of group facilitation, George, Dennis, and Nunamaker (1992) compared facilitated and non-facilitated groups using electronic meeting systems and found no significant differences between the groups in terms of alternatives generated, decision quality, satisfaction levels, or ability to reach consensus.

Anson, Bostrom and Wynne (1995) investigated the effects of human facilitation on group performance, group cohesion, and group interaction processes in group decision-making situations. Their study found that facilitated groups achieved improvements in group performance, interaction processes and group cohesion levels. Moreover, facilitation combined with GSS utilization, were found to enhance the effectiveness of group cohesion and group decision making processes. As such, facilitation was deemed critical in improving GSS effectiveness, especially for first-time users, and in situations where less restrictive GSS tools are used. Moreover, the quality of facilitation is believed to be a significant factor in improving group decision-making outcomes. Indeed, facilitators lacking proper skills may have minimal effects on improving outcomes.

Griffith et al. (1998) describe the facilitator's role as one of "improving a group's communication and information flow…to enhance the manner in which a group makes decisions without making those decisions *for* the group" (p.20). Nunamaker et al. (1997) list four functions normally provided by GSS meeting facilitators:

1. Providing technical support by initiating and terminating specific software tools and functions and guiding the group through the technical aspects necessary to work on the task.
2. Chairing the meeting, maintaining the agenda, and assessing the need for agenda changes.
3. Working with the group to highlight the principal meeting objectives and developing an agenda to accomplish them
4. Providing organizational continuity by setting ground rules for interaction, enforcing protocols and norms, maintaining the group memory repository, and acting as champion/sponsor (p.192-193).

The system-directed facilitation application used in the present study is designed to provide these four facilitator functions in providing GSS fit and appropriation support. As described more fully in the following section, the application is envisioned to provide technical support by offering a simplified tool selection interface, maintaining the agenda, highlighting principal meeting objectives, setting initial ground rules for interaction, and enforcing protocols through both audio and visual messaging.

As previously noted, Limayem and DeSanctis and others (Briggs, De Vreede & Nunamaker, 2003; Chalidabhongse et al. 2002; Ho & Antunes 1999; Lopez et al., 2002; Nunamaker & Zhao 2002; Wong & Aiken 2003) have expanded the concept of facilitation to include the use of "automated facilitation mechanisms" and "intelligent facilitation agents." Indeed, the terms "decisional guidance" and "automated facilitation" are sometimes used interchangeably to describe such software-directed group support and intervention mechanisms (e.g., Limayem, 2003; Limayem & DeSanctis, 2000).

In a survey of 45 experienced GSS facilitators, Bostrom et al. (1996) found that planning and designing a meeting agenda was significantly more important than all other facilitator functions. Other significant contributions of facilitators included matching GSS tools to the assigned task, adapting the meeting agenda is needed, clarifying meeting goals and agenda items; remaining focused on the outcome; and creating an open environment for anticipation. Traditional facilitator functions relating to managing group dynamics, such as building rapport and managing conflict were found to be significantly less important facilitator functions. The system-directed facilitation application used in the present study focuses primarily on planning and directing the meeting agenda, derived principally from Wheeler and Valacich's (1996) multiple activity group decision making heuristic.

In his definitive work on facilitators and their role in developing group effectiveness, Schwarz (1994) describes how facilitators can help improve the way that groups identify and solve problems and make better decisions by improving the manner in which group members work together. As he explains, facilitators can assume one of two roles. In basic facilitation, the facilitator guides the group in reaching an effective decision using the appropriate group process. In developmental facilitation, the facilitator teaches group members how to carry out specific processes for future problem-solving:

Schwarz's approach to facilitation is based on three values: "valid information, free and informed choice, and internal commitment to those choices" (1994, p.8). As opposed to changing group members' behaviors, he argues that the role of facilitators is to provide information to enable group members to decide *whether* to change their behavior, and if they choose to do so, to help them learn *how* to change (p.8). Schwarz asserts that for groups to become more effective, facilitators need to understand which factors contribute to group effectiveness, which factors detract from it, and how such factors can interact, in impacting group effectiveness, using a model built largely on the work of Hackman (1987) and Sundstrom, DeMeuse and Futrell (1990).

While Schwarz does not directly address the role the facilitator in the context of group support systems, his intimate knowledge of the group facilitation process, including his considerable experience in facilitating a number of diverse groups, offers valuable insights into the successful integration of group facilitation theory and practice.

Because the manner in which group members are facilitated during their utilization of a GDSS will have a "profound effect" on the outcome of GDSS use (Dickson et al., p.174) the most effective mode of providing GSS support is of critical importance. Specifically, the need for GDSS facilitation arises from two problems that must be addressed for groups using a GDSS system for the first time, namely:

1. GDSS users must "overcome the mystique" of using a new and unknown technology,
2. "A sound problem-solving process" used by the group in its GDSS interaction, including the application of the GDSS technology, must be provided (Dickson et al., p. 174).

As discussed in the following section, the automated virtual facilitation application was designed to provide task facilitative support, focusing primarily on which GSS tools to use, in addition to when and how to use them. The research framework is designed to evaluate the effectiveness of groups having such facilitation, in comparison to groups having operational facilitative support (chauffer-driven support) only.

Such "chauffer-driven" support is similar in nature to what Maier (1952) described as *free discussion* techniques, in which a leader poses a problem, then conducts the group discussion "in a permissive manner without making value judgments, but merely helps the group reach agreement on a solution" (p. 320). In comparison, the *developmental* technique for group discussion involves a leader who "breaks the problem into parts so that each part of the problem is discussed separately before the final decision is made" (Dickson, et al, p. 180). Maier found that the "developmental" approach was more effective than the "free" discussion approach in improving decision quality. In contrast, DeSanctis, D'Onofrio, Sambamurthy, and Poole (1989) found that restrictiveness did not lead to improved group consensus, and that excessive restrictiveness may indeed result in groups losing their "sense of ownership and control over the technology," resulting in lower levels of consensus.

As more fully described in the following section, the virtual facilitation application attempts to maintain the meeting agenda without being overly restrictive by requiring all group members to proceed to the next step in the multi-step decision-making process, thus granting each group member a veto power on proceeding to the next step in order to foster a more democratic decision-making process and one which helps ensure greater equality of participation.

METHODOLOGY

The present study examines the effectiveness of system-directed facilitation for supporting structured group decision making through an experiment involving internal auditors, information systems auditors, CPAs, and IT security professionals as participants. Specifically, system-facilitated teams using group decision support systems are compared to human-facilitated teams using GDSS in four areas of decision-making effectiveness: number of problems identified, number of solutions recommended, satisfaction with the decision-making process, and satisfaction with the decision-making outcome).

The number of problems identified and solutions recommended (Hypotheses 1 and 2) was determined by the number of such items submitted by each group for problem identification and solution recommendations. Scores for satisfaction with the meeting process and meeting outcome were calculated by adding the individual item Likert scores in the Briggs et al., (2003) post-session questionnaire, contained in Appendix A.

To distribute unique information among team members, a hidden-profile task was used. Hidden-profile tasks are believed to more accurately simulate real world situations in which relevant information for completing a task is known only by specific group members. In addition, a hidden-profile task does not state the specific problem for the group to solve, as is common with many tasks used in experimental research (Wheeler & Valacich, 1996, p.438).

A hidden-profile task requires all group members to participate and share information in order for the group to identify the pertinent problems and to develop a feasible solution. In a manner similar to the "School of Business Policy Task" used by Wheeler and Mennecke (1992), group members in the current study were required to identify as many IT security-related problems as possible, and to formulate as many recommendations as possible to address those problems. Different information is provided in each of the three case study roles, requiring effective information sharing among team members to successfully complete the assigned tasks.

Participants

Participants in the current study consisted of accountants, auditors, and IT security professionals in government, industry, and public practice, including CPAs, CIAs (certified internal auditors) and CISAs (certified information systems auditors). Participants received eight hours of continuing professional education (CPE) credit for attending a free day-long seminar entitled "Using COBIT for Complying with the Sarbanes-Oxley Section 404 Provisions" which was designed to cover many of the same IT security issues and information systems control objectives that were pertinent to developing appropriate recommendations for the assigned hidden profile task described in the previous section.

Procedures

In order to balance each set of teams on the basis of information systems audit expertise, participants were assigned to treatment groups based upon their level of previous IS audit experience, as reported during the registration period prior to the seminars. Participants were then randomly assigned to one of the three auditor roles of the hypothetical three-person audit team employed to investigate IT security issues.

Treatment group assignment was based upon the day the seminar was conducted (the first day

Table 1. Summary of participants by occupation

Occupation	Percentage of Total Participants
Certified Public Accountants	28%
Certified Internal Auditors/Internal Auditors	48%
IT Security Personnel	12%
Corporate Accountants and Controllers	12%

Table 2. Summary of treatment group participants by group size

Treatment Group	Total Participants
Human-Facilitated Groups	23
System-Facilitated Groups	22
Total Participants	47

of the seminars tested GSS-supported groups and the subsequent day tested unsupported groups). After participants were assigned to groups and then randomly assigned to one of the three auditor roles, each day's participants were read an identical series of introductory remarks, and were then read a series of instructions specifically tailored to each treatment group. They were then each given a specific version of the IT policy case based upon their audit team role

Human facilitated groups were instructed to complete their assigned group decision-making tasks using a prescribed agenda adapted from a group decision-making heuristic by Schwarz (1994) and consisting of problem identification, problem rating, problem drafting, solution brainstorming, solution rating, and solution drafting. Participants were also presented the normal introductory information regarding the GSS software that is typically given to participants before beginning their use of the GSS application.

System-facilitated groups were instructed on the required procedures before beginning the experiment. Participants were informed as to how the automated virtual facilitation application is used (see AVFA section), including the process of clicking an agenda item's hyperlink to hear that agenda item's instructions and subsequently completing the assigned tasks that were explained in the pre-recorded instructions. AVFA-supported groups were also informed that they would not be allowed to ask researchers or other groups for assistance, and that any problems that might occur would need to be resolved within their own group, or by using the user FAQs, or the leader FAQ's that were accessible through the AVFA software's homepage. Participants who had been assigned the "audit partner" role were designated as the team leader for each group. As such, they were required to perform the GSS management tasks that are normally carried out by the GroupSystems facilitator or "chauffer" (e.g., initiating GSS tool usage, transferring brainstorming results to the voting tool).

Automated Virtual Facilitation Application

The automated virtual facilitation application (AVFA) is a multi-modal application for prescribing GSS tools to ensure proper task-technology fit, and providing appropriation support for more effectively utilizing the underlying GSS technology. The AVFA application is used in the present research to investigate the effectiveness of virtual facilitation in comparison to conventional facilitation and unsupported group decision-making to determine whether virtual facilitation can be as effective as conventional facilitation in the areas of appropriation, efficiency, and effectiveness.

As previously discussed, the AVFA application is based primarily on operationalizing a multiple-activity group decision-making heuristic, similar to the one utilized by Wheeler and Valacich in their 1996 study. Indeed, the research design described in this chapter is to a large degree adapted from that study, including the incorporation of a hidden-profile task similar to the *School of Business Policy Task* (Wheeler & Mennecke, 1992) utilized in that study. Specifically, the automated facilitation application is intended to guide subjects in faithfully following the structured group decision-making heuristic, the sequence of which provides the basic structure of the AVFA software application. As recommended by the authors, a key extension of the present study is to test an *automated* version of a multiple activity group decision-making heuristic:

The AVFA application was designed to recommend GSS tools for the sequenced activities of the six-step heuristic by operationalizing the GSS fit profiles advocated by Zigurs and Buckland (1999) and Dennis and Valacich (1999). The multi-activity group decision-making heuristic used by Wheeler and Valacich (1996) and the problem-solving model presented by Schwarz (1994) incorporate findings from the behavioral literature regarding how heuristic structures can assist groups in overcoming common obstacles to effective decision-making, including separating divergent (idea generation) and convergent (choice) phases of group activity, and writing-out an agreed upon problem statement before working on a solution (Wheeler & Valacich, 1996, p.438). Specifically, the problem-solving model used in the present research incorporates the following two major goals and six sequenced activities:

Hypotheses

As previously noted, the present research was designed to assess the effectiveness of virtual facilitation for supporting structured group decision-making, As illustrated in Figure 1, the

Table 3. Two-step, multiple-activity group decision-making heuristic: Adapted from Schwarz (1994) and Wheeler and Valacich (1996)

Major Goals	Sequenced Activities
(1) Problem identification	Problem statement brainstorming (EB) Problem statement rating (Vote) Problem statement drafting
(2) Solution recommendation	Solution brainstorming (EB) Solution rating (Vote) Solution drafting
GSS Tool Abbreviations: EB = Electronic Brainstorming Tool, Vote = Voting Tool,	

virtual facilitation model posits that the assigned task characteristics will dictate established task-technology fit profiles (Dennis & Valacich, 1999; Zigurs & Buckland, 1999) and appropriate group problem-solving models (Briggs et al., 2003). These, in turn, will dictate appropriate GSS tools and group decision-making procedures ("meeting agendas") to be employed in completing assigned group decision-making tasks. Through this process, virtual facilitation is posited to result in efficiency levels, appropriation measures, and decision-making performance metrics that are equal to those achieved through conventional (human) facilitation.

Specifically, the current study posits the following:

H1: *System-facilitated groups will be at least as effective as human-facilitated groups in identifying problems.*

H2: *System-facilitated groups will be at least as effective as human-facilitated groups in recommending solutions.*

H3: *Satisfaction with the meeting process for system-facilitated groups will be at least equal to that of human-facilitated groups.*

H4: *Satisfaction with the meeting outcome for system-facilitated groups will be at least equal to that of human-facilitated groups.*

RESULTS

Hypothesis 1 posited that system-facilitated groups would be at least as effective as human-facilitated groups in identifying problems presented in the case study. As indicated in Table 4, while human-facilitated groups identified more problems and than system-facilitated groups, the difference was not found to be significant. Accordingly, the failure to reject the null hypothesis that system facilitated groups are less effective than human-facilitated groups resulted in the conclusion that system facilitated groups are at least as effective as human facilitated groups in this measure of brainstorming effectiveness.

Likewise, while human-facilitated groups recommended an average of 9.4 solutions per group, system-facilitated groups recommended an average 8.9 solutions, as indicated in Table 5. Accordingly, Hypotheses 2 (system-facilitated groups will recommend at least as many solutions as unsupported groups) was supported by

Figure 1. System-directed facilitation model

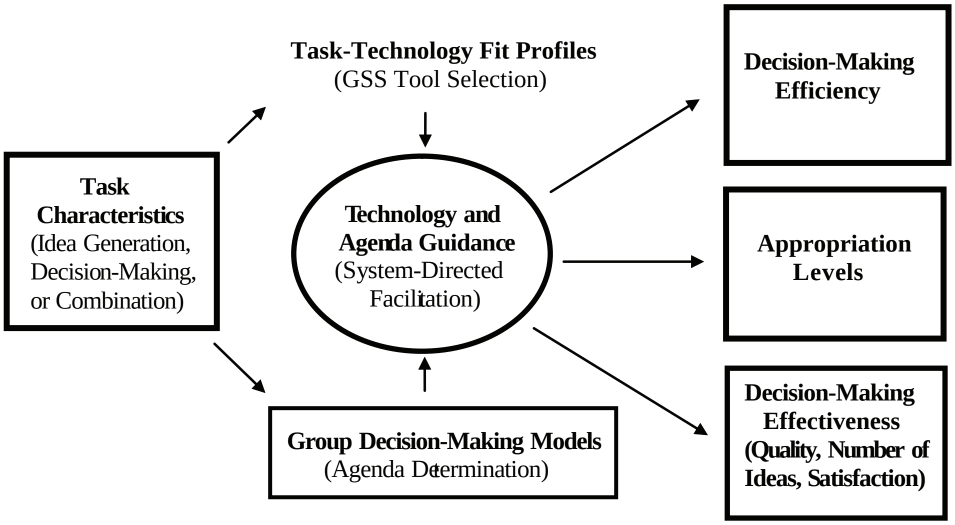

Table 4. Average number of problems identified by treatment group

Treatment Group	Mean Number of Problems Identified	Standard Deviation	Sig. (1-tailed) Human-Facilitated Groups vs. System-Facilitated Groups
Human-Facilitated Groups	15.0	5.95	.063
System-Facilitated Groups	10.6	3.01	

Table 5. Average number of solutions recommended by treatment groups

Treatment Group	Mean Number of Solutions Recommended	Standard Deviation	Sig. (1-tailed) Human-Facilitated Groups vs. System-Facilitated Groups
Human-Facilitated Groups	9.4	3.70	.390
System-Facilitated Groups	8.9	1.58	

the findings for this measure of brainstorming effectiveness.

Hypotheses 3 and 4 relate to participants' satisfaction with the meeting's process and outcome, positing that system-facilitated groups will be at least as satisfied as human-facilitated groups. Scores for satisfaction with the meeting's process were calculated by adding the individual item Likert scores in the Briggs et al. post-session questionnaire, as shown in Appendix A.

System-facilitated participants were found to be slightly more satisfied with the meeting's process than human-facilitated participants, as indicated in Table 6. Accordingly, Hypothesis 3 (satisfaction with the meeting process for system-facilitated groups will be at least equal to that of human-facilitated groups) was supported by the data.

Satisfaction with the meeting's outcome was posited in Hypothesis 4. As indicated in Table 7, system-facilitated participants were found to be slightly more satisfied with the meeting's outcome than were human-facilitated participants Accordingly, Hypothesis 4 (satisfaction with the meeting outcome for system-facilitated groups will be at least equal to that of human-facilitated groups) was supported by the data.

DISCUSSION AND CONCLUSION

This research addresses the feasibility of using system-directed guidance for facilitating users of advanced information technologies in an experiment involving CPAs, internal auditors, and IT security personnel as participants in a simu-

Table 6. Satisfaction with meeting process

Treatment Group	Mean Satisfaction with Meeting Process Score	Standard Deviation	Sig. (1-tailed) Human-Facilitated Groups vs. System-Facilitated Groups
Human-Facilitated Groups	23.6	6.75	.211
System-Facilitated Groups	25.3	3.82	

Table 7. Satisfaction with meeting outcome

Treatment Group	Mean Satisfaction with Meeting Outcome Score	Standard Deviation	Sig. (1-tailed) Human-Facilitated Groups vs. System-Facilitated Groups
Human-Facilitated Groups	24.3	6.63	.414
System-Facilitated Groups	24.7	7.36	

lated information systems audit. Contrary to the study's hypotheses, system-facilitated teams were found to be less effective than human-facilitated groups in completing their assigned tasks. Likewise, satisfaction levels for system-facilitated teams were found to be only slightly higher for system-facilitated teams in comparison to human-facilitated teams.

A significant portion of the lower than expected effectiveness levels of system-facilitated groups can likely be attributed to the complexity of the GDSS application that was used in the experiment and the fairly steep learning curve required to effectively utilize the GDSS software. In a separate post-experiment survey, a significant number of participants commented on various difficulties that were encountered in utilizing the GDSS software.

Moreover, by simplifying the user interface and improving the overall user friendliness of the GDSS application used by audit team members, it is quite likely that audit team performance levels could be significantly improved. Accordingly, future research efforts should focus on utilizing GSS systems such as Microsoft's Live Meeting application which are believed to be significantly easier to utilize and which do not have many of the complexities that participants noted in their evaluations of the GDSS application utilized in the experiment.

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APPENDIX A

Post-Session Questionnaire[*]

Dependent Variable: Satisfaction with Meeting Process (PROSATIS):

PROSATIS1: I feel satisfied with the way in which today's meeting was conducted.

___ I would strongly disagree 1
___ I would quite disagree 2
___ I would slightly disagree 3
___ I would neither agree nor disagree 4
___ I would slightly agree 5
___ I would quite agree 6
___ I would strongly agree 7

PROSATIS2: I feel good about today's meeting process.

___ I would strongly disagree 1
___ I would quite disagree 2
___ I would slightly disagree 3
___ I would neither agree nor disagree 4
___ I would slightly agree 5
___ I would quite agree 6
___ I would strongly agree 7

PROSATIS3: I liked the way the meeting progressed today.

___ I would strongly disagree 1
___ I would quite disagree 2
___ I would slightly disagree 3
___ I would neither agree nor disagree 4
___ I would slightly agree 5
___ I would quite agree 6
___ I would strongly agree 7

PROSATIS4: I feel satisfied with the procedures used in today's meeting.

___ I would strongly disagree 1
___ I would quite disagree 2
___ I would slightly disagree 3
___ I would neither agree nor disagree 4
___ I would slightly agree 5

___ I would quite agree 6
___ I would strongly agree 7

PROSATIS5: I feel satisfied about the way we carried out the activities in today's meeting.

___ I would strongly disagree 1
___ I would quite disagree 2
___ I would slightly disagree 3
___ I would neither agree nor disagree 4
___ I would slightly agree 5
___ I would quite agree 6
___ I would strongly agree 7

Minimum PROSATIS Score = 5
Maximum PROSATIS Score = 35

Dependent Variable: Satisfaction with Meeting Outcome (OUTSATIS):

OUTSATIS1: I liked the outcome of today's meeting.

___ I would strongly disagree 1
___ I would quite disagree 2
___ I would slightly disagree 3
___ I would neither agree nor disagree 4
___ I would slightly agree 5
___ I would quite agree 6
___ I would strongly agree 7

OUTSATIS2: I feel satisfied with the things we achieved in today's meeting.

___ I would strongly disagree 1
___ I would quite disagree 2
___ I would slightly disagree 3
___ I would neither agree nor disagree 4
___ I would slightly agree 5
___ I would quite agree 6
___ I would strongly agree 7

OUTSATIS3: When the meeting was finally over, I felt satisfied with the results.

___ I would strongly disagree	1
___ I would quite disagree	2
___ I would slightly disagree	3
___ I would neither agree nor disagree	4
___ I would slightly agree	5
___ I would quite agree	6
___ I would strongly agree	7

OUTSATIS4: Our accomplishments today give me a feeling of satisfaction.

___ I would strongly disagree	1
___ I would quite disagree	2
___ I would slightly disagree	3
___ I would neither agree nor disagree	4
___ I would slightly agree	5
___ I would quite agree	6
___ I would strongly agree	7

OUTSATIS5: I am happy with the results of today's meeting.

___ I would strongly disagree	1
___ I would quite disagree	2
___ I would slightly disagree	3
___ I would neither agree nor disagree	4
___ I would slightly agree	5
___ I would quite agree	6
___ I would strongly agree	7

Minimum OUTSATIS Score = 5
Maximum OUTSATIS Score = 35

[*] Briggs, R., de Vreede, G., & Reinig, B. (2003). A theory and measurement of meeting satisfaction. *In proceedings of 36th Annual Hawaii International Conference on System Sciences* (HICSS'03) - Track1

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Chapter 5.5

How Well Do E-Commerce Web Sites Support Compensatory and Non-Compensatory Decision Strategies?

An Exploratory Study

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ABSTRACT

The burgeoning growth of online retailing is forcing businesses to provide better support for consumer decision making on e-commerce Web sites. Consequently, researchers in information systems and marketing have been focusing on investigating the effectiveness of Web-based decision support systems (WebDSS) in providing accurate and satisfying choices for customers. We consider WebDSS implementation based on compensatory, non-compensatory decision strategies and synthesize the existing literature. The results of synthesis show that compensatory WebDSS perform better than non-compensatory WebDSS in terms of decision quality, satisfaction, effort, and confidence. We then investigate the level of Web site support provided for consumers' execution of compensatory and non-compensatory strategies. We examined 375 U.S.-based company Web sites and found that though moderate levels of support exists for consumers to implement non-compensatory choice strategies, virtually no support exists for executing multi-attribute-based compensatory choice strategies.

INTRODUCTION

The advent of the World Wide Web and search engines caused a revolution in the way people search for information. The Internet is now used by 73% of all American adults as of 2006 (Pew Internet and American Life, 2006). In addition, the rapid growth of e-commerce has resulted in digital marketplaces offering a wide variety of product alternatives, elaborate product related information, and great convenience for visitors. Consequently, ever-greater numbers of individuals are interacting with online environments to search for product related information and to buy products and services (Xiao & Benbasat, 2007). In fact, searching for product or service related information was the second most popular activity on the Internet in 2003 after e-mail or instant messaging (U.S. Department of Commerce, 2004). Concurrently, online sales are expected to reach $331 billion by 2010, according to a report by Forrester research.[1] The Web retailers with their retailer innovations and Web site improvements are expected to account for 13% of total retail sales in 2010, up from 7% in 2004. These statistics suggest that e-commerce is growing at a rapid pace, and individuals are increasingly using digital market places at every phase of their decision making process from search to choice.

Nonetheless, access to abundant information on the Web can be a blessing and a curse at the same time (Hauble & Murray, 2003). It is a blessing in that consumers now have access to a huge amount of information from several sources, and a curse because human beings are limited in their information processing capabilities (Simon, 1955). Therefore, many Web retailers are incorporating WebDSS to assist consumers with their decision-making process (Grenci & Todd, 2002). WebDSS capture individual user preferences for products either explicitly or implicitly and provide recommendations based on such preferences (Xiao & Benbasat, 2007). WebDSS have the potential to ease consumers' information overload and to reduce search complexity in addition to improving their decision quality (Haubl & Trifts, 2000).

The research in the area of consumer decision support on e-commerce Web sites is rapidly becoming interdisciplinary. Researchers from computer science, library sciences, social psychology, marketing, management, and information systems are beginning to make important contributions to this area of research. Consequently, the decision technology implemented on e-commerce Web sites is known with different names although they all refer to the same tool to be used by the consumers. Examples include intelligent agents, electronic product recommendation agents, recommendation systems, and WebDSS. In their extensive review of electronic recommendation agents, Xiao and Benbasat (2007) categorized recommendation agents (RAs) into three types. The first type of RAs includes content-filtering, collaborative-filtering, and hybrid agents. The second type includes feature-based and need-based RAs. Finally, the third type of RAs includes compensatory and non-compensatory-based systems.

The present article considers only compensatory and non-compensatory WebDSS and investigates the level of consumer support provided on commercial Web sites to execute compensatory or non-compensatory strategies. We present a synthesis of literature concerning the effectiveness of implementing compensatory versus non-compensatory DSS, and then examine whether or not such findings have made their way into the design of commercial Web sites. We believe that understanding the reality of the extent to which e-commerce Web sites support compensatory and non-compensatory strategies is important for several reasons. From a practical standpoint, if we find that relatively a smaller fraction of Web sites provide compensatory-based support despite a well supported finding that such support is normatively better, then that would highlight an opportunity for the Web retailers to increase the support levels to their customers. From a theoretical standpoint, such finding would raise further questions concerning the factors affecting the implementation of non-compensatory and compensatory WebDSS.

The rest of the article is organized as follows. We first present backgrounds concerning WebDSS types and research concerning the effectiveness of compensatory versus non-compensatory DSS. We then describe the methodology used for the study and present the results. We conclude with a discussion on managerial implications, directions for future research, and conclusion.

BACKGROUND: TYPES OF WEBDSS

One of the common implementations of WebDSS use filtering-based methods. Content-filtering WebDSS consider users' most desired attributes and provides recommendations accordingly. Some of the commercial implementations of content filtering WebDSS include Active Buyers Guide and MySimon (Xiao & Benbasat, 2007). Collaborative-filtering WebDSS use the suggestions provided by like-minded consumers to provide recommendations (Ansari, Essegaier, & Kohli, 2000). Amazon, CD Now provides collaborative filtering WebDSS on their Web sites.

On the other hand, WebDSS can also be implemented using decision strategies. Research investigating the decision strategies used by individual decision makers has a long history. Much of the knowledge acquired from the research domain of traditional DSSs is now guiding the research that examines the effectiveness of WebDSS implementing using different decision strategies. The scope of our study is limited to studying the commercial implementation of compensatory and non-compensatory WebDSS, and the following section provides an in-depth treatment of the related concepts.

Decision strategies refer to the rules employed by individuals to arrive at decisions (Hogarth 1987, p. 72). The decision strategies can be classified into compensatory and non-compensatory decision strategies. These strategies are discussed using an example of renting an apartment (see Table 1).

Non-Compensatory WebDSS

A non-compensatory WebDSS implements one of the many non-compensatory decision strategies. The use of a non-compensatory strategy avoids confronting the conflicts inherent in the choice situation and does not allow the decision maker to trade off a low value on one attribute against a high value on another attribute (Hogarth, 1987). In the apartment rental example, if a university student decides that covered parking represents the most important attribute, alternatives A, B, and C are immediately eliminated. Irrespective of the attractiveness of alternatives A, B, and C, the use of one attribute to make the decision results in their elimination.

Table 1. Four apartment alternatives

Alternatives	**Attributes**				
	Rent ($)	A/C	Covered Parking	Washer and Dryer	Dish Washer
A	350	Yes	No	No	No
B	400	Yes	No	Yes	No
C	450	Yes	No	Yes	Yes
D	500	Yes	Yes	Yes	Yes

There are many examples of non-compensatory strategies. The *conjunctive* strategy sets cut off points for certain attributes, and the alternatives that do not meet all of these thresholds are eliminated. The use of the *disjunctive* strategy allows an alternative to remain under consideration so long as either of two attributes has a value that meets its specified cutoff. Executing an *elimination-by-aspects* strategy (EBA) requires selecting an attribute at every stage and eliminating the alternatives that do not include such aspect. The process continues until a winner is selected. The *satisficing* strategy compares each attribute value with a predetermined cut-off level and the alternative that fails to meet the cut-off level is rejected (Hogarth, 1987).

Computer support for non-compensatory strategies focuses on allowing the consumer to have some control over viewing and manipulating features of interest. For example, a Web site could allow the consumer to specify the value of an attribute (e.g., enter text for searching a Web site or choosing from a list of criteria) to help select a set of products for further investigation. Even more support is given when the consumer can sort products based on the value of an attribute (as in sorting by price, weight, or category). Nonetheless, many Web sites do not give even this level of support, forcing the user to "drill down" in each product to find its features and their values.

In general, the use of non-compensatory WebDSS results in presentation of options that meet the predetermined thresholds set by the decision maker. However, the use of non-compensatory WebDSS by decision makers may not always yield the recommendations suggested by normative decision-making models. First, non-compensatory WebDSS do not consider a consumer's preference function for multiple attributes. Second, at times, the use of non-compensatory WebDSS may result in the elimination of some alternatives based on criterion set on one attribute, though such options may be very attractive on the other attributes.

Compensatory WebDSS

A compensatory WebDSS implements one of the many compensatory decision strategies on a Web site. The use of a compensatory strategy mandates confronting the conflicts inherent in the choice situation and allows the decision maker to trade off a low value on one attribute against a high value on another attribute (Hogarth, 1987). Using the example presented in Table 1, if a university student decides to rent an apartment, the use of a compensatory strategy would facilitate balancing the lack of some apartment features of alternative A against high value (low rent) of another apartment feature.

Compensatory strategies enable desirable values of one attribute of a product or service to *compensate* for undesirable values of another. Compensatory strategies require computations or judgmental assessments that combine multiple variables for each product being considered. An example of a compensatory strategy is a *weighted-additive* strategy in which a weight (relative importance) is assigned to each attribute and multiplied by its value. These products are summed to provide a score for each product. Then the product with the highest score is selected. Variations of the weighted-additive strategy use judgmental assessment of these trade-offs rather than an actual calculation. Compensatory strategies are more accurate than non-compensatory strategies when potential trade-offs exist between variables, such as when the consumer would say, "I would rather have a convertible, but not if I have to pay too much extra to get it." Unfortunately, compensatory strategies are so difficult that they are rarely used except for small sets of products or if some sort of computer-based assistance is provided (Johnson & Payne, 1985; Todd & Benbasat, 1994).

Computer support for compensatory strategies would also make it easier for consumers to see several attributes for several products at a time, such as when a Web site displays an array of rows of products with columns for various attributes. Such an array makes it easier for the consumer to identify and assess the trade-offs inherent in compensatory strategies. Some Web sites provide the display of such an array. Support for compensatory strategies could also enable the selection of products based on multiple criteria. Still further support would be to assist the consumer in evaluating trade-offs by providing some sort of scoring computation of the values of various attributes. Such a *model* would best serve the consumer if the consumer were allowed to say which attributes were important and how much weight to give each attribute. Finally the consumer would need a way to easily find out which products or services obtained the highest scores, such as having the system sort or select products based on scores provided by the model.

Partial support for compensatory strategies can come from allowing the consumer to see external ratings of products (such as *Consumer Reports*). External ratings have the advantages of being an overall assessment of multiple criteria (i.e., they are *compensatory*) and of being objective. They have the disadvantage that they are based on someone else's assumption about the relative importance of various criteria. They do not capture the consumer's own preferences.

Edwards and Fasolo (2001) note that "the idea of a procedure for making important decisions that does not depend heavily on human inputs seems unlikely as well as unattractive. Selection, training, and elicitation of responses from the person…become crucial" (p. 588). Compensatory WebDSS are specifically designed to implement such an idea. As opposed to a non-compensatory WebDSS, compensatory WebDSS need to draw on the processing capacity and storage abilities of the computers to implement the normative algorithms such as multi-attribute utility theory, Bayesian nets, and subjective expected utility theory that are otherwise very difficult for the unaided decision maker to implement (Larrick, 2004). Compensatory WebDSS execute algorithms in the background and also perform consistency checks on user provided weights making the decision tools more appealing to end users (Larrick, 2004).

Research Comparing the Effectiveness of Compensatory Versus Non-Compensatory WebDSS

How effective are compensatory WebDSS compared to non-compensatory WebDSS? We address this question in this section based on empirical results from five studies that compared compensatory and non-compensatory WebDSS. The results are summarized in Table 3. The compensatory WebDSS used in these studies elicit weights from users on attributes and present alternatives with final scores based on expected values. The non-compensatory WebDSS used were based on any of the conjunctive, disjunctive, EBA, or satisficing strategies. The explanations of the variables used to compare the two types of WebDSS are provided in Table 2.

Satisfaction

Previous research suggests that users experience more satisfaction with the use of compensatory WebDSS compared to that of non-compensatory WebDSS (Fasolo, McClelland, & Lange, 2005; Olson & Widing, 2002; Pereira 2001; Song, Jones, & Gudigantala, 2007). Widing and Talarzyk (1993) found that no such differences exist between the two formats. However they used only one item to measure satisfaction. The result by Fasolo et al. (2005) concerning the effectiveness of compensatory WebDSS is noteworthy because their research study employed an alternative set with negative inter-attribute correlations. Inter-attribute correlation is obtained by calculating the average correlation among the all the pair of attributes. With positive inter-attribute correlations (friendly environment), the alternative that is favorable on one attribute tends to be favorable on

Table 2.Variables used for comparing the effectiveness of compensatory and non-compensatory WebDSS

Variable	Explanation
Satisfaction	The user's satisfaction with the WebDSS in supporting the decision making process
Decision Quality/ Accuracy	Preference matching: The extent to which the choice selected by the user matches her stated preferences Product switching: Once a purchase decision is made, will the user change his mind and switch to another choice given a chance?
Effort	The amount of cognitive resources exerted by the user in processing the information to arrive at the choice
Confidence	The degree to which a user has confidence in WebDSS's recommendations
Decision Time	The time taken to arrive at the final choice

Table 3. Studies that compared the effectiveness of compensatory and non-compensatory WebDSS

	Fasolo et al. (2005)	Song et al. (2007)	Olson and widing (2002)	Periera (2001)	Widing and Talarzyk (1993)
Satisfaction	Compensatory WebDSS are better	Compensatory WebDSS are better	Compensatory WebDSS are better	Compensatory WebDSS are better	No Difference
Decision Quality/ Accuracy	Compensatory WebDSS are better	Compensatory WebDSS are better	Compensatory WebDSS are better	Compensatory WebDSS are better	Compensatory WebDSS are better
Effort	Compensatory WebDSS are better	Compensatory WebDSS are better		Compensatory WebDSS are better	
Confidence				Compensatory WebDSS are better	
Decision Time			No Difference		Non-Compensatory WebDSS took more time

others. With negative inter-attribute correlations (unfriendly environment), the more attractive level of one attribute is associated with less attractive level on the other. Alternatives characterized by negative inter-attribute correlations such as those between cost and quality, are common and lower consumer confidence and satisfaction (Fasolo et al., 2005). Therefore, consumers require more support when dealing with alternatives with negative inter-attribute correlations. Hence, existing evidence overwhelmingly supports the notion that compensatory WebDSS contribute to better satisfaction ratings compared to those of non-compensatory WebDSS.

Decision Quality

Decision quality has been measured in various ways in literature. Preference matching measures the extent to which the choice selected by the user matches his/her stated preferences (Pereira, 2001) whereas product switching measures the extent to which the user is likely to change his/her mind and switch to alternative choice given that he/she already made a purchase decision (Widing & Talarzyk, 1993). The existing evidence strongly suggests that compensatory WebDSS provide better decision quality to users compared to non-compensatory WebDSS (Fasolo et al., 2005; Olson

& Widing, 2002; Pereira 2001; Song et al., 2007; Widing & Talarzyk, 1993).

Effort

The existing evidence supports the idea that non-compensatory WebDSS requires more effort from users than that of compensatory WebDSS (Fasolo et al., 2005; Pereira, 2001; Song et al., 2007).

Confidence

Research by Pereira (2001) found out that users felt more confident when making choices with compensatory WebDSS as opposed to a non-compensatory WebDSS.

Decision Time

While research by Widing and Talarzyk (1993) suggests that non-compensatory DSS took more time to arrive at a choice, Olson and Widing (2002) found that no such differences exist. Therefore, the existing evidence is inconclusive whether the use of compensatory WebDSS saves time.

Therefore, overwhelming evidence supports the notion that compensatory WebDSS are better than non-compensatory WebDSS on important variables such as satisfaction, decision quality, effort, and confidence. In addition, even in the absence of decision tools implementing compensatory decision strategies, Web sites that facilitate the comparison of alternatives contribute to an increased use of compensatory strategies by users (Jedetski, Adelman, & Yeo, 2002). However, research also suggests that non-compensatory WebDSS support consumer decision making better than Web sites that just provide products by alphabetical order (Widing & Talarzyk, 1993). When technology makes compensatory strategies easier, consumers are more likely to use them (Todd & Benbasat, 1994). Moreover, consumers are more likely to use ratings based on their own weightings of the features, rather than someone else's preferences (Jones & Brown, 2003). Hence, based on the empirical results that non-compensatory WebDSS are better than Web sites providing alphabetical order of products, and compensatory WebDSS are better than non-compensatory WebDSS, we set out to investigate how well the commercial Web sites provide support to compensatory and non-compensatory strategies.

METHODOLOGY

Research on evaluation of Web-based information systems in the context of e-commerce has been ongoing. Previous work has examined e-commerce Web sites based on concordance analysis (Jinling & Guoping, 2005) and the factors that influence Web-based information systems success (Garrity, Glassberg, Kim, Sanders, & Shin, 2005). Garrity et al. (2005) found that decision support satisfaction plays an important role in Web-based information system success. Given this finding and the evidence that compensatory and non-compensatory WebDSS provide varying levels of decision support satisfaction (with compensatory WebDSS providing more satisfaction), we set out to evaluate retail Web sites based on three criteria:

1. Does the Web site have useful features commonly found on competitors' Web sites?
2. How much support does the Web site give to consumers' non-compensatory decision strategies?
3. How much support does the Web site give to compensatory strategies in a way that captures consumers' own preferences and weightings of product features?

Selection of Data Source

In identifying business firms used in this study (as opposed to personal or very small operations), we used the Business and Company Center database.[2] This is one of the most comprehensive

Web-based business databases available today that offers extensive information on hundreds of thousands of companies worldwide. We focused on retail and service industry based on four-digit industry codes. The scope of our analysis is restricted to the U.S.-based companies. The database contains approximately 2,600 U.S. companies out of approximately 7,600 worldwide companies. We selected about 25% of the U.S. companies by selecting every fourth company from the database consisting of 2,600 companies.

Questionnaire Preparation and Pilot Testing

The first part of the data collection procedure involved preparation of the questionnaire to be used by the researcher evaluating a Web site. The questionnaire elicited information concerning different kinds of decision support provided by Web retailers. The questionnaire was intended to capture information concerning the support provided to help users locate, evaluate, and compare products. In addition, information concerning the provision of a multi-attribute model that would elicit user preferences as well as the provision of others ratings' about products was captured. The information concerning the communication of privacy policy was also captured. The questionnaire is included in Appendix A. In a nutshell, the questionnaire was intended to capture Web site support for executing non-compensatory strategies, compensatory strategies, product related information, and security and privacy based information.

A pilot study was conducted to refine the questionnaire and to examine the agreement about the information collected. The three authors individually visited 30 Web sites and gathered data. The authors found 90% agreement on the data collected. Based on discussions about the sources of the few disagreements, further revisions were made to the questionnaire to remove ambiguities in the questions.

Data Collection

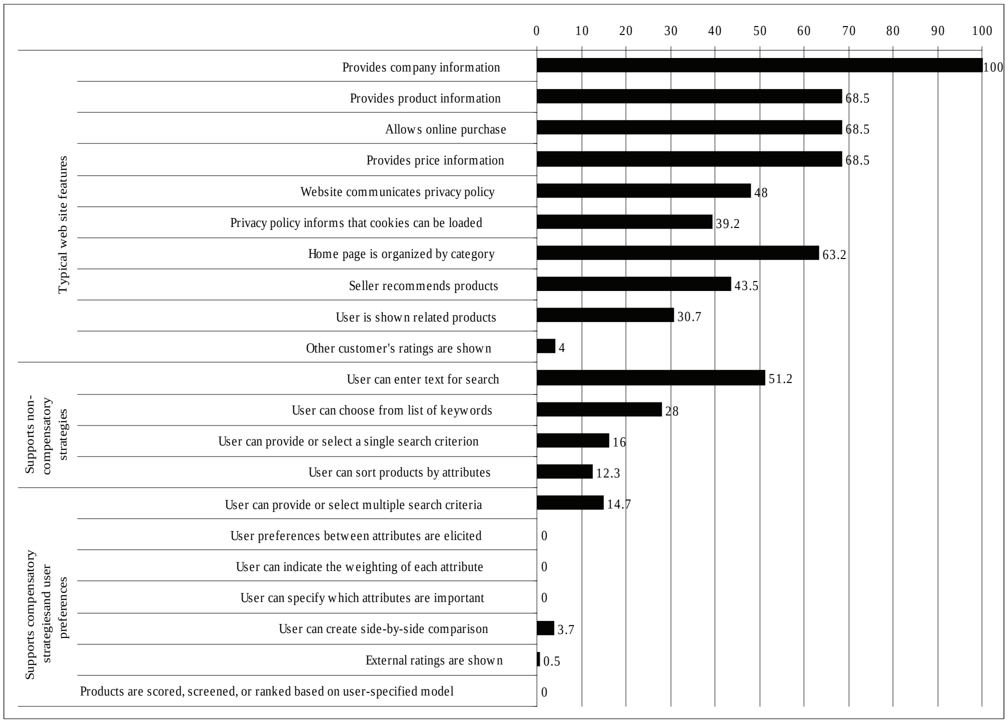
We selected about 25% of the 2,600 U.S. companies, and one of the authors visited 610 Web sites to collect data.[3] In order to reduce the possible bias in the sample, we avoided any duplication, such as companies listed in multiple SIC industries. In addition, the URLs of many companies are out of date, and some URLs represented replications of those that were already considered for the study. Finally, the data set consisted of complete observations for 375 business firms operating on the Web. Out of the 375 Web sites, 310 were retail Web sites and 65 were service Web sites. The retail industry contained Web sites on merchandize stores; apparel and accessory stores; furniture; household appliances; electronics; and so forth, where as the service industry consisted of Web sites on hotels and motels; rooming and boarding houses; sporting and recreational camps; RV parks; software services; and so forth. The collected data provided rich description of the typical features, their level of support for consumers' non-compensatory strategies, and their level of support for consumers' compensatory strategies and preferences.

To give further assurance of accuracy and validity of data collection, a second author randomly gathered data about some companies in the sample to compare to the other author's data collection. There was almost perfect agreement between the two authors.

Results

Our overall findings are displayed graphically in Figure 1. Typical Web site features are shown first. Of our sample of 375 Web sites, all give general company information and about two-thirds (68.5%) support online purchasing of products or services. Most of the Web sites that support online purchases display the privacy policy and inform that cookies can be loaded to the consumer's computer. Most of the Web sites that support online

Figure 1. The percentage of web-retailers' web sites investigated (375 total) having various web site features, including features that would support consumers' decision strategies and preferences



purchases also enable consumers to find specific categories, which facilitates consumers' search. About half of the Web sites recommend products in some way, about a third show related products. Only 4% of the Web sites surveyed show other customers' ratings.

In the middle of Figure 1, the results are shown for features that would be helpful to consumers desiring to execute non-compensatory strategies. Most of the Web sites that supported selling had at least one feature that would enable the consumer to find products based on a certain criterion, such as entering text for a search, choosing from a list of keywords, or providing a single search criterion. Nonetheless, only 12.3% of the Web sites enable the sorting of products based on an attribute value.

At the bottom of Figure 1, the results are shown for features that would be helpful to consumers desiring to execute compensatory strategies. When we considered the support for compensatory strategies that incorporated consumer preferences, we found almost no support. Just 14.7% of the Web sites supported searches based on multiple criteria. Only 3.7% displayed side-by-side comparison. Only .5% showed external ratings of products or services. NONE of the Web sites assisted the consumers by allowing the users to give weights of attributes or specify which weights are important. NONE of the Web sites provided for scoring based on user-specified models.

To gain further insight into the breakdown of the Web sites in our sample, we subdivided our sample two ways: retail versus service, and sales volume above or below average. These results are shown in Table 4. Inspection of these breakdowns reveals several patterns. First, the typical Web site features are provided more often for retail products than for services.

Service industry Web sites are more prone to just give company information and not try to sell directly on the Web site. On the other hand,

Table 4. Survey of WebDSS attributes

Attributes	All (N=375)	Industry		Sales Volume	
		Retail (N=310)	Service (N=65)	Above (N=188)	Below (N=187)
Typical Web Site Features					
Provides company information	100.0 (%)	100.0(%)	100.0(%)	100.0(%)	100.0(%)
Provides product information	68.5	72.3	50.8	69.7	67.4
Allows online purchase	68.5	72.3	50.8	69.7	67.4
Provides price information	68.5	72.3	50.8	69.7	67.4
Website communicates privacy policy	48.0	51.7	29.2	59.6	36.4
Privacy policy informs that cookies can be loaded	39.2	42.6	23.1	53.7	24.6
Home page is organized by category	63.2	66.1	49.2	63.8	62.6
Seller recommends products	43.5	47.7	23.1	50.0	36.9
User is shown related products	30.7	36.8	1.5	39.9	21.4
Other customers' ratings are shown	4.0	4.8	0.0	7.4	0.5
Web Site Features Supportive of Non-Compensatory Decision Strategies					
User can enter text for search	51.2	60.0	9.2	51.6	50.8
User can choose from list of keywords	28.0	25.5	40.0	30.9	25.1
User can provide or select a single search criterion	19.2	15.2	38.5	20.7	17.6
User can sort products by attributes	12.3	13.5	6.2	16.0	8.6
Web Site Features Supportive of Compensatory Decision Strategies or User Preferences					
User can provide or select a multiple search criterion	14.7	10.0	36.9	13.8	15.5
User preferences between attributes are elicited	0.0	0.0	0.0	0.0	0.0
User can indicate the weighting to each attribute	0.0	0.0	0.0	0.0	0.0
User can specify which attributes are important	0.0	0.0	0.0	0.0	0.0
User can create side-by-side comparison	3.7	4.5	0.0	5.3	2.1
External ratings are shown	0.5	0.6	0.0	0.5	0.5
Products are scored, screened, and ranked based on user specified model	0.0	0.0	0.0	0.0	0.0

company size did not appear to affect the extent of online selling, perhaps because there are few financial or technological barriers to a small business that wants to begin selling on the Internet. The larger companies appear to attempt to market their products somewhat more by recommending products, showing related products, and showing other customer ratings.

Retailers of products more frequently allowed users to enter text for a search, while service companies more frequently allowed a choice of keywords or provision of a single search criterion. Since these features are merely different ways of achieving the same objective, we do not see sellers of products or services as dominating in supporting ways of specifying criteria. For the few Web sites that supported sorting of products by attributes, this feature was more frequently provided by retailers of products than by service firms. The sort feature was also more frequently provided by large firms than small firms.

For compensatory strategies, the main result is that Web sites gave little support at all. For some reason service firms gave more support in searching multiple criteria than sellers of products. Of the few Web sites showing side-by-side comparisons, all were retailers of products (rather than services) and most were large companies. External ratings were all of products rather than services. This may be due to a lack of available external ratings of services.

MANAGERIAL IMPLICATIONS

The main finding of our investigation of e-commerce Web sites is a complete absence of support for consumers' compensatory strategies based on their own preferences. Given the results of academic research that compensatory WebDSS provide better decision quality, satisfaction, and confidence to consumer, and reduce effort, an opportunity is waiting for managers to start looking for ways to implement such tools.

The purpose of a DSS is to help a customer pick the best possible choice in all situations. The use of non-compensatory DSS is not associated with better decision quality (Fasolo et al., 2005). However, managers have to make sure that compensatory WebDSS are easy to use. Most of the compensatory WebDSS implemented in research experiments typically have two screens. In the real world, as the number of screens used to capture consumer preferences increases, the longer it takes for customers to make a decision. Such design may discourage users. Therefore, to the extent that compensatory WebDSS are easy to use, they are likely to be used by consumers.

The execution of compensatory strategies requires users to submit weights to attributes and then the DSS recommends products with highest expected values. But, how does a user know what algorithm is being used to come up with the results? Therefore, it is recommended that managers provide information concerning how the final scores (expected values) are calculated from the user supplied weights.

It is also possible that the lack of expertise and developmental costs may influence managers not to implement compensatory WebDSS. We believe that the extent to which the benefits of implementing such WebDSS outweigh the costs implies that it would be a worthwhile proposition for managers to consider developing compensatory based decision support tools.

Directions for Future Research

While our study results showed absence of support for executing compensatory strategies in e-commerce Web sites based on consumer preferences, with some additional research, we were surprised to find some third party Web sites providing such support. Examples of such third party sites include My product advisor (http://www.myproductadvisor.com), Select smart (http://www.selectsmart.com), and Yahoo! shopping smart sort computer and electronic recommendations (http://shopping.yahoo.com/smartsort). Future research could investigate two research questions. First, what are the factors that inhibit e-commerce Web sites from providing support for compensatory-based strategies based on consumer preferences? Second, what are the implications for e-commerce Web sites with third party Web sites providing such support when consumers expect such support from the Web retailers themselves?

A second area of research could look into the issues surrounding consumers' adoption of decision technology implemented to support individuals' decision-making processes. Research shows that less than 10% of home users visit shopbots (Montgomery, Hosanagar, Krishnan, & Clay, 2004). Therefore, future research could look into various factors that would improve the consumer adoption of decision technology. Furthermore, additional research is needed to understand how individual differences in decision makers affect adoption and usage of decision technology on e-commerce Web sites.

The present survey considers only compensatory and non-compensatory based systems, and the results suggest that an important gap exists between theory and practice. Future studies could conduct similar kinds of studies to investigate how well e-commerce Web sites provide support concerning content, collaborative, and hybrid WebDSS as well as the feature- and need-based WebDSS. It is our hope that as with our study, important insights could be brought out by conducting studies that investigate the extent of Web site support concerning other types of WebDSS.

Compensatory decision tools that are implemented in the experiments may face challenges when extended to the real world. For example, most of the compensatory WebDSS designed in experiments contain all the attribute values for a given alternative set. However, in the real world, attributes values may be missing for some alternatives, and therefore computing expected values for such alternatives could be problematic. Therefore, future research could look at the effects of missing information on consumer choices in online decision support environments.

Future research could also look at measuring the monetary benefit to an organization implementing a Web-based decision support tool on its Web site. The existing research so far has focused on decision outcome variables such as satisfaction, decision quality, effort, and so forth. Of interest to managers could be whether improved WebDSS tools augment the user's willingness to purchase.

CONCLUSION

Research conducted by decision scientists over the last few decades has examined the normative way of decision making (how decisions must be made) and identified several decision strategies individuals use to make a decision. These decision strategies are compensatory and non-compensatory in nature. After the advent of the Internet and the subsequent growth of the e-commerce market, most Web sites are implementing Web-based decision support tools to help consumer make their choices. One category of Web-based decision tools uses decision strategies to provide consumer support. In this study, we focus on Web site support for executing consumers' compensatory and non-compensatory strategies.

The study makes two contributions. By synthesizing the existing literature concerning the effectiveness of implementing compensatory versus non-compensatory WebDSS, we found that a majority of the evidence favors implementing compensatory WebDSS. If compensatory WebDSS are so effective, one would expect to observe e-commerce Web sites increasing the level of support for executing consumers' compensatory strategies. Based on a study of 375 U.S. company Web sites, we found that very little support exists for features that support compensatory strategies (such as side-by-side comparison of alternatives) and no support exists for executing compensatory strategies based on consumer preferences.

We also note several limitations of our study. As far as we are aware, there is no study that explored how well Web sites provide support for compensatory and non-compensatory based strategies. Though it is problematic to generalize the findings of U.S.-based companies to companies worldwide, a future study could look into how well such strategies are supported in Web sites worldwide. Secondly, choosing 25% of U.S.-based companies is purely arbitrary. However, we believe that the results of our study are representative of the current situation on e-commerce Web sites. For example, Fasolo et al. (2005) state that "although we have no precise data to support it, we are under the impression that real World Wide Web compensatory sites are having rougher and shorter lives than non-compensatory sites….We have anecdotal evidence that transparency and length might be a reason for the lack of success of compensatory ones" (p. 341).

The results of this study open up an opportunity for managers to start providing more support for compensatory-based decision strategies, and at the same time begs the question of the lack of popularity of such tools. A number of potential reasons have been presented and a host of research questions have been raised. It is our hope this attempt fuels further research in improving the design of WebDSS and finding factors that affect the adoption of WebDSS, ultimately contributing to the benefit of both the Web sites and users.

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ENDNOTES

[1] http://www.forrester.com/Research/Document/Excerpt/0,7211,34576,00.html

[2] Please visit http://www.galegroup.com/pdf/facts/bcrc.pdf to find more about this database

[3] The questionnaire captures general details, support for user to locate a product, evaluate individual products, support in terms of others ratings, support to compare products, support for multi-attribute models, and information about cookies. The only place where the researcher's perceptions could bias the results is the section on support provided to user to select a specific product. This part is not used in the analysis. The rest of the variables are binary in nature. For example, a Web site can provide a keyword-based search or not. Similarly, a Webs ite can let the users pick important attributes or not, weight the attributes or not. Therefore, we believe that what is needed from a data collector is general observation skills and since perceptions are not recorded, we believe that use of one of the authors to collect data is reasonable.

APPENDIX A.

URL: _________________________________ SIC Code: _________________
Preparer __________
Name of Business ____
Date__________
Types of Products Offered ____

Circle all that apply:

shows company info, shows product info, shows prices, allows online purchase

Support that Helps User Locate a Product:

Y N Home page is organized by category to assist with product search
Y N User can enter text for search
Y N User can choose from list of keywords for search
Y N User can provide or select a single search criterion (e.g., homes with 3 bedrooms, < $200,000)
Y N User can provide or select multiple search criteria
Y N User is shown related products

Support that Helps User Evaluate Individual Products:

BA A AA Products are described in detail (Below average, average, above average)
BA A AA Products are shown in high quality pictures
Special features (pictures): ____

Support that Provides User with Others' Ratings of a Specific Product:

Y N Other customers' ratings or comments are shown for products
Y N External ratings (e.g. Consumer Reports ratings) are shown for products
Source: ____
Y N Seller recommends some products (e.g., "best value")
Verbiage: ____

Support that Helps User Compare Products:

Y N User can sort products by an attribute: ____
Y N User can create side-by-side comparison of products on a single web page

Support that Creates Multi-Attribute Model of Elicited User Preferences:

Y N User can specify which attributes are important and system picks products for user to review
Explain: ____
Y N User preferences between attributes are elicted by system (e.g., providing user with pairs of product attributes and asking user which is more important).
Y N User can indicate how much weight should be given to each attribute.

Y N Products are scored, screened, or ranked (indicate which) based on multi-attribute model of user preferences

Explain: ____

System Informs of Cookies in Privacy Policy:

Y N Website communicates a privacy policy

Y N Privacy policy informs that cookies might be loaded onto user's computer

Other Type of Support:

Please describe in detail any other type of decision support provided for the consumer

____

____

____

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Chapter 5.6

E-Collaboration Using Group Decision Support Systems in Virtual Meetings

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INTRODUCTION

When e-collaborating, there is often a need to bring everyone involved together for a meeting. With potential meeting participants often widely dispersed geographically, the meeting could be conducted virtually by utilizing technology known as groupware. Procedures for conducting successful face-to-face meetings have been in place for many years. However, with the rise in the number of computer-mediated virtual meetings being held amongst e-collaborators, there are additional considerations to take into account when conducting virtual meetings using groupware. This article discusses the use of a particular type of groupware (GDSS) in virtual meetings conducted by participants collaborating in an electronic environment.

GROUPWARE

Groupware is defined as any technology that improves group productivity (Briggs & Nunamaker, 1994). It is a generic term for specialized computer aids designed for use by collaborative work groups (Johansen, 1988).

Types of Groupware

The term *groupware* can in actuality stand for many different things. Briggs and Nunamaker (1994, p. 61) have identified several names and concepts defined as equivalent to groupware: group decision support systems, electronic conferencing, team databases, computer supported cooperation, video teleconferencing, shared drawing, workflow automation, information filtering, coordination support, collaboration support, electronic meeting systems, and team scheduling and project management.

Regardless of what it is called, groupware supports e-collaboration (Kock & McQueen, 1997), communication, and coordination (Orlikowski & Hofman, 2003) and allows people to work together to perform the following types of functions in an electronic environment (Liff, 1998):

- Management support, including meeting facilitation
- Document sharing and management
- Group calendaring and scheduling
- Project management
- Information sharing and threaded discussion forums
- Real-time interactions, including audio and video conferencing and whiteboard collaboration
- Knowledge management, which allows organizations to create a corporate memory

Group Decision Support Systems

One category of groupware increasing in popularity is group decision support systems (GDSS). GDSS encourage such activities as group idea generation, voting, brainstorming, decision making, and consensus reaching (Holtham, 1994) by removing common communication barriers. Huber defines GDSS as "a set of software, hardware, and language components and procedures that support a group of people engaged in a decision-related meeting" (1984, p. 195). DeSanctis and Gallupe offer a similar definition, calling it "an interactive, computer-based system that facilitates the solution of unstructured problems by a set of decision makers working together as a group" (1985, p. 379). Pollock and Kanachowski (1993) define GDSS as a system where group members use computers interactively to support the group's decision-making capacity.

Studies have shown that technology is essential to the success of e-collaborations (see Cai, 2005). According to Poole and Holmes (1995), the strength of GDSS comes from its ability to enhance communication and information exchange, complex information processing tasks, and coordination and organization of group collaborations. GDSS facilitate e-collaboration by combining the use of computer technology (both hardware and software), video, audio, and telecommunication systems (Barnes & Greller, 1994).

There are different levels of GDSS involved in e-collaboration (DeSanctis & Gallupe, 1987). At its most basic, GDSS provide features that facilitate common communication behaviors such as voting and electronic message exchange. The next level of GDSS provide a means to model decisions and group decision techniques to reduce the uncertainty that can occur in the decision making process. At its highest level, GDSS are tools to manage group communication patterns in e-collaboration and can include expert advice in the selection and arrangement of procedures to be followed during a virtual meeting.

CONDUCTING VIRTUAL MEETINGS USING GDSS

The primary purposes of meetings are to exchange work-related information, to make decisions, or to accomplish tasks. Guidelines for conducting successful face-to-face meetings have been in place for many years. For each face-to-face meeting, four stages of meeting protocol should be adhered to:

1. Determine the need for a meeting
2. Prepare for the meeting
3. Conduct the meeting
4. Follow-up after the meeting

Even when proper procedures are followed, there are several problems that can arise in traditional face-to-face meetings. Issues not related to the relevant task can sidetrack the group. Dominant personalities can monopolize the group's time and attention. The free flow of creative thought may be discouraged by ideas being attacked or the fear of retribution. There can be premature closure of the meeting to avoid conflict. The record of the meeting can be subjective, incomplete, or lost.

Compounding traditional face-to-face meeting complexities is the rise in the number of virtual meetings, which necessitate additional considerations. As with face-to-face meetings, organizers of virtual meetings should also follow the four stages of meeting protocol mentioned previously. But because of the very nature of the virtual meeting, there are additional considerations that need to be taken into account to conduct effective virtual meetings using GDSS. By utilizing e-collaboration technologies such as GDSS, interference with collaborative activities can be reduced and problems inherent in traditional meetings eliminated (DeSanctis, 1993).

To determine if a meeting is warranted is particularly important in a virtual environment. With e-collaborators scattered around the world in several different time zones, conducting meetings virtually presents a challenge that goes beyond the issues associated with face-to-face meetings. With participants thousands of miles apart geographically, scheduling the virtual meeting can be a difficult task. The use of an e-collaboration technology such as GDSS to conduct electronically mediated meetings is very effective in reaching those geographically dispersed team members (Munter & Netzley, 2002).

Technological considerations are the most crucial part of preparing for the virtual meeting. Determining the most appropriate technology to conduct the virtual meeting depends on the meeting agenda as well as organizational resources. Consider if the information to be delivered or the task to be achieved could best be accomplished via GDSS. The technology should serve the meeting, not dominate it (Duarte & Snyder, 1998). Nunamaker, Briggs, Mittleman, Vogel, and Balthazard (1996) argue that technology cannot make up for poor planning or ill-conceived meetings, and could even make the situation worse.

The technology must be in good working order, and a back-up plan must be in place in the (very likely) event the technology will fail. All of the people at the virtual meeting need to be trained and experienced in the technology, otherwise they will not participate. Additionally, a trained GDSS facilitator must be present at the virtual meeting to ensure its success. According to Munkvold, "the use of a facilitator is an absolute necessity for running an effective, co-located electronic meeting" (2003, p. 18).

Distributing the agenda in a timely fashion is also an important part of preparing for the virtual meeting. Besides the agenda, any additional materials must also be distributed to the e-collaborators before the scheduled meeting. If the virtual meeting is held to discuss a particular report, for instance, a person at a remote site would be at a definite disadvantage if the report was not sent in time for the virtual meeting.

When conducting a virtual meeting, facilitators need to be extremely aware of the fact that words or phrases can quite easily be misinterpreted. Some GDSS are text based only and therefore do not allow e-collaborators to view nonverbal cues. The lack of nonverbal cues such as body language and facial gestures can make communication more difficult in virtual meetings, thus accentuating language, culture, and style differences (Henry & Hartzler, 1998). To avoid creating tension among the e-collaborators, everyone must make certain the communication is clear and precise with no chance for a misunderstanding.

It is easy for people to "fade into the background" during virtual meetings, particularly those facilitated by GDSS. If the virtual meeting participants can't see each other, some people may never contribute to the discussion. In a computer-mediated meeting environment, it could simply be that the e-collaborator's typing skills are poor, and keeping up with the "discussion" is too difficult. Regardless of the reason, virtual meeting facilitators must make certain that everyone is participating and has equal opportunity to share thoughts and ideas. Virtual meeting participants should also identify themselves each time they contribute to the discussion.

When the virtual meeting ends, the communication and e-collaboration do not (Hoefling, 2001). GDSS meetings tend to generate quite a bit of information (Arkesteijn, DeRooij, & VanEekhout, 2004). It is critical to follow up after virtual meetings to make sure everyone understood the results of the meeting and knows what action to take. GDSS allows e-collaborations to be recorded electronically, thereby facilitating follow-up activities from the virtual meeting. The use of GDSS can also be very valuable in collecting a myriad of data for further consideration by the e-collaborators.

Using GDSS and other types of groupware "symbolizes new ways of integrating information technology with innovations in management and group process to produce more effective forms of collaboration" (Creighton & Adams, 1998, p. 13), including virtual meetings. But while groupware tools are very effective in many e-collaboration circumstances, there are potential downfalls (Burnett, 1994; Creighton & Adams, 1998; Johansen, 1988).

The technical problems are the most obvious, since technology is vulnerable to failure. The technology may fail during the virtual meeting, effectively ending the session without completing the agenda; computers do crash. The software may not function properly. If the technology is not working, the meeting cannot be held and valuable time and energy is lost.

The other concerns are social in nature. Using GDSS to facilitate virtual meetings may result in the over-control of the e-collaborators by focusing too much on the technology and process. People may not be computer literate. Creativity may be stifled because the meeting is too structured around the groupware requirements. Meeting participants may also lose a sense of community and personal touch.

MIXED RESULTS IN THE USE OF GDSS

Results of years of research on e-collaborating using GDSS are proving to be inconclusive, with studies supporting both positive effects on collaboration using GDSS and negative effects from the use of the tool (see Limayem, Banerjee, & Ma, in press). Jessup, Connolly, and Galegher (1990) also cite numerous studies that obtained mixed results in examining the effectiveness of GDSS.

Despite the fact that decades of research have yielded inconsistent findings, overall results "suggest that the use of a GDSS improves decision quality, depth of analysis, (and) equality of participation" (Fjermestdad, 2004). The use of GDSS tends to produce more positive effects compared to face-to-face methods, particularly with respect to the type of task the participants in the virtual meeting are engaged in (Fjermestdad & Hilz, 1998/99).

TRENDS IN CONDUCTING VIRTUAL MEETINGS USING GDSS

New technologies supporting e-collaboration are being developed and evaluated in virtual meeting contexts. "Smart meeting rooms" take GDSS technologies to a much higher level and allow for augmented reality meeting support and virtual reality generation of meetings, both in real time or off-line (Nijholt, Akker, & Heylen, 2006). Meeting participants in these "smart" or "virtual" meeting rooms will conduct all the virtual meeting activities currently facilitated by GDSS (brainstorming, discussing, voting, etc.), only with virtual reality representations of themselves, instead of e-collaborating in a strictly textual environment.

CONCLUSION

GDSS assist in focusing the efforts of e-collaborators toward the task or problem at hand. They enable productivity in virtual meetings through technology-facilitated collaboration and avoid information overload. Inputs can be anonymous, so many ideas can be quickly generated to solve problems or identify opportunities. GDSS facilitate distilling those ideas to the very best ones, clarify exactly what is intended, organizing the ideas, and evaluating and prioritizing them. It can help e-collaborators build consensus and produce deliverables that result in specific actions.

Using GDSS to facilitate a virtual meeting ensures the overall quality of effort put into the process is increased, as is the probability of reaching consensus. It guarantees no single person dominates the procedure. The e-collaborators can easily stay on task and not get distracted. An objective, precise documentation of the entire meeting is generated. Virtual meetings can also be much more efficient using GDSS.

The use of GDSS is intended, among other things, to promote e-collaboration by providing the opportunity to generate a wealth of ideas from virtual meeting participants since they can input their thoughts using the computer without interrupting another person (Olson & Olson, 2003). Using GDSS in a technology-mediated collaborative meeting environment can greatly increase efficiency. As Lococo and Yen observe, “Efficient sharing of ideas can be transformed into shared understanding and into shared priorities” (1998, p. 91). Smith (2001) argues that by improving how meetings are conducted, communication, morale and productivity will also improve.

GDSS can be very powerful tools for conducting effective virtual meetings. Used properly, as previously discussed, e-collaboration technologies such as GDSS have tremendous potential to successfully facilitate virtual meetings. While “the same technology will not provide the same results with each group and in each setting” (Boiney, 1998, p. 343), e-collaborating using GDSS has many benefits.

Duarte and Snyder (1999) emphasize the importance of understanding the issues regarding e-collaboration by making five points regarding virtual meetings:

1. Facilitating a virtual meeting includes managing the agenda, the participants, and the technology
2. Select the technology that is appropriate for the outcome of the meeting. Match the use of technology to specific agenda items
3. Leverage the agenda and the use of technology to maximize participant recall, the opportunity for participants to contribute, motivation of the participants, and to reduce social pressure on the participants
4. Make use of social protocols and best practices for using the selected technology
5. Make certain that logistics cover issues such as compatibility of technology training in using new systems as well as backup plans

For virtual meetings to be effective when they are conducted via GDSS, traditional meeting procedures need to be adjusted and redefined to take into consideration the special circumstances involved in using technology that facilitates e-collaboration. As Grenier and Metes (1995) observe, “This meeting’s not over, it’s just gone to another medium.”

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KEY TERMS

Computer-Mediated Collaboration: Working together by using technology-facilitated means.

Computer-Mediated Communication: Communicating by using technology-facilitated means.

E-Collaboration: Working together in an electronic environment.

Group Decision Support Systems: A category of groupware that encourages activities such as group idea generation, voting, brainstorming, decision making, and consensus reaching.

Groupware: Technology that supports collaboration, communication, and coordination in an electronic environment.

Meeting Protocol: The rules or conventions of correctly conducting a meeting.

Virtual Meetings: Meetings conducted electronically, not face-to-face.

Virtual Meeting Protocol: The rules or conventions of correctly conducting a virtual meeting.

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Chapter 5.7

Open Content Distribution Management in Virtual Organizations

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INTRODUCTION

Future scenarios of **organization**s envision companies that are organized around a central **knowledge** base in the form of a **network**. It is assumed that each company contributes its own expertise and intellectual capital to the network's knowledge base. This article discusses the use of **open content** distribution management systems (OCDMSs) in knowledge-intensive fields, such as content production and software development, in order to ensure seamless and open collaboration between the firms in the organization.

OCDMSs offer participants several advantages. For instance, such systems can be seen as a way of enhancing the competitiveness of small and micro-sized knowledge-based firms by ensuring that each firm receives fair compensation for the content it develops. OCDMSs are revolutionary in the sense that they allow participants to contribute content to a common resource pool and add all the required **metadata** to the content. A common information pool where information is shared with well-defined rules lowers transaction costs between participating organizations. This article looks at one open content distribution management system that was developed in a university-industry research project and is being further developed by a company that is a spin-off company from the project.

BACKGROUND

Virtual Organizations

Developments in information technology as well as new organizational concepts have led to the emergence of new types of organizations. Miles, Miles, and Snow (2004), Miles and Snow (1995), and Miles, Snow, and Miles (2000) have discussed network organizations that rely on collaboration between independent units. The term virtual organization has become ever more commonplace in organizational literature. Walters (2004) discusses the business model of the virtual or holonic organization and refers to McHugh, Merli, and Wheeler (1995) in listing the following properties of a virtual organization.

- The organization consists of businesses of equal standing; that is, there is no hierarchy between the individual businesses in a virtual organization.
- Information can be accessed and exchanged freely throughout the organization and across its boundaries; that is, the organization is open.
- The organization is evolutionary and is involved in constant interaction with its environment.

One interesting form of virtual organizing is the virtual web, defined by Franke (1999) as "the base of virtual corporations" (p. 211). According to Franke, a virtual web belongs to the typology of dynamic networks, as defined by Miles and Snow (1986), which has the following characteristics.

1. **Vertical Disaggregation:** Different organizations in the network perform separate functions that have been performed by functional units in a traditional organization.
2. **Brokers:** Brokers bring together the necessary functions available in the organization and play a leading role in building business units and subcontracting for needed services. Brokers can operate at different levels of a dynamic network and, thereby, have varying degrees of responsibility.
3. **Market Mechanisms:** These hold the network together and regulate its functioning. Competition is promoted amongst the members of the network and also with external companies, and this regulates the internal prices of the services available in the network.
4. **Full-Disclosure Information Systems:** Companies wishing to become a part of the network, even for a fixed-term project, are expected to connect their information systems to the network's continuously updated information system via broadband access in return for a general payment structure for the value they add to the network. The purpose of this, according to Miles and Snow (1986), is to facilitate the rapid and mutual assessment of contributions and to speed up the trust-building process.

According to Franke (1999), virtual corporations are involved in temporary partnerships established by brokers in a virtual web in order to bring together the necessary combination of skills and resources. In order for a virtual web to successfully generate virtual corporations, the web must offer an environment that encourages the member companies to participate in virtual corporations without compromising confidentiality and intellectual property rights, while, at the same time, preserving the dynamic and flexible properties of the virtual corporation.

Virtual Communities

Lee, Vodel, and Limayem (2003) have analysed various definitions of virtual communities and have identified four elements that they found common to most definitions. First, a virtual community should exist in cyberspace; that is, the members of a virtual community use computer-mediated spaces in order to interact. Second, the activities of a virtual community are supported by computer-based technologies, such as e-mail, message boards, and chat. Third, the main focus and content of virtual communities are participant driven, and the content of such communities is formed through the communication between the members of the community. The fourth and final element that Lee et al. found to be common to all virtual community definitions was the formation of a sustained relationship as a result of the interaction between the members of the community. Koh and Kim (2003-2004, 2004) have also observed cyberspace to be a usual feature for identifying virtual communities. However, they also found the interaction of many virtual communities to take place off line as well as online, especially in the case of communities that have originated off line. Koh and Kim's definition of a virtual community is "a group of people with common interests or goals, interacting for knowledge (or information) sharing predominantly in cyberspace" (p. 157). Etzioni and Etzioni (1999) point out the discrepancies in the definitions given for computer-mediated communities (CMCs) by different authors; some authors may refer to tightly knit communities while others to groups of acquaintances. The authors have found communities to have two common features: networks of relationships that may overlap rather than single links between the members, and a common set of values and norms to which the members of the community adhere and are committed and a common shared history.

One of the most productive virtual organization models is the free and **open source** software (later FOSS) movement (see DiBona, Ockman, & Stone, 1999). It uses licenses that allow the use and modification of FOSS program components. Open-source licenses grant rights that are otherwise exclusive to the copyright holder. FOSS licensing enables the flexible but controlled use of software resources. FOSS is a multibillion-dollar business that has shown how less restrictive content sharing can lead to considerable benefits for the whole software industry and society at large.

The uncontrolled sharing of information goods leads to exploitation that does not benefit content providers or society in the long run. According to Kwok, Yang, Tam, and Wong (2004), digital and peer-to-peer (P2P) technologies have made it easier to produce and distribute illegal copies of copyrighted material. Thus, a virtual web that is supported by a common broadband information system, to which all the participants are linked, poses risks in terms of content and copyright management. Digital rights management (DRM) is one of the concepts for managing the rights of information products. Benkler (2002) points out how computers have changed copyrights into "privately created and enforced exclusion—created by contracts and enforced by technology" (p. 81). In most cases, DRM systems limit access to information through the use of technical protection measures. This does not serve the purposes of virtual organizations. While DRM might be an overly restrictive tool, some control is needed. This can be obtained by using digital rights expression (DRE).

DIGITAL RIGHTS EXPRESSION

In the digital environment, it is possible to attach a license to a work. Most new music, image, and text formats have a field reserved for metadata. The attaching of metadata that describes the copyright status of a work is called digital rights expression. DRE uses semantic web methods to let users know of the permission that they have. Unlike DRM systems, DRE does not use technical means to restrict users from violating these terms.

One of the most commonly used ways of expressing digital rights is W3C's (World Wide Web Consortium's) resource description framework (RDF). It provides a foundation for the processing and exchange of machine-understandable information on the Web. RDF can be used for cataloguing (to describe content that is in a digital format on a Web page, in a digital library, or on a P2P network), for resource discovery (for example, to let a search engine search for works that have certain licenses), and by intelligent software agents (to facilitate knowledge sharing and exchange) in content rating. The W3C glossary (http://www.w3.org/2003/glossary/) defines metadata as “Data about data on the Web, including but not limited to authorship, classification, endorsement, policy, distribution terms, IPR, and so on.” Most file formats support metadata. Metadata can be easily attached and read from Mp3, PDF (portable document format), mpeg4, and HTML (hypertext markup language) formats. Machine-understandable metadata can be used to efficiently define rights in the information management system of a virtual organization. Metadata can hold pricing and author information as well as licensing terms.

Open content can be briefly defined as being creative works that are in a format that explicitly allows their copying and distribution. Open content must also have a license that allows copying and distribution, or must belong to the public domain. By automating the licensing procedure, transaction costs can be further lowered. While the licenses are expensive to write, they can be used over and over again with minor modifications. These modifications can be made automatically through the use of a licensing engine. In this way, licensing can be fixed to an organization’s work flow. Creative Commons (http://www.creativecommons.org), a nonprofit organization, has produced a set of open content licenses and a Web interface that allow content producers to tailor copyright licenses that suit their needs. They also provide licenses in RDF format. More than 4 million works have been licensed with Creative Commons licenses.

Open content files carrying legal metadata serve virtual organizations by lowering transaction costs. Members of an organization do not have to search for the holders of the rights and negotiate license agreements, and they have the content at their disposal. Open but controlled sharing also has a positive impact on marketing (Nadel, 2004). Benkler (2002) notes how organizations should adapt different information policies and levels of exclusivity depending on their business models. Open content systems benefit creative networks that depend on cooperation.

For the rights holder, the system enables easy licensing, a distribution channel, and the possibility for price discrimination. The price can be set dynamically for different projects. For example, the Magnatune record company (http://www.magnatune.com) uses dynamic pricing for their records that are available online. Magnatune music is available for free for noncommercial use, but commercial licenses must be bought from the Magnatune Web site. The price is preset and is fixed by the licensee, who has to enter the details of the commercial activity. Magnatune’s system calculates the prices of licenses, which depend on the size of the budget and the rights to be licensed. The system also generates a license that is valid after the license payment has been made.

AN EXAMPLE OF AN OPEN CONTENT INFORMATION SYSTEM

Virtual organizations and communities that have grown on the Internet and out of networks of content-production companies need systems for managing content contributed by their members for common use. This article discusses one such system, the Digital Content Distribution Management System (DiMaS). DiMaS is a prototype of a system designed for use within a community of content producers and was developed in cooperation with the Digital Economy Core (DE Core) and Mobile Content Communities (MC^2) research projects at the Helsinki Institute of Information Technology (HIIT).3 The following description is based on two papers by Reti and Sarvas (2004a, 2004b) that outline the functions of the system.

DiMaS enables multimedia producers to publish their works along with content metadata. The content-import user interface is the front end of the system and contains the user registration, user-information database, log-in, user manual, and content-import functionalities. At the point of registration, the user must accept the system's rules of conduct. After registration, the content provider can upload content to a server. Users enter content-related metadata using a chain of Web forms that appear in a particular succession and between which the user can move freely backward and forward. During the upload procedure, the content provider can add metadata, preview files, and feedback questions for the primary content payload. Once entered, the content file, metadata, and preview image are stored in the system until the user publishes them using a specific control button in the user interface.

The structure of the DiMaS system is shown in Figure 1.

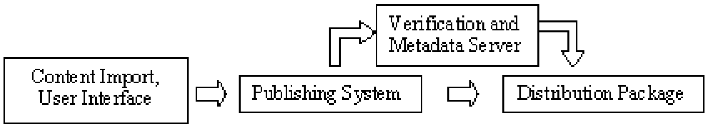
After being uploaded, the content is forwarded to the publishing system. The publishing system forms a distribution package using the inserted content file, preview file, user interface, and metadata. The publishing system can be in a closed or open environment. Publishing can be performed in uncontrolled peer-to-peer networks, such as Gnutella or KaZaa. DiMaS also enables content encryption. In this way, the content can be distributed on public P2P networks and stored on uncontrolled servers. If the content is access controlled, it is not open content.

When consumers, or other end users, find content that they want, they can download and open it, for instance, on their PDAs (personal digital assistants). When opening the content, a user application that resembles a DVD (digital videodisc) menu appears and the system can update the content metadata, for example, the description of the content stored on the metadata server. This makes it possible for the content provider to change the pricing or licensing terms after the content has been uploaded and even after it has been distributed to end users. This feature can be used to set the price of the product according to the product's life cycle. Novel works may carry a higher price tag than vintage material. The system can also notify the user when a new version of a work is available. Users can browse through the copyright license or contract in the price section of the application. The only technology required by the end user in order to run the distribution package is the Java Standard Edition Runtime Environment (http://java.sun.com).

In open content mode, an entire virtual organization can browse the content freely. The metadata inform users on how the content can be modified or exported out of the virtual organization for commercial use. DiMaS also has a feedback option. The system can collect user feedback after content browsing and store this information along with the metadata. Feedback enables content rating, which helps to distinguish premium content from large information masses.

DiMaS is an MIT-licensed open-source product and can be customised to meet the needs of specific content-production communities. The goal of DiMaS is to be executable without specific client software and independent of the type of content to be distributed. The DiMaS prototype supports Windows Media Player files and, as mentioned above, requires that the user have the Java Standard Edition Runtime Environment installed on his or her system. As yet, DiMaS has not been used in any real-life organizations since it is still in the prototype stage.

Figure 1. The structure of DiMaS



CONCLUSION AND FUTURE TRENDS

This article has discussed the problems related to the management of digital rights in virtual communities and the meaning of open content systems. It also presents the prototype of one system for content distribution: DiMaS. DiMaS allows content producers to attach metadata to their works, share works on a publishing platform, and modify the metadata attached to content after the content has been published. DiMaS enables version handling as well as the dynamic pricing of copyright licenses. Because the system packs the metadata into a distribution package, it does not have to rely on any proprietary file format. This also means that the system can be used to distribute all kinds of content without introducing new file formats or players.

Semantic webs and metadata will be a part of knowledge management in future organizations. The management of the vast knowledge bases of networks will require systems that can handle different types of files and can hold all various types of information. Already, file sharing and P2P technologies have made it important for organizations to have in place tools for the management of content with different rights, and there is a clear market for technologies that allow different users different levels of access to common content pools.

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KEY TERMS

Digital Rights Expression (DRE): The attachment of metadata to a work in order to describe the copyright status of that work

Digital Rights Management (DRM): The limitation of the access of users to information in a repository through the use of technical protection measures.

Metadata: Metadata are data about data. In information repositories, metadata are used for labeling the content of such repositories with appropriate descriptions.

Resource Description Framework (RDF): RDF provides the foundation for the processing and exchange of machine-understandable information on the Web. RDF can be used for cataloguing, for resource discovery, and by intelligent software agents in content rating.

Virtual Community: Virtual communities are communities of users that have the following characteristics.

1. They exist in cyberspace and the communication between the members of the community is computer mediated.
2. They use communication technologies, such as e-mail, message boards, blogging, and online chatting, for communication.
3. They develop largely through the activeness and interests of their participants. The content of virtual communities is formed through the communication between the members of such communities.
4. They lead their members to form sustained relationships as a result of their interaction.

Virtual Organization: An organization in which business partners and teams work together across geographical or organizational boundaries through the use of information technology. It is also a strategy for revolutionizing customer interaction, asset configuration, and knowledge leveraging.

Virtual Web: A form of virtual organization that belongs to the typology of dynamic networks and has the following properties.

1. The member organizations of the network perform separate functions that are performed by functional units in traditional organizations.
2. Brokers in a virtual web combine resources to build business units and subcontract to bring together the necessary functions available in the organization. They play a leading role in building business units and subcontracting for needed services.
3. Internal and external market mechanisms hold the network together and regulate its performance.

4. The information system is open, and there is free access to the web's joint knowledge base. Companies belonging to the network have integrated their information systems into the network's continuously updated information system via broadband access in return for a general payment structure for the value they add to the network.

ENDNOTES

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[3] More information on the DE Core and MC^2 projects is available at http://www.hiit.fi/de/core/ and http://pong.hiit.fi, respectively.

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Chapter 5.8

User Participation in the Quality Assurance of Requirements Specifications:

An Evaluation of Traditional Models and Animated Systems Engineering Techniques

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ABSTRACT

Improper specification of systems requirements has thwarted many splendid efforts to deliver high-quality information systems. Scholars have linked this problem to, between others, poor communication among systems developers and users at this stage of systems development. Some believe that specifying requirements is the most important and the most difficult activity in systems development. However, limitations in human information processing capabilities and the inadequacy of the structures available for communicating specifications and obtaining feedback and validation help to exacerbate the difficulty. This chapter presents an overview of both longstanding and newer requirements specification models and evaluates their capability to advance user participation in this process and incorporate stated quality attributes. It also reports on preliminary evaluations of animated system engineering (ASE), the author's preferred (newer) technique, which indicate that it has the capability to improve the specification effectiveness.

INTRODUCTION

It is estimated that between 30% and 80% of software projects fail (Dorsey, 2003; Standish

Group, 1994), depending on whether the basis is budgets or number of projects. Many of these software projects fail because of their inability to adequately specify and eventually meet customer requirements (Zave & Jackson, 1997). The following quotation from The Standish Group (1994) provides an excellent summary of the situation and puts the problem in perspective:

> *In the United States, we spend more than $250 billion each year on IT application development of approximately 175,000 projects. The average cost of a development project for a large company is $2,322,000; for a medium company, it is $1,331,000; and for a small company, it is $434,000. A great many of these projects will fail. Software development projects are in chaos, and we can no longer imitate the three monkeys—hear no failures, see no failures, speak no failures.*
>
> *The Standish Group research shows a staggering 31.1% of projects will be cancelled before they ever get completed. Further results indicate 52.7% of projects will cost 189% of their original estimates. The cost of these failures and overruns are just the tip of the proverbial iceberg. The lost opportunity costs are not measurable, but could easily be in the trillions of dollars. One just has to look to the City of Denver to realize the extent of this problem. The failure to produce reliable software to handle baggage at the new Denver airport is costing the city $1.1 million per day.*
>
> *Based on this research, The Standish Group estimates that in 1995 American companies and government agencies will spend $81 billion for canceled software projects. These same organizations will pay an additional $59 billion for software projects that will be completed, but will exceed their original time estimates. Risk is always a factor when pushing the technology envelope, but many of these projects were as mundane as a driver's license database, a new accounting package, or an order entry system.*

The fact is that too many software projects fail, that these failures may be due to both technical and behavioral reasons. Obtaining accurate systems requirements (Zave & Jackson, 1997) and translating them into feasible specifications is a well-discussed problem; however, involving potential users in the development project is an important factor in this process. In Levina and Vaast's (2004) investigation of how innovations are brought into enterprises, they underscored the pivotal nature of user involvement in successful implementation.

The specification of the requirements of an information system occurs fairly early in the development lifecycle. To accomplish this task, users and developers collaborate to describe the processes and static structures that are involved in the application domain and define their relationships. Quite often both sides speak a different language, using terminology that may be unfamiliar to the other. Clients express themselves using (in the view of technocrats) informal business terminology; developers write system specification from a technical perspective. It is widely acknowledged that this miscommunication is the reason for the prevalence of poorly specified systems and the root cause of many of the failed information systems (Byrd et al., 1992; Raghaven et al., 1994).

To solve this problem, the information system community introduced several models to improve communication between developers and users, particularly the accuracy and understandability of the representation of the business process information that eventually will be used to create the design artifact. But even with these models, users often experience some difficulty in assimilating the essence of the specification details. Sometimes they do not participate in the process because of cognitive limitations and an inability to comprehend the models. However, user participation in this process is essential to the production of accurate specifications. This has intensified the need to provide representational schemes for communicating specifications that are both accurate and easy to understand.

This chapter uses a real life scenario to assess a variety of modeling techniques and tools that have been employed to improve the quality of systems specifications and their success at accommodating user participation to improve user-developer communication. It reviews the models and demonstrates how they represent the scenario details. The discussion is organized somewhat chronologically beginning with the earlier techniques and culminating with a more detailed description of a proposed set of methods — animated system engineering (ASE) — which the author believes may overcome many of the difficulties of earlier models.

USER INVOLVEMENT IN IMPROVING THE QUALITY OF REQUIREMENTS SPECIFICATION

Several quality assurance initiatives have been undertaken in information systems development since Dijkstra (1972) alluded to the “software crisis”. Earlier efforts focused on the quality assurance of computer programs. Soon it was recognized that this was far too late to be effective. Either programs were implemented with significant patchwork or they had to be extensively revised. In the worst-case scenarios, total recoding was necessary, which, according to Knoell and Suk (1989), was tantamount to sabotage. However, it has long been acknowledged that software quality assurance should at least begin with requirements specification (Karlson, 1997). At this point, there is already enough information compiled to necessitate a quality review.

While several well-established characteristics exist to assess the quality of a finished software product, these cannot be applied to requirements specification. The concern at this stage is how to drive toward the attainment of the eventual software quality by applying standards that will increase the quality of the deliverable at this stage of development. Scholars have begun to focus on this area. For example, Davis et al. (1997) identified several quality criteria related to software requirements specification, and Knoell et al. (1996) provided an ontology of quality terms in requirements specification to simplify and promote user understanding and participation in the process. In this chapter we refer to the quality criteria for requirements specification that have been suggested by the German working group of accounting auditors (IDW, 2001) because of their simplicity and absence of technical nomenclature. Table 1 summarizes these characteristics.

Despite the existence of these quality criteria, the problems with requirements enumerated by Dorsey (2003), which include incomplete and ambiguous specification and lack of change management and user involvement in requirements specification, are remarkably similar to those Boehm and Ross (1989) identified. This suggests that very little has changed within that last 15 years, and improper specification of software requirements continues to thwart many splendid efforts to deliver high-quality information systems (Dorsey, 2003).

Scholars have linked this problem to, among other things, poor communication between systems developers and users at this stage of systems development (Raghaven et al., 1994). Metersky (1993) and Zmud et al. (1993) believe that specifying requirements is arguably the most important and the most difficult activity in systems development. However, limitations in human information processing capabilities and the inadequacy of the structures available for communicating specifications to users to obtaining their feedback and validation help to exacerbate the difficulty.

This is because software requirements specification depends on the constructive collaboration of several groups, typically with different levels of competence, varying interests and needs (Knoell & Knoell, 1998). The challenge is how to effectively communicate the perspectives of all stakeholders, in a manner that is understandable to all, to help them participate in a process

Table 1. Quality characteristics of requirements specification

Quality Characteristics	**Meaning**	**How Determined**
Completeness	Inclusion of all information about work sequences and objects (transactions and entities), including a reliable catalog of all attributes of transactions, transaction types, entities, and entity types	When the attributes for application projects, processes, entities, transactions and functions are given content values in the validity range for the respective attribute.
Consistency	No contradiction in the information about transactions and entities in the catalog of all permissible transactions and entities	Cross-checking the attributes of the system components
Clarity	Precise and unambiguous statement of the system features in terms that can be understood by all those participating in the project	Verification of system specification with future users and through forward traceability into the design
Factual accuracy	The extent to which functions of the existing business system description are contained in the requirements specification.	Verifying that all the internal processing rules, operational procedures , and data are accounted for
Feasibility.	Whether the requirements are achievable with the available resources	Matching resources against project demands

of information sharing to rationally decide the correct approach and unearth creative solutions that may well involve non-technical issues such as new work flows and business process alterations. There is little doubt that user involvement in this process is pivotal and the models used to capture and present this perspective for effective user decision making even more so.

In the following sections, we provide an overview of traditional methods and then describe newer and less known models. The older ones are still useful in various contexts as we will describe; however, complex new systems also require other models to incorporate user participation in order to accommodate desirable quality characteristics and improve results.

OVERVIEW OF MODELS USED FOR SPECIFICATIONS

In order to more clearly demonstrate the techniques that will be described and make their underlying principles more concrete, the following real-life scenario will be used to construct a simple example of the models that will be discussed. These methods are flow charts and a modified version of the flow chart, data flow diagrams, entity relationship diagrams, decision tables, the use case diagram — one of the models from the family of the unified modeling language (UML) that supports object-oriented development — and Petri Nets, a modeling language used to graphically represent systems with facilities to simulate dynamic and concurrent activities.

This scenario involves requirements for a system at a non-profit organization in Germany, which supports grieving families after the loss of a child. Besides membership administration, the organization maintains lists of contact persons, rehabilitation hospitals, speakers, and seminars and distributes books, brochures, and CDs to interested persons and organizations. The three major tasks in the process of distributing informational material are order entry, order checking, and sending notifications about the status of orders.

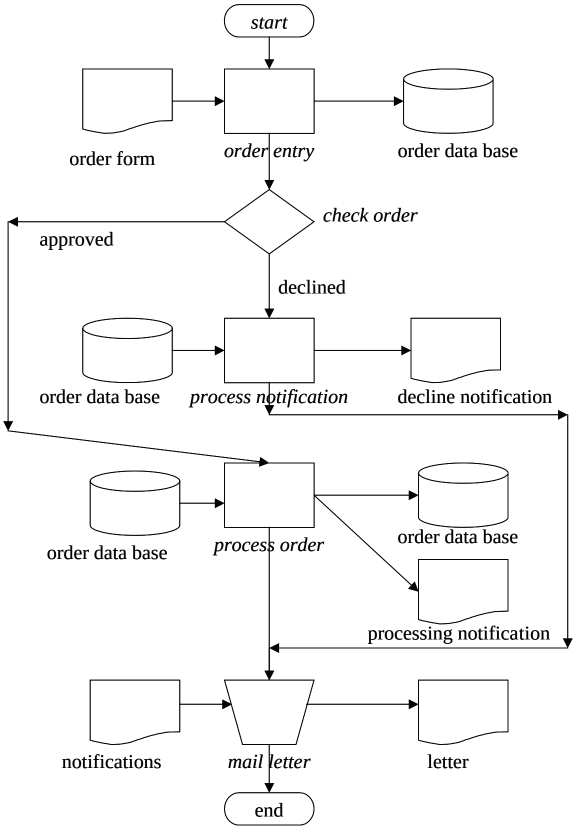
Flow Charts

The flow charting technique has been around for a very long time, so long in fact, that there is no "father of the flow chart" and no one individual is accorded rights of authorship. In general, a flow chart can be customized to describe any process in order to communicate sequence, iteration, and decision branches. It may be used in a variety of situations and is recognized as an excellent technique for helping to demonstrate processes in order to improve quality (Clemson University, 2004). Figure 1 shows the flow chart for our case study.

The Modified Flow Chart

The basic flow chart technique has been modified by Knoell et al. (1996) in order to enhance communication by the introduction of additional symbols that make it easier for non-technical users to understand. This modified technique distinguishes between objects (ellipse or oval) and actions (rectangle) by including icons, which symbolize the object and action, respectively. Figure 2 depicts the modified version. This representation has been used successfully in several projects and has been well accepted by non-technical users. It has also been used in the design phase, where several refinement levels have been added (Knoell et al., 1996).

Figure 1. Order processing flow chart



Data Flow Diagrams

Structured Analysis (SA) (DeMarco, 1979; Svoboda, 1997; Yourdon, 1979) has been developed to support systems analysis and particularly to demonstrate process and data structures in order to improve user-developer communication and understanding of the processes to be automated. Three basic models exist: (1) the data flow diagram, which supports requirements specification (and will be elaborated on later), provides a functional view of processes including what is done (processes) and the flow of data between these processes; (2) the entity relationship diagram, which provides a static view of data relationships; and (3) a transition diagram, which provides a dynamic view of when events occur and the conditions under which they occur.

The data flow diagram uses two symbol sets (or representation schemes) (Svoboda, 1997): one originated by Yourdon and DeMarco (DeMarco, 1979) and the other provided by Gane and Sarson (1977). We have selected the Yourdon-DeMarco notation in this chapter.

The description of the system is refined into as many levels as needed. The first is the context level data flow diagram (Figure 3), which depicts the interaction of the system with external agents that provide and receive information to and from it. This level is used to give a general overview of the system to be developed. It is the basis for the

Figure 2. Processing orders as a KS-Diagram (Knoell et al., 1996)

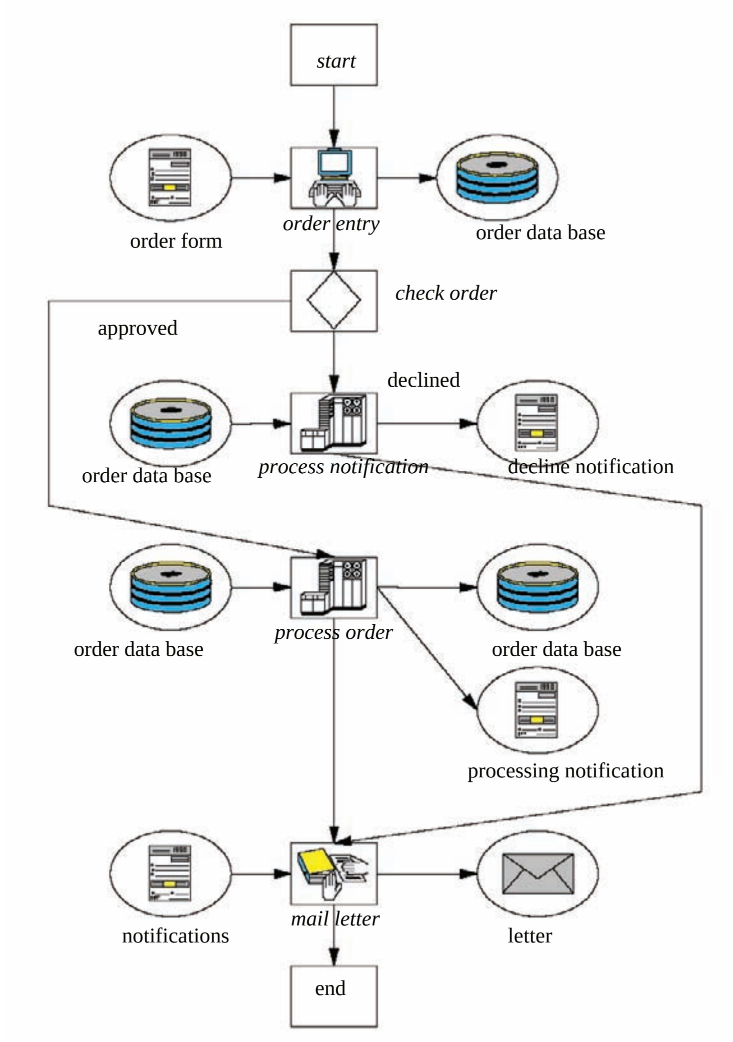
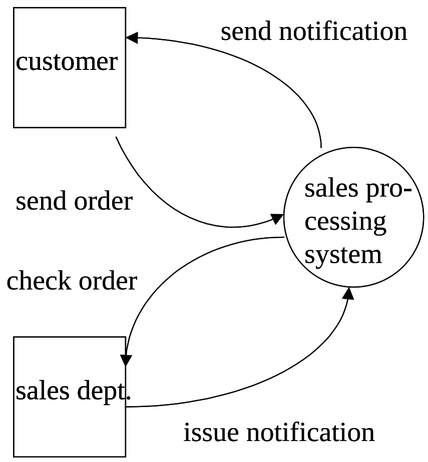


Figure 3. Context level data flow diagram

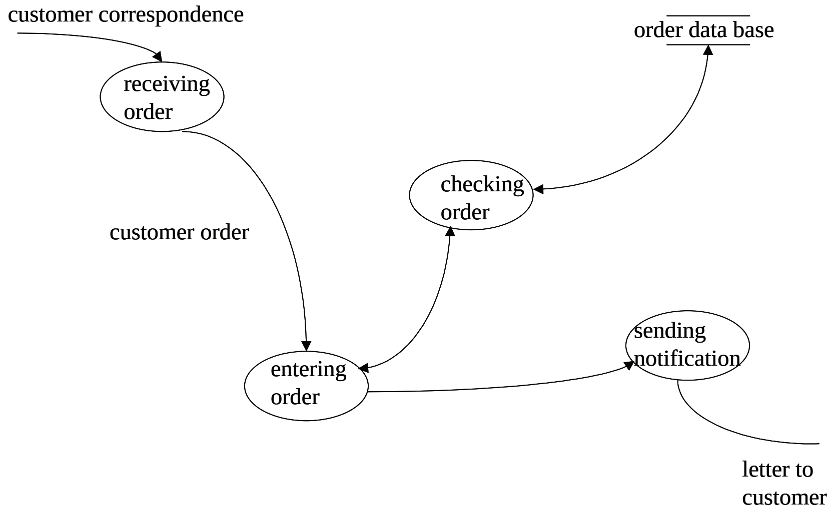


first meetings with users. As soon as this level is accepted by the users and acknowledged to be feasible by the systems analysts, the next level, a data flow diagram, is developed (see Figure 4).

The functions of the level 0 data flow diagram are shown in Figure 4. It is a high level view of the system. Each process can be elaborated in its own diagram until the so called "functional primitive" level is reached. At that point, there is little communication value in decomposing the process further.

In addition to data flow diagrams, which were very prominent in the 1980s and 1990s, several other methods have been used to support func-

Figure 4. Level 0 data flow diagram



tional analysis. Newer techniques, such as those provided by the Unified Modeling Language (UML), the de facto notations and modeling standard used in object-oriented development, have made structured techniques redundant in many cases. Although SA is still in use in industry, most universities have switched to UML. According to the experience of IT consultants (Berger, 2001; Kuehl, 2001), the SA Data Flow Diagrams have been harder for non-IT users than flow charts — "The average user thinks like that: I take A, perform B and the output is C" (Berger, 2001).

Entity Relationship Diagrams (ERD)

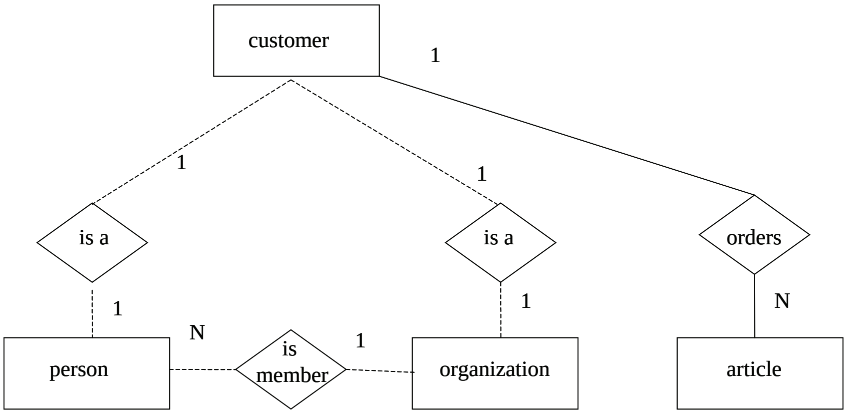
The data-oriented approach to requirements specification (Jackson, 1975) was introduced during the period when large software systems threatened to confound programmers, a phenomenon that Dijkstra (1972) dubbed the "Software Crisis." Chen (1976) helped to solve the problem of representing information in a way that systems analysts, programmers, and customers could all understand; this solution was the Entity Relationship Diagram (ERD) approach to database design, which was extended to the ERD technique for systems design (Chen & Knoell, 1991). The ERD approach enlightened both technocrats, who had struggled with a combination of hierarchical databases (and the emerging relational databases), as well as users, who began to understand the structure of data.

Figure 5 demonstrates the entities and their relationships involved in the scenario that is used as an example in these models. It gave the customer and the programmer a relatively simple way to discuss the requirements of the system to be built. Chen developed rules to create optimum databases out of the ERDs (Chen & Knoell, 1991), which helped the analysts and programmers develop normalized, non-redundant relational databases.

Decision Tables

Sometimes, because of the many rules to apply to certain decision points in a process, it is not useful to use diagrams with decision branches (such as flow charts, or UML and Petri Nets, which will be discussed later). A graphic representation of such complex decision processes is often difficult to understand, especially for non-technical users. In those situations decision tables, which have been the basis for program generators in

Figure 5. Entity-relationship diagram (Chen, 1976)



COBOL in the 1980s like Vorelle (mbp GmbH) and SWT (SWT GmbH) (Grawe, 2001), are far more suitable. A decision table is divided into quadrants: upper left (a list of conditions); upper right (the combination of conditions into rules); lower left (a list of possible actions); and lower right (the combination of actions according the rules — combination of conditions).

Unlike the methods described previously, a decision table is not suitable for outlining the logical structure of the information, or the flow of data, or the sequence of processes. It is an add-on to the other methods, used to describe the system's behavior at a certain point of the process flow. However, the decision table is well suited for specification negotiations with business users who are more accustomed to working with tables. If the process is very complex, nested decision tables may be used to decompose a very large decision into smaller, interdependent tables in which the master decision table contains the dependent decision tables as actions.

USE CASES FROM THE UNIFIED MODELING LANGUAGE (UML)

UML integrated the concepts of Booch (1993), Object Modeling Technique (OMT) (Rumbaugh et al., 1991) and Object-Oriented Software Engineering (OOSE) developed by Ivar Jacobson in 1992 (*Wikipedia*, 2004), by combining them into a single, common notation and modeling standard for object-oriented software development that is now widely used to model concurrent and distributed systems (Wikipedia, 2004) and was the basis for the Object Management Group (OMG) Unified Modeling Language Specification (OMG, 2003). Of the several UML models, the most popular is the Use Case diagram for requirements

Figure 6. Example of a decision table

Conditions	**Rule #1**	**Rule #2**	**Rule #3**	**Rule #4**	**Rule #5**	**Rule #6**	**Rule #7**	**Rule #8**
wholesaler	Y	Y	Y	Y	N	N	N	N
regular customer	Y	Y	N	N	Y	Y	N	N
order value > $ 10,000.-	Y	N	Y	N	Y	N	Y	N
actions								
3 % discount	-	X	-	X	X	-	X	
5 % discount	X	-	X	-	-	-	-	-
free shipping	X	X	-	-	X	X	-	-

specification, and, in the experience of the author, it is easily understood by users. In Figure 7 we have modeled the main processes of the system highlighted in the case scenario in an UML Use Case diagram. The model also further supports a narrative description of the use case (which is not developed here).

Rational Rose is one of the several tools that have been developed to support the construction of use case diagrams. It was developed by James Rumbaugh and Ivar Jacobson and later acquired by IBM and incorporated into the Software Group Division where it became an IBM software brand. Originally, Rational Rose was designed to support the development of ADA programs but later C++ and Java were added. In the newest version, Rational Rose supports the development of any object-oriented software system and allows animations of the designed UML diagrams in order to verify the process sequences and the associated data structures (IBM, 2004).

Petri Nets

The Petri Net models described below are methods for capturing and graphically representing requirements that attempt to facilitate better user understanding, assimilation, and assessment in order to increase the odds of accommodating quality attributes. Like the other tools, they assist visual communications but, in addition, can simulate dynamic and concurrent activities. Petri Nets are a well-known design method in Europe, though not as widely used in the United States. Originally they were used in technical computing (e.g., in switchboards); however, for the last 20 years or so, they have been used increasingly in information systems development.

The Petri Net methodology was developed by Petri (1962) primarily to show the behavior of finite state machines (a theoretical construct in computer science). Initially, its application was restricted to technological problems, but since the 1990s it has been used in the specification phase of information systems development. Petri Nets can be animated, but they are mostly used for the resolution of technical problems like concurrent, asynchronous, distributed, parallel, non-deterministic, and/or stochastic systems.

Nowadays, an abundance of Petri Net-based design tools are available. These range from open-source facilities in the public domain to expensive professional tools. Three such tools, that are outstanding for their animation features, are BaaN Dynamic Enterprise Modeler, Pavone Process Modeler, and Animated Process Illustration (APRIL).

The BaaN Dynamic Enterprise Modeler (DEM) (BaaN, 1999) is a graphic program, which is used for the representation of the company's business processes. This model is used to assist users to customize the BaaN system and for the

Figure 7. UML use case diagram

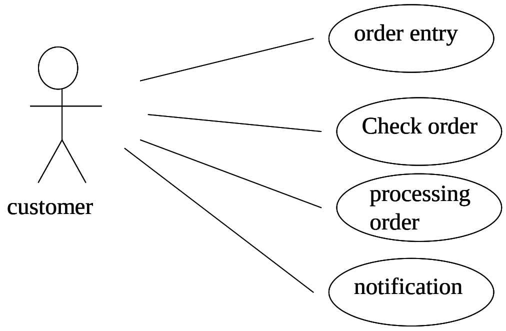
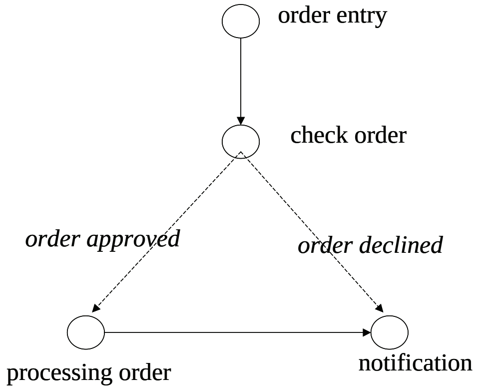


Figure 8. Petri Net

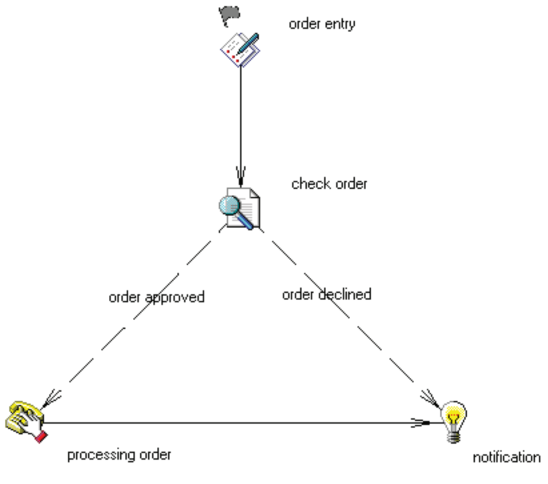


transfer of the business process model into the BaaN ERP system. The DEM has an animation mode in which users can check settings prior to the installation of the ERP software system. Furthermore, the graphic model is the user interface, from which users can trigger BaaN sessions.

The Pavone Process Modeler (Pavone, 2001) was developed to support the design of workflow in Lotus Notes applications. Figure 9 shows an example drawn with this program. For computer-naïve personnel, this depiction is much easier to understand as the Process Modeler uses icons to the differentiation of various processes. In addition, the persons or groups associated with the process have to be added. The Process Modeler also has an animation mode, similar to BaaN DEM, which is used to trace process flows, a feature is particularly helpful in communication with non-IT staff.

Animated Process Illustration (APRIL) is a Petri-Net-based approach to developing information systems that uses diagrams to make the process more transparent to both system engineers and users. The diagrams are used throughout the entire software development process. APRIL diagrams provide the means to simulate and analyze the system's behavior by synthesizing common techniques and adjusting them to each other and generating prototypes. The CASE tool NEPTUN is used in conjunction with APRIL to automatically generate a stand-alone platform and database system independently of the system's generic model (Simon et al., 1997). APRIL diagrams and the CASE-tool NEPTUN are integral parts of the Animated Systems Engineering Method, which is described in detail in the next section.

Figure 9. Modified Petri Net – Pavone Process (Modeler, 2001)



ANIMATED SYSTEMS ENGINEERING (ASE)

Animated systems engineering is based on the philosophy that prototyping in the problem definition, analysis, and design phases through animation will help to circumvent most of the communication and decision errors that are typical of participating stakeholders (Boehm & Ross, 1989). The term animation is used instead of simulation because no executable specification is generated based on the dynamic model (Marx, 1998). ASE uses a graphic method to give the vivid representation of the dynamic system behavior without programming. For quality assurance purposes, executable specifications are available too late in the software development life cycle to figure out misunderstandings in the actual state analysis regarding requirements definition.

The animation of a Petri Net allows one to visualize the performance of a system (e.g., user interaction and loops) and to find problems in the system. It provides a good opportunity to recognize missing or misunderstood parts in the model under construction, because of the needed knowledge about the correct order of actions and object flows and not only about the static structure. It will also be useful for management to prove the progress of a project.

Pahnke and Knoell (1999) found that the ASE method indirectly improved the quality of specifications during groupware development by:

- structuring the software development process under consideration of quality criteria;
- showing the dynamics of the groupware processes;
- reducing the impact of language differences, which increases user participation by promoting agreement among project participants;
- managing complexity with easy-to-understand graphic elements; and
- producing an early graphic prototype to develop an executable problem description or requirements analysis.

To effect these benefits, ASE includes several tools such as the METAPLAN-Technique, Petri Net diagrams, object modeling diagrams, animation, mask/screen and text generators, and a document management system with versioning. These are noted below:

- The METAPLAN (2003) moderation is a communication and discussion technique, which motivates a working atmosphere, within participating groups that are free of hierarchy influences (Pütz, 1999). In our students' projects the METAPLAN cards should be used in the form of prefabricated APRIL-Symbols to speed up the discussion.
- APRIL prototype from the Neptun Project of the University of Koblenz (Neptun, 2002) is used for the validation of ASE.
- Object Modeling Diagrams (OMD) are not directly needed for the core method, but they are useful from the detailed design phase and include the object oriented representation of the static view (data view), using classes, attributes and roles, as well as the graphic representation of association, aggregation, and inheritance.
- Animation is the core part of the ASE method. It is used to build and show scenarios during the investigation and analysis of the actual state. Scenarios show a sequence of events according to Rumbaugh et al. (1991). Animation is more effective than prototyping and provides more than the look and feel dimension of prototyping; its processes are performed on a higher level of abstraction. For user acceptance, this modeling approach needs easily understandable graphic elements. It should be used as late as possible (after a structure of the system is visible, but as early as needed) to get an overview of the dynamics of the system.

The following components of ASE are directly needed for quality assurance of specifications. They serve to fulfill the requirements for quality explanation according to ISO 12119 (ISO, 1994); the Capability Maturity Model (Paulk et al., 1993); standards in the pharmaceutical industry (which has very strict rules for software development, generally, and requirements specification, in particular; for example, ISO 10007, 1995); and European Community guidance note for Good Clinical Practice (APV, 1996; Committee for Proprietary Medical Products, 1997).

- The Mask/Screen Generator is needed to produce the graphic user interface as early as possible, to easily develop a simple representation of menus. This representation should help novice users to overview and develop a vision of feasible solutions.
- A Text Generator is also very useful for documenting the decisions of the development team participants. The ideal situation would be the capability to branch from the respective Petri Net or animation directly to these documents.
- A Document Management System with versioning is required to prove the changes during the phases and identify requirements. The Petri Net animation has to be integrated into a document management system, to allow versioning through an archive.

Indications of the Effectiveness of ASE

The motivation for recommending ASE as a possible cure for the communication problems that often beset requirements specification is based on indications of its successful use. Pahnke et al. (2004) reported on supervised students in two independent projects and further conducted a case study of a groupware development project at a pharmaceutical company in which ASE played a significant role in generating high-quality requirements.

In the two independent student projects, teams of students, each using a different method, generated the requirements specification of software systems. They were required to elicit requirements and present and discuss the specification with the future users. They then developed a prototype of the system. In both projects the teams using ASE were judged to be the ones that obtained the highest quality results and produced the best prototype (Pahnke, 2003).

The case study (Pahnke et al., 2001) was a more elaborate undertaking. It involved the pharmaceutical company, Merck KgaA. Merck has to meet quality standards specified by the US Food and Drug Administration (FDA). All of the drug studies submitted by Merck to the FDA and other regulatory agencies must satisfy good laboratory practice (GLP), good clinical practice (GCP), and good manufacturing practice (GMP). The FDA also requires that computer hardware and software used in drug studies satisfy good practices and conform to standards. The company uses several groupware and workflow systems and puts them through a quality assurance (QA) process using advanced QA concepts beyond the "fitness for purpose" requirement of ISO/IEC 12119 (ISO, 1994); these include user convenience, effectiveness, and data safety.

The company launched the Merck Electronic Document Management & Information System (MEDIS) to manage the global collection, electronic compilation, and dissemination of information through the planning, preparation, and publication of documents and dossiers, and related management processes including the preparation of all pharmaceutical submissions to regulatory agencies. Triple D (short name for Drug Data to Disc) was the project name for a document and workflow management system, developed to satisfy special needs of Merck's pharmaceutical submissions.

Merck adopted groupware as the management technology and implemented role-based privileges for managing the creation, and publishing of dossiers. An essential mandate of the FDA and other regulatory agencies is for dossier creation and submission to be under version control. In Merck's case, those allowed to create documents are able to build their own information workflows; however, the workflows for review and approval have to be predefined for some roles within a working group. The project therefore required the collaboration of several stakeholders and coordinated decision-making by several participants.

Merck decided to apply ASE after evaluating the presented examples in relation to the special QA needs of the MEDIS project. Participants were trained in ASE techniques and later determined the ASE features that would be required to monitor and achieve their quality requirements in all development phases. They selected a mask/screen generator and an integrated text generator as well as version management to support the QA requirement for traceability of documents.

ASE contributed to the success of the project by significantly lowering error rate and contributing to higher user satisfaction in comparison to previous projects in the company. Gunther Knabe, the project manager of MEDIS, expressed it thus: "We have never had such a smooth project like this before. At first sight ASE seemed to require greater effort. But finally these efforts paid off" (Knabe, 1999).

SUMMARY AND CONCLUSIONS

Software development efforts are often complicated by the fact that decisions taken early in the development process are pivotal to the eventual quality of the system. However, such decisions are often based on incomplete and insufficient information. This is related to the inadequacy of communication models to assist the capture and assimilation of information to guide the specification of requirements, an activity that is universally acknowledged as pivotal to successful outcomes. Wrong decisions from poor information typically cost organizations a great deal.

Several models have been used to assist users and developers communicate more effectively about, and specify, the requirements that are needed to produce useful and usable systems with high quality. However, despite the extensive use of these models over several years, indications are that inadequate systems, resulting from poorly specified requirements, are still very prevalent. Effective user participation in the specification phase of a software project contributes to the elimination of misunderstandings of the requirements in the earlier phases, the enhancement of quality, and saves time and money in subsequent phases. Effective QA depends on the definition of quality criteria in user language and a useful and understandable structure for depicting the specifications that can also identify deficiencies.

This chapter discussed most of the existing models that are used to promote user-developer communication during requirements specification under the umbrella of traditional (and popular) models and more recent (but less well known) ones. Some of the older models are still very useful; however, like information technology that has been coming at us at a rapid pace, we need to explore new and improved techniques to match the complexity of new systems and provide effective tools for accommodating desirable quality attributes into the process of specifying requirements. In this regard, our research presented in this chapter suggests that the set of ASE techniques has proven to be reasonably successful in circumventing some of the problems that have plagued other approaches.

Animation and virtual reality have been applied successfully in a variety of technologies to simulate actual usage experience of physical structures (for example, in computer aided design). We should make use of its capability to better incorporate user views and improve the accuracy in requirements specification. After all, most of the quality-enhancing methods in the later stages of systems development are still destined to failure if we cannot improve the quality of the specifications by affording users tools to better contribute their own information and assimilate the contributions of others in order to positively influence the completeness, consistency, clarity, accuracy, and feasibility of specifications.

The preliminary indications from our rudimentary assessment of ASE need to be followed by more rigorous research efforts to establish the limits of the efficacy of this approach and to provide insights into its strengths and weaknesses. It would be useful to conduct such studies with industrial strength applications and to apply it in combination with other techniques to evaluate whether some synergies would result from such applications. Other future research efforts could examine more sophisticated tools to enable more realistic animated simulations of IS in development and determine the effects on the quality of the deliverables they support as well as the quality of the final product.

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Chapter 5.9

The Value of Information Systems to Small and Medium-Sized Enterprises:

Information and Communications Technologies as Signal and Symbol of Legitimacy and Competitiveness

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ABSTRACT

Small and medium-sized enterprises (SMEs) face more serious challenges to their survival than do larger firms. To succeed, SMEs must establish and maintain credibility in the marketplace to attract the resources required for survival. Most co-opt legitimacy by mimicking the cues that signal credibility to convince potential stakeholders that something stands behind their promises. This research examines the role of information and communications technology (ICT) in legitimacy-building from the perspective of both SME founders and customers. In-depth, semi-structured interviews were conducted in a variety of industries to determine whether the ICT-related legitimacy schema from the customers' perspective differs substantially from that of firm founders. Results indicate that customers compare the ICT information provided in SME's sales pitches to pre-existing ICT expectations about the nature of desirable sales transactions.

We describe the relationship between violations of ICT expectations, legitimacy, and purchase decisions. Implications for theory and practice are discussed.

INTRODUCTION

All firms want to survive and thrive. As new information and communication technologies (ICTs) are developed, attempts to understand their adoption and use by small and medium-sized enterprises (SMEs) have determined that many of the resources developed for larger firms to guide strategic IS planning, alignment and the evaluation of ICT investments are often inappropriate for SMEs (Wainwright, Green, Mitchell, & Yarrow, 2005) and have identified barriers to adoption including negative attitudes and financial and knowledge constraints (Parker & Castleman, 2007). Underlying this research is an emphasis on the role of ICT in deriving business value for SMEs by efficiently managing internal operations and supply chain activities to improve productivity and profitability (Levy & Powell, 2005).

Although SME success is related to internal operational efficiency and effectiveness, it also requires access to external resources such as labor, financing, and most importantly, a steady stream of income from sales (Harrison, Dibben, & Mason, 1997). For SMEs, most sales are made to other businesses (Levy & Powell, 2005) and success depends on the firm persuading potential customers to actually make purchases, a decision that hinges on perceptions of the firm's legitimacy (Suchman, 1995; Zimmerman & Zeitz, 2002). Legitimacy is especially important for new firm survival (most begin as SMEs) because smaller and newer firms fail at a higher rate which suggests that obtaining access to resources may be more difficult (Singh, Tucker & Meinhard, 1991). However, previous research on ICT use by SMEs has not considered its role in perceptions of legitimacy and purchase decisions.

New venture lore is replete with anecdotes relating how founders deliberately manage perceptions of legitimacy (e.g., Darwell, Sahlman & Roberts, 1998). In most cases, firms co-opted legitimacy (Starr & MacMillan, 1990) by garnering endorsements and associations and by mimicking the standards, practices, and cues of their relevant industries. This article investigates whether these standards include expectations regarding the use of ICT and whether ICT acts as a signal and symbolic of legitimacy among potential customers.

This approach extends the literature on SMEs and IS in an important way. The IS field has long recognized the symbolic meaning of ICT and its use as a signal by various stakeholders (Feldman & March, 1981; Kling & Iacono, 1988). Research on the computerization of work has explored what ICT symbolizes to employees, shareholders and developers or special interest groups (e.g. Jackson, Poole & Kuhn, 2002; Prasad, 1993; Ranganathan & Brown, 2006; Swanson & Ramiller, 1997). Missing from this research is a systematic exploration of the link between an SME's ICT, the customers' image of the firm, and the likelihood of purchase, a central concern for managers and researchers.

This work also extends the organizational theory literature in two important ways. First, it focuses on establishing legitimacy whereas the existing literature focuses on its maintenance and repair (Suchman, 1995). Secondly, we examine both how SMEs convey impressions and what potential customers expect to hear whereas the existing literature usually examines only one or the other (e.g., Arnold, Handelman & Tigert, 1996; Harrison et al., 1997).

If potential customers form impressions of an SME based on its use of ICT and these impressions are positively related to purchase behavior, managers who want to attract and retain customers may want to consider adopting ICT as a signal, not just for its productivity-related business value. If these impressions are negatively related to purchase behavior, SMEs may consider avoiding the ICT, or at least obscuring its use. Thus, the customers' perceptions of the symbolic meaning of ICT forms an important component of its total business value, which may include both improvements in internal operational efficiency and its ability to act as a signal and affect purchase behavior among external stakeholders.

The first two related research questions addressed here are: Do prospective SME customers infer legitimacy from the presence of ICT? Does this perceived legitimacy affect the likelihood that customers will make a purchase? To answer these questions, we investigate 1) whether these symbol meanings are tacit or explicit; 2) whether customers' and SME founders' views of ICT's symbolic meanings are sufficiently similar to one another to enable accurate signaling; 3) whether SME founders are aware of the customers' perspective and could purposefully manipulate their firm's images through their choice of ICT; and 4) what attributions about SMEs are drawn from the use of ICT emphasizing customer expectations and the implications when these are violated. The third research question addressed is: Why and how does ICT act as a symbol of legitimacy?

We begin by briefly describing the existing corporate image literature with particular attention to identifying the potential role of ICT in assessing firm legitimacy. This is followed by an in-depth presentation of an inductive investigation of why ICT signals legitimacy by investigating the importance of matching customer expectations. Although it is generated from the more specific results, the findings from this phase begin with the presentation of the abstract theoretical frame or paradigm model (as recommended by Strauss and Corbin, 1998), highlighting the importance of mental models in creating a corporate image and the symbolic role of ICT in judging legitimacy. Each element of the model is then described with supporting evidence and comparisons between the findings and existing legitimacy theory to identify areas of confirmation or contradiction, allowing the generation of an integrative, general and particularistic theory of the symbolic role of ICT in a corporate image of legitimacy (Martin & Turner, 1986). Finally, implications of this model for managers and directions for future theory and research are discussed.

BACKGROUND AND HYPOTHESES

Corporate Image

No existing theory has looked specifically at the role of an SME's ICT use in creating legitimacy and encouraging customers to make purchases. The ICT and SME literature has focused on the role of ICT in improving operational efficiency and overcoming barriers to adoption (Parker & Castleman, 2007). The ICT literature has investigated how ICT adoption and use have affected the views of various organizational stakeholders (e.g. Fichman, 2000; Orlikowski & Iacono, 2000), but has not focused on customers' views of a firm. The organizational literature has investigated how firms are perceived by stakeholders and the effects of these views on organizational members (Gioia, Schultz, & Corley, 2000), but has not considered the role of ICT and the customer perspective.

How a firm is perceived has been termed its corporate image and definitions of corporate identity and image[1] have been extensively debated. Briefly, corporate identity is a firm's personality or the essence of what the firm is (Albert & Whetten, 1985; Balmer, 1998). It is reflective of the firm-level mission, values, history, philosophy, culture, and behavior (Ind, 1992; Van Riel, 1997). Recent work in corporate brand management supports an inclusive and multidimensional conceptualization of corporate identity including the expression of a firm's: 1) corporate culture; 2) brand and organizational structure; 3) industry identity; and 4) strategic positioning; through 5) the behavior of the corporation, its employees, and managers; 6) corporate communication; and 7) corporate design, which includes corporate visual identity elements such as buildings, clothes, and graphics (Melewar & Karaosmanoglu, 2006).

Definitions of corporate image vary depending upon whose view of the corporation is emphasized. Consistent with the work of Berg (1985), our interest is in the views of customers. The perception of customers is the firm's corporate image (Melewar & Karaosmanoglu, 2006) and the importance of establishing a corporate image has long been accepted (Christian, 1959; Hatch & Schultz, 1997; Pfeffer & Salancik, 1978). The literature provides broad guidance on the dimensions of an SME that play a role in creating a corporate image but does not provide information about the detailed particularistic meanings of specific cues such as ICT.

Institutionalism and Firm Image

From a more macro perspective, institutionalism focuses on the social structure of the environment and its effects on individual behavior. Researchers have argued that managers' choices, such as those involving adoption of ICT, often represent attempts to manage external images of the firm held by stakeholders such as customers (Pfeffer & Salancik, 1978). A firm may differentiate itself in the marketplace by creating a distinct identity, managing its image by leveraging the symbolic and physical resources institutionalized in their business environment. Managers manipulate symbols to convey the impression that the firm adheres to customer expectations and codes of conduct, which have been identified as central to corporate identity (Pfeffer & Salancik, 1978). Success depends on whether the manager knows and understands customer expectations and which symbols convey the "right" impression (Feldman & March, 1981). However, previous investigations of ICT adoption and use by SMEs have not considered their effects on customer's images of the firm and the pressures these exert on decision-makers. If SMEs are aware of their customers' assumptions, they can adopt and use ICT to create a desirable corporate image that appeals to its target market (Dutton & Dukerich, 1991).

Legitimacy

One important task of SME founders is to create and maintain an image that attracts resources such as customers (Elsbach, Sutton & Principe, 1998; Meyer & Rowan, 1977; Starr & MacMillan, 1990). Legitimacy is a universally desirable corporate image that is judged based upon conformity to social norms and beliefs and is linked to purchasing and repeat business (Suchman, 1995; Zimmerman & Zeitz, 2002). Legitimacy is defined as a "generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, beliefs, and definitions" (Suchman, 1995, pg. 574). It is a quality of the firm, but is conferred by observers (who refer to a firm that is credible or real (Human & Provan, 2000)). Customers' assumptions about the appropriateness of adoption and use of ICT by an SME should affect their judgment of the SME as legitimate and desirable as an exchange partner (Dutton & Dukerich, 1991; Feldman & March, 1981; Winter, Saunders, & Hart, 2003) and influence the likelihood that they will make a purchase.

ICT and a Firm Image of Legitimacy

When examining the role of ICT in creating an image of a firm as legitimate, one is asking how SMEs can use ICT in ways that meet customer expectations. This study develops a particularistic account of the symbols that ordinary people use to convey and evaluate images of legitimacy, focusing specifically on the role of ICTs as a cue and their meaning. These results are then related to existing theories identifying areas in which the data confirm or contradict existing explanations (Martin & Turner, 1986), integrating the inductively derived concepts with abstract theory and providing analytic generalization (Yin, 1989).

METHOD AND RESULTS

An inductive grounded methodology (Eisenhardt, 1989; Glaser & Strauss, 1967; Martin & Turner, 1986; Strauss & Corbin, 1998) was used to discover the role of ICT in communicating image and triggering a sale. Inductive grounded techniques are particularly appropriate for investigating relationships among context (including customer expectations) and actors, providing particularistic details to elaborate abstract substantive theories (Eisenhardt, 1989; Martin & Turner, 1986). Semi-structured in-depth interviews enabled a greater depth of understanding than could be developed with a questionnaire. Inductive methods allowed identification of the dimensions and language that are meaningful to the informants with legitimacy and customer expectations acting as sensitizing concepts (van den Hoonaard, 1997).

Procedures

To control for issues unrelated to the use of ICT that could affect an SME's image (e.g. a previous track record) we focused on sales pitches of new firms. Sales pitches of new firms are particularly appropriate for studying the process of creating legitimacy and acquiring customers. Founders often recount how they managed impressions of their firms when making their first sales, so the phenomena should be familiar to them (Darwell, et al., 1998) and attempts to establish perceptions all begin at the sales pitch to which each party brings a set of assumptions, so it should be easier to identify participants' ICT assumptions. However, the meaning of ICT and the legitimacy images created are not expected to vary by firm age.

- **Informants:** Two kinds of samples were drawn: SME founders and prospective customers (experienced buyers who have purchased from new firms). This allowed cross-checking and substantiation of the resulting constructs (Martin & Turner, 1986; Strauss & Corbin, 1998). The goal was to map the diversity of responses and generate theory applicable to various contexts, so the sample was constructed to include variety rather than statistical representation. This practice (called theoretical sampling (Denzin, 1989)) precludes drawing inferences about the norms in specific industries. When new interviews failed to yield novel responses, dimensions, or relationships, data collection ended. Two rounds of data collection allowed refinement of the questions and expansion of the sample (Denzin, 1989).
  - **SME Founders:** Samples were drawn using the Dun and Bradstreet database[2]. The first round included 15 founders in the San Francisco Bay Area; the second included 18 founders in South Florida (in total, a 27% participation rate). Founders often work in excess of 12 hours a day and many were too busy to participate.
  - **Potential Customers:** The second round included purchasers at 14 businesses in South Florida (a response rate of 15%) who received sales calls from a variety of vendors, and had recently used at least one new firm. To avoid inflating the degree of agreement, we included three buyers who had done business with a new firm in our sample and eleven who had not[3]. As shown in Appendix A, the firms represented various sectors, scopes and sizes. Purchase decisions also were diverse and ranged from purchasing office supplies, business services, raw materials and finished goods for resale through sub-contracting portions of the firm's activities.

- **Procedures:** Sessions were conducted at the participants' places of business, lasted 45 to 90 minutes, were tape-recorded and later transcribed. The first round was performed by a trained master's student, the second by one of the authors.
- **First Iteration:**
  - **Data Collection:** The first round included only founders; open-ended questions encouraged respondents to talk about the issues that they considered important in convincing their first customers to place an order. Informants described the work their firm performs, their products, customers, competitors and the content of their first sales pitches. Probes asked about the most effective cues or tactics, including the role of ICT.
  - **Data Analysis:** The analysis proceeded iteratively; moving between the data, emerging theory and existing literature (Eisenhardt, 1989; Glaser & Strauss, 1967) allowing discrepancies to be reconciled, leading toward closure (Denzin, 1989). In open coding, categories were identified and microscopic data examination generated initial categories, recognized taken-for-granted assumptions, and identified other cases for theoretical sampling (Strauss and Corbin, 1998). Theoretical comparisons were made between the images created by visual identity symbols such as furnishings and wardrobe and those created by ICT. Data were coded for the importance of violations of expectations, a sensitizing construct linked to legitimacy. Concepts were organized by recurring themes, forming stable and common categories during axial coding (Martin & Turner, 1986; Strauss & Corbin, 1998) yielding broad categories and associated concepts that described the participants' understanding of the symbolic information transmitted by ICT and its role in the purchase decision.
  - **Findings[4]:** The first step in determining whether prospective legitimacy is inferred from the presence of ICT was to determine whether the signaling function of ICT was tacit or explicit. As shown in Table 1, 85% of founders in the first round of interviews indicated that ICT improved operations, mentioning this aspect a total of 32 times. Some denied that ICT had any symbolic value and insisted that its only value was its functionality, although many were forthcoming about the symbolic role of office attire, location, and office furnishings.
  - **Proposal Development & Presentation Training***:*

    The technology is essential … but it is simply the tool…The thing that gives us an edge is not the technology but the office space.

Table 1. Percent of 1st round SME founders (n=13) who discussed a category. Results of Fisher's Exact test of the difference between 1st and 2nd round founders also shown.

Element	%
Functional (Improves Operational Efficiency, Productivity, or Effectiveness)	85
Legitimacy	38*
Prototype Expectations	85
Taken-for-granted	77
Novel-Neutral	8*
Novel-Positive	23
Novel-Negative	0*
Support Decision	46
Positive	31
Negative	0
Neutral	15

* *p < .05*

About a third (38%) said that ICT symbolized their firm's legitimacy (e.g. seriousness, professionalism, size, or financial strength).

These results reflect the norm of rationality in the U.S. and an emphasis on the functional value of ICT in improving SME operations (Feldman & March, 1981; Hirschheim & Newman 1991; Kling & Iacono, 1984; Levy & Powell, 2005; Winter, 1996). They are consistent with literature suggesting that the symbolic meaning of an artifact such as ICT is unlikely to be elicited through direct questioning because meanings are often deeply connected with assumptions about the way the world works (Schein 1985).

This raised questions about whether symbolism works differently for ICT than it does for other artifacts, whether SME founders are unaware of ICT's symbolic value to customers or whether the symbolic meaning is tacit and so cannot be readily articulated. Consistent with Strauss and Corbin (1998), we hypothesized that our results reflected a taken-for-granted assumption about ICT and collected additional data to better understand the symbolism of ICT.

- **Second Iteration:**
    - **Data Collection:** Consistent with Denzin (1989) the second round of data collection included both SME founders and potential customers and the data collection methods were changed to surface taken-for-granted assumptions. New questions reflected "breaking experiments" and used the flip-flop technique (Feldman, 1995; Garfinkel, 1967; Strauss & Corbin, 1998). Additional structured focus group techniques such as bounded and cued open-ended questions and providing background information were used (Krueger, 1998; Stewart & Shamdasani, 1990). Sentence completion and a projective technique (an analogy between a Ferrari and a Honda Civic) were also included and SME founders were asked to take the role of customers (Greenbaum, 1998; Krueger, 1998; Sudman, Bradburn & Schwarz, 1996). Questions are shown in Appendix B.
    - **Data Analysis:** Analysis of the second round proceeded much like that of the first with inductive open coding that included legitimacy, expectations and violations as sensitizing concepts (Martin & Turner, 1986). One author read the founder interview transcripts; another read those of customers. Each created a preliminary inclusive framework representing the features of the data and the distinctions made by the informants (Martin & Turner, 1986; Strauss & Corbin, 1998). Comments were coded based on apparent category membership and axial coding was used to organize concepts (Martin & Turner, 1986; Strauss & Corbin, 1998). The data gathered from founders and customers were compared to identify their degree of overlap and a single integrative framework was created when it became clear that they included similar concepts. Comparing the data to the emerging model and discussing disagreements about the elements allowed continued refinement of the typology. These networks of categories were used to create theoretical constructs and associated maps of causal elements that were constructed into a theory of the role of ICT in firm legitimacy and purchase decisions. A model of the important elements, their cues and interrelationships was developed. The resulting framework derives empirical validity from accounting for the data and provides a general pattern across the data sources (Martin & Turner, 1986).

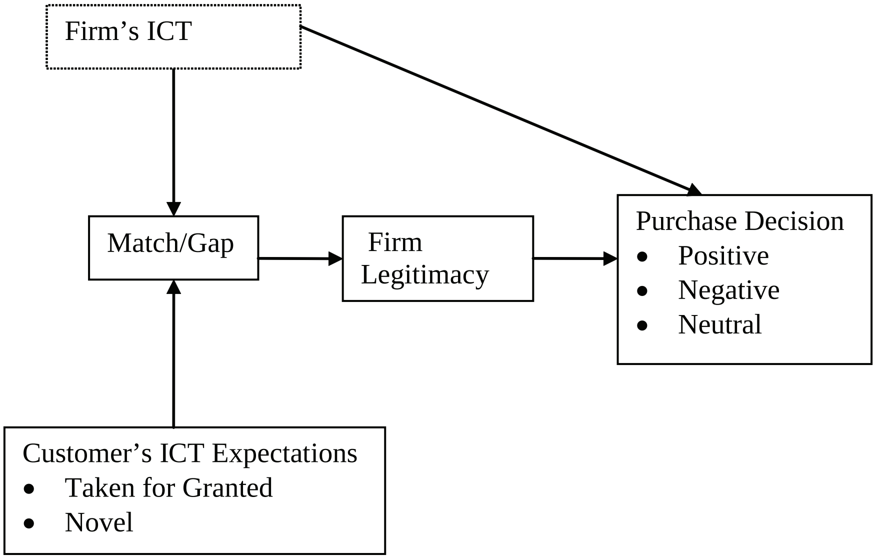
Transcripts were then coded for each element by the third author who counted the number of participants who mentioned a category and the number of times a category was mentioned. Fisher's Exact[5] tests were performed to determine whether the responses of second round founders differed from first round founders or from customers.

Findings – Theoretical Frame: Although developed later as an aggregation of the more detailed results, the abstract theoretical frame (paradigm model) that summarizes the theory is presented first (Strauss & Corbin, 1998). It shows how the elements of the constructs are connected and acts as a map to steer through the detailed results, which are presented after the model. At the highest level of abstraction, the purchase decision process (shown in Figure 1) resembles schema theory (Fiske & Taylor, 1991) and is influenced by the prototypes and mental models held by the prospective customer who infers SME legitimacy from the symbolic information provided by a firm's ICT.

The SME founders and potential customers have formed mental models about various kinds of firms and their activities. A mental model consists of sets of interconnected information elements (including ICTs) and a prototype is a typical set of elements for a category. This mental model includes possible firm categories represented as prototypes, some of which are more likely to result in a positive transaction experience than others. The firm may be a legitimate, serious, professional, adequately capitalized company or an illegitimate company, a category that includes both inexperienced undercapitalized hobbyists trying to become professionals and firms of dubious legality sometimes called fly-by-night.

SMEs use ICTs in providing their products or services including both office technologies (e.g. inventory management systems, cell phones) and production technologies (e.g. CAD/CAM, robotics). A firm's representative contacts a potential customer and makes a sales pitch describing the company and its products or services and may describe their ICTs or provide indirect evidence of them. During a sales pitch, the potential customer tries to learn what kind of firm he or she is dealing with to determine the likelihood that placing an order would result in a positive transaction. Potential customers match the firm's ICT to those expected in each prototype and categorize a firm as legitimate or illegitimate based on the characteristics shared. Some ICTs will be taken-

Figure 1. Model of ICT, customer expectations, firm legitimacy and purchase



for-granted or assumed to be in use, others may be novel or optional in that they may or may not be present. Once a firm has been categorized, it is assumed to have other characteristics of the category (honesty, trustworthiness, etc.) based on the interconnected information elements in the mental model, even if the potential customer has not experienced them directly. These inferred characteristics of the firm then influence the likelihood that a potential customer will actually place an order. In addition to corporate image effects, ICT has a direct effect on purchase decisions if customers find them more convenient.

In the following section, these concepts and their interactions are discussed in detail.

Findings – Model Elements: Participants were clearly more comfortable discussing the functionality of ICT than its symbolic meaning, suggesting that functionality is explicit and symbolic meaning is more tacit. However, we found four patterns linking ICT to corporate image. First, customers' symbolic meanings and those of founders were very similar suggesting that accurate signaling can occur and that the latter could purposefully manipulate their ICT use to create desired corporate images. Further, founders were aware of the customers' perspective and those meanings were instrumental in their ICT adoption decisions. Second, firm legitimacy characteristics are inferred from ICT and linked to decisions to support the firm. Third, three distinct patterns link violations of their expectations about a firm's ICT to its image. A firm could be missing an ICT whose presence had been taken-for-granted, include a novel ICT that detracts from a firm's image, or include a novel ICT that enhances its image. Each of these areas is described in more detail below.

Functionality vs. Symbolic Meaning: As shown in Table 2, an overwhelming majority of second round participants (97%) mentioned the functional value of ICT 126 times in total. How-

Table 2. Percent of 2nd found respondents who discussed a category broken down by SME founder vs. customer. Results of Fisher's Exact test of the difference between 2nd round founders and customers also shown.

	Founders n=15	Customers n =14	Founders & Customers n=29	
Element	%	%	%	No. of Times Mentioned
Functional (Improves Operational Efficiency, Productivity, or Effectiveness)	93	100	97	126
Legitimacy	87	93	90	92
Prototype Expectations	100	100	100	433
Taken-for-granted	93	86	90	254
Novel-Neutral	67	71	69	93
Novel-Positive	47	86*	66	72
Novel-Negative	40	36	38	14
Support Decision	60	100*	79	125
Positive	33	79*	55	61
Negative	20	7	14	5
Neutral	47	93*	69	59

* $p < .05$

ever, the use of focus group techniques yielded much more information about the symbolic meaning of ICT than was uncovered in the first round of interviews. As shown in Tables 1 and 2, the percentage of first and second round founders linking ICT to legitimacy increased significantly (1st round: 38%; 2nd round 87%; Fisher's Exact p<.05) and 90% of the second round participants linked ICT and legitimacy.

- **Similarity between Founder and Customer Views:** In the second round of interviews, participants articulated a consistent set of issues surrounding legitimacy, ICT and purchase decisions. Both founders and customers reported similar views of each of the ten elements of the model, but four of these elements appear to be more salient to customers than to founders. Customers were significantly more likely to identify ICTs that were novel and helped form a positive image of the firm (mentioned 16 times by 47% of founders vs. 56 times by 86% of customers), to link ICT directly to support (mentioned 26 times by 60% of founders vs. 99 times by 100% of customers), to discuss a positive link between ICT and making a purchase (mentioned 29 times by 33% of founders vs. 49 times by 79% of customers), and to identify ICTs that would have no effect on their decision to make a purchase (mentioned 10 times by 47% of founders 47% vs. 49 times by 93% of customers).
  Founders also indicated that they were aware of the customer's perspective and that ICT adoption decisions were influenced by the desire to create a particular corporate image.
  - **Medical Lab:** I think that to be in the business world you need a Web page and people do judge you … whether they be potential clients or whoever, and they'll look at your Web page and … there's a better feel for us as a company when they see our Web page.

This strong overlap between the views of founders and customers is not surprising. Shared meanings, communication, and organized action are reciprocally interdependent (Donnellon, Gray, & Bougon, 1986) and would be required for an SME founder to successfully create an image of legitimacy.

- **Legitimacy Inferred From ICT:** There was no difference between the percentage of founders (87%) and the percentage of customers (93%) who reported inferring an SME's legitimacy from its ICT. ICT acts as a cue symbolizing dimensions of legitimacy (Suchman, 1995), which was mentioned by the overwhelming majority (90%) of the participants a total of 92 times. Participants agree that legitimacy influences the firm's ability to attract customers, and often mention legitimacy elements (size, seriousness, professionalism, capitalization) and support together.
  - **Apparel Catalog:** It's the little things that make you aware of what type of company you're dealing with. Again, if they don't have voice mail, if they don't have a cell phone, if they don't have fax capabilities, e-mail capabilities, these are the signs. This is what you sense. This is how you know that this isn't a real big company. If they make the commitment to have a fax machine, to have everything in place before they start up then they are a little more serious and maybe you'll take the chance and take the risk of putting the product in the book… You know that they're not financed if they don't even have a fax machine

Although conceptually distinct, the elements of legitimacy are mentioned together and cued by the same symbol, suggesting that they co-occur in participants' mental models of legitimate and illegitimate firms. This is consistent with the retrieval of prototype characteristics as outlined in the earlier paradigm model (Fiske & Taylor, 1991). Large, serious, professional firms are often contrasted with "hobbyists" or "fly-by-night" firms, suggesting that these represent common firm prototypes. Consistent with previous research on legitimacy, no participants wanted to work with "hobbyists" or "fly-by-night" firms.

Our results suggest that the adoption and use of ICT is a form of behavior linked to judgments that a firm is legitimate, an image that is universally desirable and is central to a firm's success (Zimmerman & Zeitz, 2002). Customers' assumptions about the appropriate adoption and use of ICT affect their judgment of the firm as legitimate. If decision-makers adopt and use ICT in ways that are consistent with customers' assumptions about what is appropriate, they can create an image of legitimacy, avoid being labeled "fly-by-night", and improve the likelihood that they will receive customer orders (Dutton & Dukerich, 1991).

Creating and maintaining a corporate image requires SMEs to choose behavioral, verbal and non-verbal symbols to convey the impression that the firm adheres to the stakeholders' expectations and codes of conduct identified by institutionalism (Pfeffer & Salancik, 1978). These codes of conduct reflect the system of meaning that underlies the social construction of reality (Berger & Luckmann, 1967; Feldman & March, 1981; Schein, 1985) and allows actors to make sense of their world by interpreting symbols (Gioia, 1986). This article provides evidence that ICT is one of those symbols and that these expectations form accepted standards for ICT use (DiMaggio & Powell, 1983) informed by customers' mental models and SME prototypes. Legitimacy influences purchase decisions, a crucial determinant of SME survival.

- **ICT Linked To Purchase Decisions:** An SME's ICT can make purchase decisions more likely or less likely, often depending on the ICTs involved (although sometimes they have no effect). However, some participants linked support with specific ICTs, while others linked it to an SME being "high tech" reflecting the influence of a constellation of ICTs.

As previously mentioned and shown in Table 2, support issues were more salient to customers than to founders, but overall 79% of participants mentioned a link (positive, negative or neutral) between ICT and support 125 times. More specifically, 55% mentioned 61 times that some ICTs could increase the probability of support (often, this was stated in the negative in that they would not make a purchase from a firm that did not have an ICT, implying that having the ICT is positively related to support).

- ○ **System Integrator:** I can't imagine that they would want to do business with somebody that didn't use email.
- ○ **Promotional Products:** If a company now doesn't have a fax machine, I probably wouldn't do business with them

About two-thirds (69%) of participants mentioned 59 times that that having or not having some forms or ICT would have no effect on purchase decisions.

- ○ **Spa and Beauty Supply:** I don't expect it (fax machine, computer, beepers, cell phones) and I would not stop doing business with somebody because of it. Nor would I necessarily consider not doing business with them because of that.

A small percentage of respondents (14%) mentioned 5 times that some ICTs would decrease the likelihood of a sale.

- ○ **Community Association Manager:** I prefer a company that does not have voicemail, but they're hard to find.

Thus, ICT is among the elements considered by customers in deciding whether or not to place an order with an SME, an example of what the legitimacy literature calls providing active support (Suchman, 1995). Although conceptually distinct, many authors treat legitimacy and support of a firm as overlapping constructs and some indicators of legitimacy (e.g. certification) are also indicators of support (Suchman, 1995). The use of ICT may allow SMEs create an image of legitimacy (Pfeffer & Salancik, 1978) and provide a survival advantage because ICT's symbolic meanings increase the likelihood that an SME will attract customers.

- **Mismatches and their Effects on Corporate Image of Legitimacy:** Creating an image of legitimacy requires conformity with customer expectations (Meyer & Rowan, 1977; Pfeffer & Salancik, 1978; Suchman, 1995; Zimmerman & Zeitz, 2002). So, we examined the effects of mismatches between the use of ICT and customers' expectations, one of our sensitizing concepts. We found three different kinds of mismatches that affected legitimacy and purchase decisions. A firm could be missing an ICT that customers had taken-for-granted; include an ICT that is novel in that it is not taken-for-granted, but enhances the firm's image; or it could include an ICT that is novel and detracts from the firm's image.

Table 2 shows that both SME founders and customers had expectations about the kinds of ICT firms should have (mentioned 433 times by 100% of participants). Three distinct patterns link violations of expectations about firm's ICT to its image. First, 90% of participants indicated 254 times that some kinds of ICT are taken-for-granted.

- ○ **Environmental Clean-up Consulting:** [Didn't have e-mail?] 'Wow! Where have you been?' You know, it's like they should have it. Even if it's at hotmail.com … That's just, I expect it.
- ○ **Systems Integrator:** I can't imagine a company existing without pagers. I mean, we use pagers so you can send a message. I just can't imagine.

This is consistent with what Saga and Zmud (1994) have called the routinization stage of ICT implementation, and with schema theory, the use of mental models, and prototypes (Fiske & Taylor, 1991). Some ICTs have been so completely integrated into the business world that customers' SME prototypes invariably include this element. When a mental model of legitimate firms is accessed, these ICTs are among the characteristics assumed to be present, even if they have not been observed. SMEs that do not have them are less likely to be seen as legitimate. Their absence violates expectations and raises legitimacy concerns because of the symbolic meaning attached to the technology.

But, contrary to legitimacy theory, mismatches do not always lead to judgments that a firm is not legitimate and may not even reflect positively on the firm if the ICT is novel rather than taken-for-granted. About two-thirds (66%) of participants indicated 72 times that the symbolic meaning of a novel ICT is also considered and can lead customers to infer that a firm shares their values, and that they should place an order.

- ○ **Wireless Services Provider:** E-mail, yes. They don't have to have it but it's a one up, it's a plus if they do.
- ○ **General Contractor:** [Vendors who bring in results of computer runs] Gives us a comfort level as opposed to the one that's scratched out on a piece of paper.

Of course, the converse is also true. Customers use the symbolic meaning of novel ICT to infer that a SME's actions will be undesirable, although it may not reflect upon the firm's legitimacy. For example, customers often encounter automated call routing to answer incoming calls, so the presence of this ICT cannot be considered a violation of expectations. However, many infer that firms using call routing are large, uncaring and will treat them impersonally. Overall, 38% of participants indicated 14 times that a novel ICT can be considered detrimental to a firm's image without affecting its legitimacy.

- **Community Association Manager:** [Automated call routing indicates a firm is] too big. Unpersonal [sic]. Yeah, I don't like it. I hate it.

The determining factor is whether the underlying symbolic meaning ascribed to the novel technology is consistent with the customer's values and ideas about desirable firms. For example, if industry leadership is considered desirable, an ICT that signals this enhances a firm's image. If large, uncaring firms are considered undesirable, automated call routing ICT that signals this detracts from a firm's image. Thus, consistent with Saga and Zmud's (1994) implementation phases, ICT that is accepted, but not taken-for-granted, is viewed as novel.

Schema theory would suggest that these technologies are not elements of all SME prototypes, so their presence or absence is used in classifying firms according to their desirability as exchange partners (Fiske & Taylor, 1991). In contrast, legitimacy theory asserts that the presence of a novel ICT violates expectations, so the probability of a purchase should always be diminished (Suchman, 1995). Our data contradicts legitimacy theory by providing evidence that these mismatches can be positive, enhancing an SME's image, and increasing the likelihood of a sale depending upon the inferences that customers draw about the firm's values and the desirability of its actions based on the symbolic meaning underlying a novel ICT. When these are positive, the firm's image is enhanced. When they are negative, it is diminished. In contrast, violating expectations regarding a taken-for-granted ICT always diminishes a firm's image. This relationship is shown in Table 3.

- **How and Why ICT Acts as a Symbol:** Information about SMEs is stored as mental models comprising multiple elements. Pre-existing categories of firms form prototypes that reflect particular constellations of elements, including ICT artifacts which act as cues from which a firm's legitimacy dimensions (e.g. size, professionalism, seriousness, and capitalization) are inferred. These dimensions are bundled together in the mental model, along with additional details that are filled in (inferred). As the SME founder makes a sales pitch, customers glean information about the firm's ICT and compare it to their expectations regarding each ICT mental model element. The observed and inferred characteristics are used to categorize firms by comparison with existing firm prototypes (e.g. legitimate vs. hobbyists or fly-by-night). SMEs that share a large number of characteristics with the prototype for a legitimate and desirable exchange partner will be considered legiti-

Table 3. Relationship between ICT novelty, presence, and corporate image of legitimacy

ICT	Taken-for-granted	Novel	
		Positive	Negative
Present	Legitimate	Positive Image	Negative Image
Absent	Not Legitimate	Neutral Image	Neutral Image

mate and be preferred by customers. When customers and founders attribute similar meanings to ICT, the SME can better control the image communicated.

This process resembles schematic processing of symbols, which can include artifacts such as ICT and actions such as their use (Bargh, 1984; Gioia, 1986; Morgan, Frost & Pondy, 1983). Information processing begins with the classification of stimuli based on matching attributes with those of pre-existing categories stored in schemas. Once categorized, missing pieces are filled in with category-consistent information. When a potential symbol is encountered, it is compared to existing schemas to generate meaning (Gioia, 1986). When a symbol is associated with a schema, understanding occurs that guides interpretation and action in ambiguous or uncertain situations. The communicative power of symbols lies in the meaning attached to them, which, like schemas, varies in different situations or social groups.

In the absence of prior interaction with an SME, potential customers generate meaning by scrutinizing available signals, such as ICT (Synder & Stukas, 1999), compare this information to their schemas for the use of ICT by legitimate firms, classify the firm into an appropriate category, fill in missing information, and make inferences about the desirability of the SME as an exchange partner. Quite simply, legitimacy is judged based partly upon ICT whose meaning has been stored in schemas reflecting social institutions (Barley & Tolbert, 1997). The ICT acts as a symbol of conformity to the expectations and values of the perceiver for legitimate firms. To be judged desirable, a firm should match customers' schemas for desirable firms or violate them in a manner that indicates pursuit of goals that conform to market segment values. Thus, an ICT's symbolic meaning affects a firm's image and influences purchase decisions that determine survival.

Contributions and Limitations

We developed a general and particularistic model of the issues surrounding the symbolic value of ICT, legitimacy, and customers' purchase behavior. This study extends our understanding of the creation of legitimacy, mental models, and schemas to identify the language, behavior and symbols that ordinary people use to convey and evaluate images, focusing specifically on the role of ICT as a signal, the firm characteristics that are linked to legitimacy, and how ICTs carry meaning. In addition, it clarifies that mismatches between audience expectations about an SME's ICT are not always negative.

DISCUSSION

Our results show that ICT does signal legitimacy. When asked directly, participants suggest a purely functional explanation for ICT adoption, reflecting the norm of rationality and social desirability (Feldman & March, 1981; Kling & Iacono, 1984; Winter, 1996). However, less salient dimensions were elicited using focus group techniques.

The ultimate purpose of a sales pitch is to make a sale, but a proximal purpose is the display of symbols such as ICT that create a positive image of the firm. Potential customers clearly use ICT to infer legitimacy and fill in unknown details from existing prototypes. They seek to categorize the firm in terms of its type, based in part on a comparison of its ICT capabilities with those that were expected. Classification into the preferred exchange partner category is crucial to the survival of SMEs because they seldom have the resources to overcome a poor corporate image.

This study extends the literature on the symbolic meaning of ICT by considering the customer's view of SMEs and the effects of ICT on purchase behavior and extends the literature on corporate image to include the effects of ICT.

Implications for Managers

Purchase decisions are influenced by potential customers' images of the firm. Decisions about the use of ICT in SMEs should consider image issues and symbolic meaning in addition to operational efficiency and effectiveness concerns and executives must be familiar with their stakeholders' expectations regarding an ICT. As institutionalism predicts, an SME that fails to adopt an ICT that has become taken-for-granted will find it more difficult to make the sales required to survive. As schema theory predicts, for ICT that is novel, executives must understand the symbolic meaning underlying its use to ensure a positive interpretation. Managing corporate image through the use of ICT is particularly importance for SMEs that must create an image before they have established a reputation based on performance, a large customer base or a broad marketing campaign. SMEs must rely most heavily on signals and symbols and should include both the symbolic and the productivity dimension in any calculation of the business value of ICT.

Implications for Theory

This study found a strong relationship between the symbolic meaning of an ICT, a corporate image of legitimacy, and purchase behavior. SME's that wish to attract customers should consider the benefits of choosing ICT that creates a corporate image of legitimacy, even if the ICT yields limited improvement in productivity. To be most effective, an SME's ICT choices should be guided by customer expectations.

These results also contribute to our understanding of the relationship between symbolic meaning and action. Organizational cognition suggest that the symbolic meaning of an ICT will dominate diffusion before its productivity effects have been documented and may continue thereafter as the presence of an ICT innovation becomes an institutionalized norm. Corporate image forms a valuable link between the symbolic meaning of ICT and its diffusion. Integrating these fields clarifies how an ICT acquires symbolic meaning allowing it to be used by SMEs to create and maintain corporate images. Social cognition and the role of schemas in interpreting an ICT as a cue are central to the creation of perceptions that a firm is legitimate, is a desirable exchange partner and is more likely to be supported.

CONCLUSION

SMEs face particularly difficult survival challenges with success dependent upon persuading potential customers to actually make purchases, a decision that hinges on perceptions regarding the firm's legitimacy (Suchman, 1995; Zimmerman & Zeitz, 2002). Consequently, SME survival depends in large part on creating and maintaining impressions of the firm's legitimacy among external stakeholders (Darwell, et al. 1998). This study has shown that potential customers make snap judgments about a firm's legitimacy based on expectations regarding the use of ICT due to its symbolic meaning and begun to explore the processes by which ICT acts as a symbol. Future research should consider other valued organizational outcomes related to the symbolic meaning of ICT for external stakeholders, such as attracting valued employees, financing and accreditation or licensure. In addition, the meanings of ICT and mediating concepts of corporate image will likely differ by industry, time period and culture. To provide additional value in guiding practice, considerably more work is needed to map the meanings of particular ICTs to different contexts. Understanding the complex multidimensional costs and benefits of ICT will allow us to develop a more complete view of its business value.

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ENDNOTES

[1] The term "corporate image" is widely accepted in the marketing literature, but is not meant to exclude not-for-profit, volunteer, or governmental organizations.

[2] Firms were 2 - 5 years old and experienced a rapid growth rate (annual sales of at least 25%). The focus on purchase decisions dictated that firms be at least 2 years old since they are likely generating income from sales.

[3] A list of potential customers was developed through referrals from SME founders and the local telephone book. Many would not knowingly support a new firm or were unwilling to make the time commitment.

[4] Percentages and counts suggest the extent to which perceptions were shared among the respondents, but do not represent population values or an issue's importance. Quotes provide a sense of the spirit of the responses.

[5] Differences in the percentage of participants mentioning a category could not be tested with Chi-Square because the relatively small sample sizes and uneven distribution of responses yielded a high number of cells with expected values smaller than five. Under these conditions Chi-Square values become unstable; Fisher's Exact test is preferred

APPENDIX A. INFORMANT CHARACTERISTICS

New Firm	**Products/Services**	**Market**	**Scope**
Seafood Wholesaler	Fresh Fish	Retail Groceries & Restaurants	Local
Wholesale Exporter of Textiles & Foodstuffs	Manage Exports of Mid-Sized Manufacturers, mostly to Mexico	Distributors	International
Electronic Components	Spot Market Broker	Large Computer Manufacturers	State
Skateboard Design/Manufacturer	Skateboards	Retailers and Distributors	National
Fiberglass Manufacturer	Custom Auto Parts	Consumers	Regional
Private Label Accessories Manufacturer	Handbags & Belts	Specialty Retailers	International
Electrical Contractor	New Construction Wiring	Construction Companies	Local
Environmental Engineering Contractor	Engineering Project Design and Management	Government	State
General Engineering Contractor	Environmental Clean-up & Construction	Large Primary Contractors	Local
Building Supply	Construction Supplies	Contractors	Local
Moving Company	Packing, Storage and Delivery Services	Consumers, Government, Businesses	Regional
Medical Lab	Renal Testing	Clinics	National
MRI Lab	Radiography Services	Doctors & Patients	Local
Dietary Supplements Wholesaler	Herbal Supplements	Grocery & Health Stores	National
Diabetes Supplies	Testing, Injection & Medication Materials	Patients	National
Internet Service Provider	Value-added Networks & Internet Backbone	Local & Regional ISPs & Businesses	National
Pager	Pagers & Services	Paging Services Providers	National
Systems Integrator	Systems Development & Maintenance	Mid-size Businesses	Local
Web Consultant	Web Site Development & Maintenance	Businesses	State
Software Development & Hardware Resale	Multimedia Applications	Businesses & Education	State
Software Development	Groupware	Software Consultants	National
Computer Systems Consulting	Hardware Resale, Systems Development & Support	Consumers & Businesses	National
Technical Systems Consultant	Install & Maintain Info. Systems	Mid-size Businesses	

APPENDIX A. CONTINUED

Graphic Design & Macintosh System Consulting	Print & Electronic Graphics	Businesses	Regional
Landscape Architecture	Landscape Designs	Developers	State
Temporary Agency	Temporary Workers	Businesses	Local
Legal Copying Service	Duplication	Legal Firms	Local
Community Association Manager	Groundskeeping & Maintenance	Businesses	Local
Music Content Recording	Recorded Music	Music Distributors & Film Producers	National
Film Producer	Production Services	Commercial Movie Studios	National
TV & Web Production	Program Production	Businesses	National
Proposal Development & Presentation Training	Grant Writing; Program Development; Evaluation Research	Non-profit & Govt. Agencies; Architecture, Engineering or Construction Mgmt Firms	Local
Niche Publications (pregnant women and new parents)	Pamphlets & Books	Businesses	

Customers	**Products**	**Market**	**Scope**	**# Vendors**
Flowers/Gifts Retailer	Fresh Flowers & Related Gift Items	Consumers	National	200-300
Promotional Products Distributor	Custom Promotional Products	Businesses & Resellers	Regional	1000
Food Import/Export	Processed Foods	Retail Groceries & Restaurants	Inter-national	200
Wireless Services Provider	Paging and Cell Phone Services	Consumers & Businesses	National	1000
Facilities Manager	Supervise Maintenance, Grounds Keeping & Supplies	Consumers	Local	10-15
General Contractor	Construction Management	Developers Owners & Public Agencies	National	800-1200
Environmental Clean-up Consulting	Engineering, Design, Consulting & Contracting	Major Oil Cos.& Firms w/ Underground Tanks	Southeast U.S.	200
Health Spa	Beauty, Spa, Fitness & Nutrition Services	Consumers	Local	50
Architecture/Interior Design	Architectural Plans, Interior Designs & Decoration Services	Consumers & Designers	Local	20-25
Apparel Catalog	High-end Apparel	Consumers	National	100

APPENDIX A. CONTINUED

Custom Linens	Bedroom, Bath, Table Linens, Upholstery, Drapes & Accessories	Designers & Consumers	Local	1000
Book Exporter	Foreign Language Lit.	Distributors	Inter-national	30-40
Fitness Center	Fitness Services	Consumers	Local	6-10
Metal Framing Contractor	Management of Residential & Commercial Framing & Finishing	Owners & General Contractors	Local	500

APPENDIX B: INTERVIEW QUESTIONS

Customer

A. BACKGROUND

1. Please tell me what business you are in and the types of products and/or services you provide to your customers.
2. What raw materials or finished products do you purchase? What do you do with them before they are sold to your customers?

B. SUPPLIERS

3. Can you tell me who are your major suppliers of raw materials or finished products?

4(a) About how many suppliers would you say you use in total? About how many are sole suppliers of a particular material?

4(b) When you are choosing among suppliers, are there many that offer very similar products or services?

4(c) Given a choice, would you say that you would prefer to stay with a single supplier or to spread your orders around to several suppliers?

5(a) On average, how many new suppliers do you use each year? Have you ever added a new supplier that was also a brand new company perhaps one for which you would be their first customer? If not, why not? If yes, how did it work out? Are they still an active supplier?

5(b) When deciding to use any new vendor, about how many meetings or conversations do you engage in before placing an order? How would this differ if the new vendor is also a new company and you would be their first customer? Would this depend on the size of the order and whether you had multiple sources?

5(c) During these conversations, what are you trying to learn about established new vendors? Would this differ from what you would try to learn about a brand new company? How would this be influenced by the size of the order and whether there were multiple vendors available?

6(a) What would you say your reputation is among your suppliers?

6(b) Why would you say that?

7(a) When you are contacted by a potential new supplier, what are the factors that you consider in deciding whether or not to place an order? What's on your mind when you are listening to their sales pitch?

For these next questions, I'd like you to think about switching to a new supplier that is a brand new start-up business maybe approaching you to be one of their very their first customers.

7(b) What are the factors you consider in deciding whether or not to place an order when the supplier is a new start-up business rather than an established firm?
7(c) When there are several new start-up businesses offering comparable products or services, what factors would be important in deciding which to use?
7(d) What assurances do you look for from a new venture?
7(e) What does a new venture founder have to say to you so that you are really convinced that he or she can deliver the promised goods or services?
On time? At cost? According to specifications? Any other factors?
7(f) How concerned are you about the longevity of a new venture, that is, that it will be around a couple of years from now? How long would you want a supplier to be around? How short would be too short?
7(g) What do you have to hear or see from a new venture so that you are really convinced that it will indeed be around long enough?
7(h) How important is it to you that a new venture review with you ahead of time how they might handle problems if they arise?
7(i) Do you do any background check on new ventures? If so, what kind?]
7 (j) What can new ventures do or say to give you permission to believe the assurances they provide to you? What cues can they provide to signal that they can handle your contract?
7(k) Of the things you've mentioned (read list) which do you think is the most important thing you want to know about a new supplier's capabilities? What was second most important? Third? etc.
Of course getting a good deal from your suppliers is important, but there must be more than one firm that could provide the same type of product or service.
7(l) When you choose among new ventures competing for your business, what little things do you believe tip the balance in favor of one company over their similar competitors or your current suppliers? In other words, what little extra do you look for? What factors would work against a new supplier?
7(m) Given that these were important things for a supplier to show you, how would you know about them? In other words, what cues would you have to see for a new supplier to give you permission to believe that their company has this extra edge and should win the contract? What else would you want to see? Of course, you would want a supplier to dress appropriately, but I'm sure that it is more than just their smile that allows you to believe in their company. What is the real key to believing in a new venture? How would you expect these cues be communicated?

C. ROLE OF TECHNOLOGY

We know that the technology a supplier has performs many important business-related functions. However, lots of things that we interact with are functional, but also act as symbols. For example, a Ferrari and a Honda Civic both provide transportation. You can get from point A to point B in either one, but doing it in a Ferrari symbolizes wealth and a certain style. Designer clothing keeps us warm, but also acts as a symbol.

8(a) Do you think that a supplier's technological capabilities helps convince you to choose them over their equally qualified competitors? Does it help you to believe that a new venture is better than its competitors? Why do you say that? What would you think of a new supplier if its representative talked a lot about technology-related subjects in their sales pitch?

8(b) What do you know or assume about a new suppliers' technological capabilities? How do you know about it? Did they provide any cues? If not, why not? What would it have meant to you if the supplier had highlighted their technological capabilities?

9(a) In your opinion, what is the difference between a Mac user and an IBM user?

9(b) In your opinion, what is the difference between a company that has ________ and one that does not? Cell phones, Pagers, Voice mail, E-mail. Do your suppliers give you their cell phone #, pager #, voicemail access, or e-mail address? Why do they do this? What would it mean to you if you did not get this information?

9(c) How important is it to you that the new venture have the ability to check things like inventory, order status, and prices immediately (on a laptop or palm top), or is it okay to get back to you later about this (within an hour or two)? How would your impression differ if they checked paper files versus doing it on a laptop or palm?

9(d) In your opinion, what is the difference between a company that uses Kinko's to send and receive faxes and one that has its own private fax? Do you send faxes from a private number? What would it mean to you if you received a fax from a potential supplier and saw that it was sent from, say, Kinko's instead of a private fax #? Would it mean different things for different suppliers? Why?

9(e) In your opinion, what is the difference between a company that has a Web page and one that does not? Do your suppliers have Web page addresses? What would it mean to you if you did not receive a Web page address from a supplier?

9(f) Would you consider contacting a potential supplier based solely on its Web page? Why do you say that?

9(g) What would you think if you called this supplier early in the day planning to leave a message that they would get at the start of business, but instead woke up the company's sole employee because the business was run out of his private home? Why do you say that?

10. I'm going to read you a list of technologies that may perform important functions that allow your suppliers to provide excellent products or services. Over and above their functional use, these items may also provide cues that would give you permission to believe that a supplier has the qualities that would be required to provide a better product or service than their competitors. For each one, please tell me if you would expect a supplier to have it, if it could act as a cue to allow you to believe in their abilities, and, finally, if you would just assume that they had it, or if you would ask your suppliers about them or hear about them during the marketing or sales pitch: Cellular Phones for Work, Pagers/Beepers for Work, Voice Mail, Answering Machine, Fax Machines, Photocopiers, Color Copier, Personal Computers, Laptop Computers, Palmtop Computers, Data/Graphics Scanners, Graphics Capabilities, Desktop Publishing, Modem, Fax Modem, Modem Links to Clients, Ability to e-mail clients, Internal e-mail, Connections to Internet, Presence on Internet (Web Page), Intranet, Electronic Data Interchange, Database Systems, Groupware (e.g., Lotus Notes), Workflow Software, Wireless Data Communications, Machines for Manufacture of Products or Services [ASK RESPONDENT TO DESCRIBE]

11. What technologies do you believe your suppliers ought to have, that is, the minimum items you believe are necessary to serve you?
12(a) Thinking about all the technology your suppliers have, are there any specific pieces that you believe are essentially standard in your industry, that is, having them helps suppliers achieve parity with their competitors? Which ones?
12(b) How do suppliers know that these are the standard choices?
12(c) Do any of your suppliers have exceptional technological capabilities? What are these capabilities and do they allow this supplier to serve you better?
13. Again, thinking about all the technology your suppliers have, are there any specific items that you believe would give them a distinct advantage versus their competitors?
Which ones? Why do you say that?
14(a) If you were planning to start a new venture to supply your current employer, what pieces of technology would you insist on having? Why?
14(b) Would you tell your customers about these pieces? Why do you say that?
15. If you were teaching a class of students who were thinking about starting a new business supplying companies in your industry, what would you tell them about how to use technology as a selling point with their potential customers?
16. By now you have a pretty good sense of what we're trying to study. Is there anything you think we should have talked about that we haven't asked?
17. Is there anything else we should know about your business or about your suppliers?

Founder

A. BACKGROUND

To start, I'd like to get familiar with your business and your customer base.

1. Please tell me about the products and/or services you provide to your customers.
2. Who are your customers?
3. Who would you say are your serious competitors? How similar are their products and services to yours?
4(a) What would you say your reputation is among your customers?
4(b) Why would you say that?

B. EARLY SALES

For the next few questions, please think about when you first started your business.

5. When you were preparing to contact your first potential customers, what were the things that you worried about? What did you want to accomplish?
6. Who were your earliest customers
7. Did you have competitors who offered a product or service that was quite similar to yours? Who were these competitors?

8(a).For the very first sales you made or were trying to make in those early days, could you walk me through your sales pitch?
8(b) What would you say were the most important things your early customers wanted to know about you and your company's capabilities?
8(c) Of the things you've mentioned (read list) which do you think was the most important thing your customer wanted to know about you and your company's capabilities? What was second most important? Third? etc.

Of course getting a good deal was important for your customers, but there must have been other firms that could provide the same type of product or service.

8(d) When your first customers were deciding who to buy from, what little things do you believe tipped the balance in favor of your company over similar competitors or over their current suppliers? In other words, what little extra did you provide? What factors do you believe worked against you?
8(e) Given that these were important things to show your customers, how did your customer know about them? In other words, what gave your customer permission to believe that your company has this extra edge? What cues did you provide to allow them to believe that you or your company possessed these qualities? What else did you do? You made sure to dress right, didn't you? But I'm sure that it was more than just your smile that allowed them to believe in your company. What was the real key to convincing your customers?

C. ROLE OF TECHNOLOGY

We know that the technology you have performs many important business-related functions. However, lots of things that we interact with are functional, but also act as symbols. For example, a Ferrari and a Honda Civic both provide transportation. You can get from point A to point B in either one, but doing it in a Ferrari symbolizes wealth and a certain style. Designer clothing keeps us warm, but also acts as a symbol.

9(a) Do you think that your technological capabilities helped convince your customers to choose you over your equally qualified competitors? Did it help your customer to believe that your company was better than your competitors? Why do you say that? Did you avoid any technology-related subjects in your sales pitch so that clients would not get the wrong impression of you or of your firm?
9(b) What do you think your customers knew or assumed about your technological capabilities as you made your sales pitch? How did they know about it? Did you provide any cues? If not, why not? What would it have meant to your customer if you had highlighted your technology?
10(a) In your opinion, what is the difference between a Mac user and an IBM user?
10(b) In your opinion, what is the difference between a company that has _________ and one that does not? Cell phones, Pagers, Voice mail, E-mail. Do you give your customers your cell phone #, e-mail address, voicemail #, or pager #? Why do you do this?

What would it mean to them if they did not get this information?

10(c)In your opinion, what is the difference between a company that uses Kinko's to send and receive faxes and one that has its own private fax? Do you send faxes from a private number? What would it mean to your customers if they received a fax from you and saw that it was sent from, say, Kinko's instead of a private fax #? Would it mean different things to different customers? Why?

10(d) In your opinion, what is the difference between a company that has a Web page and one that does not? Do you give prospective customers your Web page address? What would it mean to your customers if they did not receive a Web page address from you?

11. I'm going to read you a list of technologies that may perform important functions that allow your suppliers to provide excellent products or services. Over and above their functional use, these items may also provide cues that would give you permission to believe that a supplier has the qualities that would be required to provide a better product or service than their competitors. For each one, please tell me if you would expect a supplier to have it, if it could act as a cue to allow you to believe in their abilities, and, finally, if you would just assume that they had it, or if you would ask your suppliers about them or hear about them during the marketing or sales pitch. Cellular Phones for Work, Pagers/Beepers for Work, Voice Mail, Answering Machine, Fax Machines, Photocopiers, Color Copier, Personal Computers, Laptop Computers, Palmtop Computers, Data/Graphics Scanners, Graphics Capabilities, Desktop Publishing, Modem, Fax Modem, Modem Links to Clients, Ability to e-mail clients, Internal e-mail, Connections to Internet, Presence on Internet (Web Page), Intranet, Electronic Data Interchange, Database Systems, Groupware (e.g., Lotus Notes), Workflow Software, Wireless Data Communications, Machines for Manufacture of Products or Services [ASK RESPONDENT TO DESCRIBE]

12. What technologies do you believe your customers expect you to have, that is, the minimum items they believe necessary to service them?

13(a) Thinking about all the technology you have, are there any specific pieces that you believe are essentially standard in your industry, that is, having them helps you achieve parity with your competitors? Which ones?

13(b) When you purchased these items, was your choice pretty much the standard in your industry or did you choose them for other reasons?

13(c) How did you know that these were the standard choices

13(d) [FOR THOSE THAT WERE CHOSEN FOR OTHER REASONS:] Please explain how you chose this /these.

13(e) Do you think there was a carryover from your former company or job in terms of the technology you chose or not?

14. Again, thinking about all the technology you have, are there any specific items that believe give you a distinct advantage versus your competitors? Which ones? Why do you say that?

15(a) If you were starting this business today, what pieces of technology would you insist on having? Why?

15(b) Would you tell your customers about these pieces? Why do you say that?

16. If you were teaching a class of students who were thinking about starting a new business in your industry, what would you tell them about how to use technology as a selling point with their potential customers?

17. By now you have a pretty good sense of what we're trying to study. Is there anything you think we should have talked about that we haven't asked you about?
18. Is there anything else we should know about your business?
19. In order to get a complete picture of the challenges facing new companies, I would like to get the customer perspective on these issues. Do you know of any buyers who may be willing to talk with me about the factors they consider when choosing a new supplier?

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Chapter 5.10

Patterns for Organizational Modeling

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ABSTRACT

Business needs have driven the design, development, and use of Enterprise Resource Planning (ERP) systems. Intra-enterprise integration was a driving force in the design, development, and use of early ERP systems, but increased globalization, intense competition, and technological change have shifted to focus to inter-enterprise integration. Current and evolving ERP systems thus reflect the expanded scope of integration, with greater emphasis on things like supply chain management and customer relationship management. This manuscript explores the evolution of ERP, the current status of ERP, and the future of ERP, with the objective of promoting relevant future research in this important area. If researchers hope to play a significant role in the design, development, and use of suitable ERP systems to meet evolving business needs, then their research should focus, at least in part, on the changing business environment, its impact on business needs, and the requirements for enterprise systems that meet those needs.

INTRODUCTION

Twenty years ago supplier relationship management was unique to the Japanese (those firms who embraced the JIT philosophy), China was still a slumbering economic giant, the Internet was largely for academics and scientists, and certainly not a consideration in business strategy; the very idea of a network of businesses working together as a virtual enterprise was almost like science fiction, and hardly anyone had a cell phone. The world has changed. The cold war is over and economic war is on. We have moved rapidly toward an intensely competitive, global economic environment. Countries like China and India are fast positioning themselves as key players and threatening the economic order that has existed for decades. Information technology (IT) is more sophisticated than ever, yet we still struggle with how to best use it in business, and on a personal level as well. E-commerce (B2B, B2C, C2C, G2C, and B2G) has become commonplace and M-commerce is not far behind, especially in Europe and Japan. This is the backdrop against which we will discuss the evolving enterprise information system. At this point we will call it ERP, but is should become evident in the course of reading this manuscript that ERP is a label that may no longer be appropriate.

In this article we define ERP and discuss the evolution of ERP, the current state of ERP, and the future of ERP. We will emphasize how the evolution of ERP was influenced by changing business needs and by evolving technology. We present a simple framework to explain that evolution. Some general directions for future research are indicated by our look at the past, present, and particularly the future of ERP.

ERP DEFINED

The ERP system is an information system that integrates business processes, with the aim of creating value and reducing costs by making the right information available to the right people at the right time to help them make good decisions in managing resources productively and proactively. An ERP is comprised of multi-module application software packages that serve and support multiple business functions (Sane, 2005). These large automated cross-functional systems are designed to bring about improved operational efficiency and effectiveness through integrating, streamlining, and improving fundamental back-office business processes. Traditional ERP systems were called back-office systems because they involved activities and processes in which the customer and general public were not typically involved, at least not directly. Functions supported by ERP typically included accounting, manufacturing, human resource management, purchasing, inventory management, inbound and outbound logistics, marketing, finance, and, to some extent, engineering. The objective of traditional ERP systems in general was greater efficiency, and to a lesser extent effectiveness. Contemporary ERP systems have been designed to streamline and integrate operation processes and information flows within a company to promote synergy (Nikolopoulos, Metaxiotis, Lekatis, & Assimakopoulos, 2003) and greater organizational effectiveness. Many new ERP systems have moved beyond the backoffice to support front-office processes and activities. The goal of most firms implementing ERP is to replace diverse functional systems with a single integrated system that does it all faster, better, and cheaper. Unfortunately, the "business and technology integration technology in a box" has not entirely met expectations (Koch, 2005). While there are some success stories, many companies devote significant resources to their ERP effort only to find the payoff disappointing (Dalal, Kamath, Kolarik,& Sivaraman, 2003; Koch, 2005). Let us examine briefly how we have come to this point.

The Evolution of ERP

The origin of ERP can be traced back to materials requirement planning (MRP). While the concept of MRP was understood conceptually and discussed in the 1960s, it was not practical for commercial use. It was the availability of computing power (processing capability and storage capacity) that made commercial use of MRP possible and practical. While many early MRP systems were built in-house, often at great expense, MRP became one of the first off-the-shelf business applications (Orlicky, 1975). In essence, MRP involves taking a master production schedule, inventory records, and a bill of materials and calculating time-phased material, component, and sub-assembly requirements, both gross and net. Note the term "calculating" was used rather than forecasting. With a realistic MPS, lead times that are known and predictable, accurate inventory records, and a current and correct BOM, it is possible to calculate material, component, and assembly requirements rather than forecast them. The shear volume of calculations necessary for MRP with multiple orders for even a few items made the use of computers essential. Initially, batch processing systems were used and regenerative MRP systems were the norm, where the plan would be updated periodically, often weekly. MRP employed a type of backward scheduling wherein lead times were used to work backwards from a due date to an order/start date. While the primary objective of MRP was to compute material requirements, the MRP system proved to be a useful scheduling tool. Order placement and order delivery were planned by the MRP system. Not only were orders for materials and components generated by a MRP system, but also production orders for manufacturing operations that used those materials and components to make higher-level items like sub assemblies and finished products. As MRP systems became popular and more and more companies were using them, practitioners, vendors, and researchers started to realize that the data and information produced by the MRP system in the course of material requirements planning and production scheduling could be augmented with additional data and meet other information needs. One of the earliest add-ons was the Capacity Requirements Planning module, which could be used in developing capacity plans to produce the master production schedule. Manpower planning and support for human resources management were incorporated into MRP. Distribution management capabilities were added. The enhanced MRP and its many modules provided data useful in the financial planning of manufacturing operations, thus financial planning capabilities were added. Business needs, primarily for operational efficiency and, to a lesser extent, for greater effectiveness, and advancements in computer processing and storage technology brought about MRP and influenced its evolution. What started as an efficiency-oriented tool for production and inventory management had become a cross-functional information system serving diverse user groups.

A very important capability to evolve in MRP systems was the ability to close the loop (control loop). This was largely because of the development of real time (closed loop) MRP systems to replace regenerative MRP systems in response to the business need and improved computer technology—time-sharing rather than batch processing as the dominant mode of computer operation. On time-sharing mainframe systems, the MRP system could run 24/7 and update continuously. Use of the corporate mainframe that performed other important computing tasks for the organization was not practical for some companies because MRP consumed too many system resources. Subsequently, some opted to use mainframes (they were becoming smaller and cheaper, but increasing in processing speed and storage capability) or mini-computers (which could do more, faster than old mainframes) that could be dedicated to MRP. MRP could now respond to timely data fed into the system and produced by the system. This closed the control loop with timely feedback for decision making by incorporating current data from the factory floor, warehouse, vendors, transportation companies, and other internal and external sources, thus giving the MRP system the capability to provide current (almost real-time) information for better planning and control. These closed-loop systems better reflected the realities of the production floor, logistics, inventory, and more. It was this transformation of MRP into a planning and control tool for manufacturing by closing the loop, along with all the additional modules that did more than plan materials—they planned and controlled various production resources—that led to MRPII. Here, too, improved computer technology and the evolving business need for more accurate and timely information to support decision making and greater organizational effectiveness contributed to the evolution from MRP to MRPII.

The MRP in MRPII stands for manufacturing resource planning rather than materials requirements planning. The MRP system had evolved from a material requirements planning system to a planning and control system for resources in manufacturing operations—an enterprise information system for manufacturing. As time passed, MRPII systems became more widespread, and more sophisticated, particularly when used in manufacturing to support and complement computer integrated manufacturing (CIM). Databases started replacing traditional file systems, allowing for better systems integration and greater query capabilities to support decision makers, and the telecommunications network became an integral part of these systems in order to support communications between and coordination among system components that were sometimes geographically distributed, but still within the company. In that context, the label CIM II was used to describe early systems with capabilities now associated with ERP (Lope, 1992). The need for greater efficiency and effectiveness in back-office operations was not unique to manufacturing, but was also common to non-manufacturing operations. Companies in non-manufacturing sectors such as health care, financial services, aerospace, and the consumer goods sector started to use MRPII-like systems to manage critical resources, thus the M for manufacturing seemed not always to be appropriate. In the early 90s, these increasingly sophisticated back-office systems were more appropriately labeled enterprise resource planning systems (Nikolopoulos, Metaxiotis, Lekatis, & Assimakopoulos, 2003).

MRP II was mostly for automating the business processes within an organization, but ERP, while primarily for support of internal processes, started to support processes that spanned enterprise boundaries (the extended enterprise). While ERP systems originated to serve the information needs of manufacturing companies, they were not just for manufacturing anymore. Early ERP systems typically ran on mainframes like their predecessors, MRP and MRPII, but many migrated to client/server systems where, of course, networks were critical and distributed databases more common. The growth of ERP and the migration to client/server systems really got a boost from the Y2K scare. Many companies were convinced by vendors that they needed to replace older main-frame based systems, some ERP and some not, with systems using the newer client/server architecture. After all, since they were going to have to make so many changes in the old systems to make them Y2K compliant and avoid serious problems (this was what vendors and consultants often told them) they might as well bite the bullet and upgrade. Vendors and consultants benefited from the Y2K boost to ERP sales, as did some of their customers. Since Y2K, ERP systems have evolved rapidly, bringing us to the ERP systems of today. Present day ERP systems offer more and more capabilities and are becoming more affordable even for small-to-medium-sized enterprises.

ERP TODAY

As ERP systems continue to evolve, vendors like PeopleSoft (Conway, 2001) and Oracle (Green, 2003) are moving to an Internet-based architecture, in large part because of the ever-increasing importance of E-commerce and the globalization of business. Beyond that, perhaps the most salient trend in the continuing evolution of ERP is the focus on front-office applications and inter-organizational business processes. ERP is creeping out of the back office into the front and beyond the enterprise to customers, suppliers, and more in order to meet changing business needs. Front-office applications involve interaction with external constituents like customers, suppliers, partners, and more—hence the name front office because they are visible to "outsiders." Key players like Baal, Oracle, PeopleSoft, and SAP have incorporated advanced planning and scheduling (APS), sales force automation (SFA), customer relationship management (CRM), supply chain management (SCM), and e-commerce modules/capabilities into their systems, or repositioned their ERP systems as part of broader enterprise suites incorporating these and other modules/capabilities. ERP vendor products reflect the evolving business needs of clients and the capabilities of IT, perhaps most notably Internet-related technologies.

While some companies are expanding their ERP system capabilities (adding modules) and still calling them ERP systems, others have started to use catchy names like enterprise suite, E-commerce suite, and enterprise solutions to describe their solution clusters that include ERP among other modules/capabilities. Table 1 lists the various modules/capabilities (with modules deemed similar combined in cells) taken from the product descriptions of vendors like PeopleSoft, Oracle, J.D. Edwards, and SAP, who are major players in the ERP/enterprise systems market.

Perhaps, most notable about ERP today is that it is much more than manufacturing resource planning. ERP and ERP-like systems have become popular with non-manufacturing operations like universities, hospitals, airlines, and more, where back-office efficiency is important and so, too, is front-office efficiency and effectiveness. In general, it is fair to say that today's ERP systems, or ERP-like systems, typically include, or will include (per vendor plans), modules/capabilities associated with front-office processes and activities. Alternatively, ERP modules are packaged with other modules that support front-office and back-office processes and activities, and nearly anything else that goes on within or between organizations and stakeholders. ERP proper (the back office system) has not become unimportant because back-office efficiency and effectiveness was, is, and will always be important. Today's focus, however, seems more to be external, as organizations look for ways to support and improve relationships and interactions with customers, suppliers, partners, and other stakeholders. While integration of internal functions is still important, and in many organizations still has not been achieved to a great extent, external integration seems now to be a primary focus. Progressive companies desire to do things—all things—faster, better, and cheaper (to be agile), and they want systems and tools that will improve competitiveness, increase profits, and help them not just to survive, but to prosper in the global economy. Today, that means working with suppliers, customers, and partners like never before.

Table 1. ERP modules

Modules
Enterprise Resource Planning (ERP)
Customer Relationship Management (CRM)
Asset Management Financial Management
Supplier Relationship Management (SRM) Business Collaboration
Inventory Management Order Processing
Data Warehouse Knowledge Warehouse Business Information Warehouse
Business Intelligence Analytics and Reporting Data Mining
E-Commerce Sales Management Field Service Management Retail Management
Facilities Management Maintenance Management
Warehouse Management Logistics Management Distribution Management
Project Management
Human Resource Management

Vendors are using the latest technology to respond to these evolving business needs as evidenced in the products and services they offer. Will ERP be the all-encompassing system (with an updated name like ERPII) comprised of the many modules and capabilities mentioned, or will it be relegated to the status of a module in the enterprise system of the future?

ERP and the Future

New multi-enterprise business models like value collaboration networks, customer-centric networks that coordinate all players in the supply chain, are becoming popular as we enter the 21st century (Nattkemper, 2000). These new business models reflect an increased business focus on external integration. While no one can really predict the future of ERP very far into the future, current management concerns and emphasis, vendor plans, and the changing business and technological environments, provide some clues about the future of ERP. We turn our attention now to evolving business needs and technological changes that should shape the future of ERP.

E-commerce is arguably one of the most important developments in business in the last 50 years (it has been called the "Viagra" of business), and m-commerce is poised to take its place alongside or within the rapidly growing area of e-commerce. The Internet, intranets, and extranets have made e-commerce in its many forms (B2B, B2C, B2G, G2C, C2C, etc.) possible. Mobile and wireless technology are expected to make "always on" Internet and anytime/anywhere location-based services a reality, as well as a host of other capabilities we categorize as m-commerce. One can expect to see ERP geared more to the support of both e-commerce and m-commerce. Internet, mobile, and wireless technologies should figure prominently in new and improved system modules and capabilities (O'Brien, 2002; Sane, 2005; Bhattacharjee, Greenbaum, Johnson, Martin, Reddy, Ryan, et al., 2002). Vendors and their customers will find it necessary to make fairly broad, sweeping infrastructure changes to meet the demands of e-commerce and m-commerce (Bhattacharjee, Greenbaum, Johnson, Martin, Reddy, Ryan, et al., 2002; Higgins, 2005). Movement away from client-server systems to Internet-based architectures is likely. In fact, it has already started (Conway, 2001). New systems will have to incorporate existing and evolving standards and older systems will have to be adapted to existing and evolving standards, and that may make the transition a little uncomfortable and expensive for vendors and their customers. Perhaps the biggest business challenge with e-commerce, and even more so with m-commerce, is understanding how to use these new and evolving capabilities to serve the customer, work with suppliers and other business partners, and function internally. Businesses are just beginning to understand e-commerce and how it can be used to meet changing business needs as well as how it changes business needs, and now m-commerce poses a whole new challenge. It is a challenge for application vendors and for their clients. Back-office processes and activities and front-office processes and activities are being affected by e-commerce and will be affected by m-commerce. The strategic ramifications are significant as the Internet and mobile technology take a prominent place in the future of ERP systems. They will be key in meeting evolving business needs, and on the flip side, one can argue that the evolving technologies will give rise to new business needs.

The current business focus on process integration and external collaboration is a driving force for change that should continue for some time to come. Some businesses are attempting to transform themselves from traditional, vertically integrated organizations into multi-enterprise "recombinant entities" reliant on core competency-based strategies (Genovese, Bond, Zrimsek, & Frey, 2001). Integrated SCM and business networks will receive great emphasis, reinforcing the importance of IT support for cross-enterprise collaboration and inter-enterprise processes (Bhattacharjee, Greenbaum, Johnson, Martin, Reddy, Ryan, et al., 2002). Collaborative commerce (c-commerce) has become not only a popular buzzword, but also a capability businesses desire/need. c-Commerce is the label used to describe Internet-based (at least at present) electronic collaboration among businesses, typically supply chain partners, in support of inter-organizational processes that involve not just transactions, but also decision making, coordination, and control (Sane, 2005). ERP systems will have to support the required interactions and processes among and within business entities, and work with other systems/modules that do the same. The back-office processes and activities of business network partners will not exist in a vacuum—many will overlap. There will be some need then for ERP processes to span organizational boundaries (some do at present), requiring a single shared inter-enterprise ERP system that will do it (we might call it a distributed ERP), or at least ERP systems that can communicate with and co-process (share/divide processing tasks) with other ERP systems—probably the most practical solution, at least in the near future. Middleware and enterprise portal technologies will likely play an important role in the integration of such modules and systems (Bhattacharjee, Greenbaum, Johnson, Martin, Reddy, Ryan, et al., 2002). In short, greater external integration that complements internal integration will be important in the future of ERP, as providers strive to enable companies to communicate and collaborate with other entities that comprise the extended enterprise (Bhattacharjee, Greenbaum, Johnson, Martin, Reddy, Ryan, et al., 2002). Internet-based technologies seem a necessary ingredient in this integrated, cross-enterprise ERP capability.

It is not uncommon now for companies to select only "suitable" modules rather than purchasing a complete packaged system, which may not be necessary given the core business processes of a company. That said, module capabilities and prices vary widely among vendors, and ERP is not cheap. Whether a company buys a "complete" solution or select modules, it still face several challenges with the development and implementation of ERP systems including: (i) the cost of the systems, (ii) alignment between information and business models, (iii) implementation issues (like integration, interoperability, and resistance to change), and (iv) post-implementation problems.

Web services are expected to play a prominent role in the future of ERP (O'Brien, 2002; ACW Team, 2004). Web services range from simple to complex, and they can incorporate other Web services. The capability of Web services to allow businesses to share data, applications, and processes across the Internet (O'Brien, 2002) may result in ERP systems of the future relying heavily on the service-oriented architecture, within which Web services are created and stored, providing the building blocks for programs and systems. Web service technology could put the focus where it belongs: on putting together the very best functional solution to automate a business process (Bhattacharjee, Greenbaum, Johnson, Martin, Reddy, Ryan, et al., 2002). The use of "best in breed" Web service-based solutions might be more palatable to businesses, since it might be easier and less risky to plug in a new Web service-based solution than replace or add on a new product module. A greater role for Web services is expected, and that, too, would heighten the importance of an Internet-based architecture to the future of ERP.

All from one, or best in breed? Reliance on a single vendor would seem best from a vendor's perspective, but it may not be best from the client's standpoint. While it may be advantageous to have only one proprietary product to install and operate, and a single contact point for problems, there are risks inherent in this approach. Switching cost can be substantial, and if a single vendor does not offer a module/solution needed by the client, then the client must develop it internally, do without it, or purchase it from another vendor. At any rate, the client may be faced with trying to get diverse products to work together, and the problems of doing so are well documented. The single source approach means an organization must place great faith in the vendor. So what about best in breed? That approach will be good if greater interoperability/integration among vendor products is achieved (Bhattacharjee, Greenbaum, Johnson, Martin, Reddy, Ryan, et al., 2002). There is a need for greater "out of the box" interoperability, thus a need for standards. Ideally, products will reach a level of standardization where software modules exhibit behavior similar to the plug-and-play hardware—you just plug in a new module, the system recognizes it, configures itself to accommodate the new module, and eureka, it works! While this is much to hope for, increased standardization brought about by developments like the Service-oriented architecture might make this a reality, though probably not anytime soon. The fact that many are embracing standards for XML and more does give one some reason to hope, but whether the future of ERP software trends toward the single source or best in breed approach remains to be seen. Regardless of the direction, integration technologies will be important in the new breed of modular, but linked, enterprise applications. Middleware providers see a significant opportunity here in that their products facilitate module interaction. Increasingly, modules and or entire systems are provided by a new breed of vendors called application service providers (ASPs). These companies typically deliver their services via the Internet, and may become "the way" business partners integrate their systems—all partners could use the same ASP and the ASP systems would be the integrating force.

Data warehouses, data mining, and various analytic capabilities are needed in support of front-office and back-office processes and activities involved in CRM, SRM, SCM, field service nanagement, business collaboration, and more. Likewise, they are important in strategic management. Data warehouses are expected to play an important role in the future of ERP, either as a capability within ERP, or by working with the ERP system to exchange data needed to support related activities and processes. Ideally, the data warehouse would be integrated with all front-office, back-office, and strategic systems to the extent that it helps close loops by providing timely data to support decision making in any context. Knowledge management systems (KMS) endowed with neural networks and expert system capabilities should play a key role in decision making as they become more able to capture, model, and automate decision-making processes. Data warehouses and KMS should enable future ERP systems to support more automated business decision making (Strategic Systems of the Future, 1999; Bhattacharjee, Greenbaum, Johnson, Martin, Reddy, Ryan, et al., 2002). More automated decision making in both front-office and back-office systems should eliminate/minimize human variability and error, greatly increase decision speed, and hopefully improve decision quality. Business intelligence (BI) tools, offered by some vendors and planned by others, take data and transform it into information used in building knowledge that helps decision makers to make more "informed" decisions—no pun intended. Current business intelligence (BI) tools are largely designed to support strategic planning and control but will likely trickle down to lower-level decision makers, where their capabilities will be put to use in tactical and perhaps operational decision contexts. BI tools use data, typically from a data warehouse, along with data mining, analytic, statistical, query, reporting, forecasting, and decision support capabilities to support managerial planning and control. In combination with the data warehouse, KMS and BI should contribute to faster, better, and less costly (in terms of time and effort involved) decisions at all organizational levels.

At least in the near future, it appears that greater emphasis will be placed on front-office systems, as opposed to back-office systems, and sharing data, applications, and processes across the Internet (O'Brien, 2002). Back-office systems will not be unimportant, but they are more mature as a consequence of past emphasis, and many work quite well. Emphasis will be on more thorough integration of the modules that comprise back-office systems, integration of back-office systems with front-office and strategic systems, and integration of front-office, back-office, and strategic systems with the systems of other organizations. At present, greater organizational effectiveness in managing the entire supply chain all the way to the end customer is a priority in business. The greater emphasis on front-office functions and cross-enterprise communications, and collaboration via the Internet, simply reflects changing business needs and priorities. A 2004 ITtoolbox survey of ERP users in Europe, North America, Asia, India, and elsewhere showed great interest in improved functionality and ease of integration and implementation (top motives for adding new modules or purchasing new ERP systems). Furthermore, the same survey showed greatest interest in modules for CRM, Data Warehousing, and SCM (top three on the list). The demand for specific modules/capabilities in particular shows that businesses are looking beyond the enterprise. This external focus is encouraging vendors to seize the moment by responding with the modules/systems that meet evolving business needs. The need to focus, not just on new front-office tools but also on strategy, will encourage greater vendor emphasis on tools like data warehouses and capabilities like business intelligence that support strategy development, implementation, and control.

The evolving environment of business suggests a direction for these comprehensive enterprise systems that would seem to make ERP less fitting as an appropriate label. The Gartner group has coined the term ERPII to describe their vision of the enterprise system of the future, with increased focus on the front office, strategy, and the Internet. ERPII is a business strategy and a set of collaborative operational and financial processes internally and beyond the enterprise (Zrimsek, 2002). Gartner projected that by 2005, ERPII will replace ERP as the key enabler of internal and inter-enterprise efficiency (Zrimsek, 2002). While the ERPII label may stick for a while, it is likely that ERP will be relegated to module/capability status, while a name more fitting for evolving inter-enterprise front office, back office, and strategic systems will replace the ERPII label, in much the same way that ERP replaced MRPII. Perhaps "enterprise systems" will be that new name, as it seems to be finding favor among vendors.

THE ERP EVOLUTION FRAMEWORK

This framework simply summarizes the evolution of ERP relating the stages in its evolution to business needs driving the evolution, as well as changes in technology. Table 2 presents the framework. As MRP evolved into MRPII, then ERP, and finally to ERPII (present state of ERP), the scope of the system expanded as organizational needs changed, largely in response to the changing dynamics of the competitive environment. As business has become increasingly global in nature, and cooperation among enterprises more necessary for competitive reasons, systems have evolved to meet those needs. One can hardly ignore the technological changes that have taken place, because the current state of technology is a limiting factor in the design of systems to meet evolving business needs. From our examination of the evolution of ERP, we would conclude that the next stage of the evolution will come about and be shaped by the same forces that have shaped each stage, that being evolving business needs and advances in technology. The future of ERP systems seems destined to follow one of two courses: ERP will be relegated to the status of module within some broader system, or ERP will evolve into that all-encompassing system, call it

Table 2. The evolution of ERP

System	Primary Business Need(s)	Scope	Enabling Technology
MRP	Efficiency	Inventory management and Production planning and control.	Mainframe computers, batch processing, traditional file systems.
MRPII	Efficiency, effectiveness and integration of manufacturing systems	Extending to the entire manufacturing firm (becoming cross-functional).	Mainframes and Mini computers, realtime (time sharing) processing, database management systems (relational)
ERP	Efficiency (primarily back office), effectiveness and integration of all organizational systems.	Entire organization (increasingly cross functional), both manufacturing and non-manufacturing operations.	Mainframes, Mini, and micro computers, Client server networks with distributed processing and distributed databases, Data warehousing and mining, knowledge management.
ERPII	Efficiency, effectiveness and integration within and among enterprises.	Entire organization extending to other organizations (cross-functional and cross-enterprise--partners, suppliers, customers, etc.).	Mainframes, Client Server systems, distributed computing, knowledge management, Internet technology (includes Web services, intranets and extranets).
IRP, Enterprise Systems, Enterprise Suite, or whatever label gains common acceptance.	Efficiency, effectiveness and integration within and among all relevant constituents (business, government, consumers, etc.) on a global scale.	Entire organization and its constituents (increasingly global) comprising supply chain from beginning to end as well as other industry and government constituents.	Internet, Web service Architecture, wireless networking, mobile wireless, knowledge management, grid computing, artificial intelligence.

ERPII or something else, that contains most or all of the modules discussed herein. We expect the former as opposed to the latter will occur, with ERP (the traditional back office system) taking its place with MRP and MRPII. The functions ERP systems perform will remain important and necessary as have the functions of MRP and MRPII, but ERP will become part of something bigger, taking its place as an integral part of the enterprise system of the future. Whether that all-encompassing system is called ERPII, Interprise resource planning, enterprise suite, enterprise system, or a name that currently resides in the back of some vendor employee or researcher's mind, remains to be seen. One thing seems certain, the next stage in the evolution will hinge on the same forces shaping systems of the past—business need and technological change.

CONCLUSION

ERP has evolved over a long period of time. MRP gave way to MRPII, then MRPII to ERP, and finally ERP to ERPII. It seems quite likely that ERPII will give way to a new label. MRP still exists as will ERP, but most likely as a module, or capability rather than the label applied to an increasingly broad set of capabilities and modules that support the back-office, front-office, strategic planning and control, as well as integrating processes and activities across diverse enterprises comprising business networks. Whatever the name, current trends suggest certain characteristics which we can reasonably expect. This future system will have to support e-commerce and m-commerce, thus wireless technology, including but not limited to mobile, and the Internet will be key in the evolving architecture. An Internet-based architecture seems likely, and it may be a service-oriented architecture, wherein Web services are key, ASPs, or both. The increased emphasis on front-office systems and strategic planning and control will likely influence new capabilities introduced by vendors for the next few years. Increased automation of decision making is to be expected with contributions from knowledge management and business intelligence systems fueled by advancements in the field of artificial intelligence. Greater interoperability of diverse systems and more thorough integration within and between enterprise systems is likely to remain a priority. An environment for applications much like the "plug and play" environment for hardware would make it easier for organizations to integrate their own systems and have their systems integrated with those of other organizations. Such an environment awaits greater standardization. This ideal "plug and play" environment would make it easier for firms to opt for a "best in breed" strategy for application/module acquisition as opposed to reliance on a single vendor for a complete package of front-office, back-office, and strategic systems. Moreover, such a development might move us closer to effective inter-organizational system integration and make fully integrated supply chain management a reality. Perhaps we might call the evolving system interprise resource planning to emphasize the inter-enterprise nature of these systems. Whatever they are called, it seems that what they will do goes far beyond what the enterprise resource planning (ERP) label would aptly describe, even when the "II" is appended.

From the discussion of ERP's future one can extrapolate certain desired capabilities for the enterprise systems of the future. Following is a list of desired/required capabilities:

- Facilitates an integrated supply chain
- Data transfer between modules is smooth and consistent
- Flexibility to support agile companies responding to dynamic business environment
- An architecture reflective of evolving enterprise models and evolving technology, like mobile wireless
- Database models/solutions support transaction-intensive applications (front office and back office), query intensive applications, and internal and external interaction with the database
- Systems take into account partnering enterprise characteristics like culture, language, technology level, standards, information flows, and provide flexibility to adapt as partnering relationships change
- Global vendor alliances to better meet needs of clients in any country
- Vendors and user companies adopt standards like XML, the Web service architecture, and evolving wireless standards with due consideration to global business requirements
- Greater flexibility and interoperability of modules, systems, and enterprises

For researchers and practitioners the advice is simple. There were two primary drivers in the evolution from MRP to MRPII, ERP, and finally ERPII. Those drivers were business need and technological change. Technological change made possible the development of systems to meet changing business needs. The needs may exist for a while before the technology can help meet them, and the technology can exist for a while before someone recognizes that it can be used to meet a current or evolving business need. In either case, the focus should be on monitoring business needs and monitoring technological change. Research that does both and is geared towards bringing the two together could make significant contributions to business. The Enterprise System of the future, whatever it is called, will be found at the convergence of business need and technological change. Perhaps researchers need to explore how we can do more to make that happen, rather than wait for it to happen and describe it as we have in this manuscript.

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Chapter 5.11

K-link+: A P2P Semantic Virtual Office for Organizational Knowledge Management

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ABSTRACT

This chapter introduces a distributed framework for OKM (Organizational Knowledge Management) which allows IKWs (Individual Knowledge Workers) to build virtual communities that manage and share knowledge within workspaces. The proposed framework, called K-link+, supports the emergent way of doing business of IKWs, which allows users to work at any time from everywhere, by exploiting the VO (Virtual Office) model. Moreover, since semantic aspects represent a key point in dealing with organizational knowledge, K-link+ is supported by an ontological framework composed of: (i) an UO (Upper Ontology), which defines a shared common background on organizational knowledge domains; (ii) a set of UO specializations, namely Workspace Ontologies or Personal Ontologies, that can be used to manage and search content; (iii) a set of COKE (Core Organizational Knowledge Entities) which provides a shared definition of human resources, technological resources, knowledge objects, services; and (iv) an annotation mechanism that allows users to create associations between ontology concepts and knowledge objects. K-link+ features a hybrid (partly centralized and partly distributed) protocol to guarantee the consistency

of shared knowledge and a distributed voting mechanism to foster the evolution of ontologies on the basis of user needs.

INTRODUCTION

In the 1990s, Nonaka and Takeuchi proposed a new organizational paradigm (Nonaka et al., 1995). This paradigm identifies knowledge as a key resource for organizations and aims at establishing paths to be followed for better exploiting organizational knowledge. While earlier organizational models (Taylor, 1911) saw the organization as a box with the aim to maximize the output or as something that can be scientifically and rigorously managed, more recently the theme of managing knowledge has become more important (Simon, 1972) and the role of the organization in KM (Knowledge Management) processes has changed notably. The organization becomes a way to connect the knowledge of many subjects into a more complete understanding of the reality. Also the role of technologies has changed; they have become a way to increase people's rationality by enabling both knowledge management and exchange. Throughout the years, several other theories about knowledge have been proposed. A generally accepted classification proposed by Polanyi (Polanyi 1966; Polanyi 1997) and extended by Nonaka (1994) identifies on the one side "tacit knowledge" as the knowledge resulting from personal learning within an organization. On the other side, "explicit knowledge" is a generally shared and publicly accessible form of knowledge. Explicit knowledge can also be classified on the basis of the following forms: "structured" (available in databases); "semi-structured;" (generally available in Web sites: HTML pages, XML documents, etc.) and "unstructured" (available as textual documents: project documents, procedures, white papers, etc.). More recently, new importance has been given to social processes and to the CoP (Communities of Practice) as sources of knowledge. A CoP can be viewed as a group of people with shared goals and interests that employ common practices, work with the same tools, and express themselves in a common language (Lave & Wenger, 1991). In a CoP, individuals can produce and learn new concepts and processes from the community, allowing the same community to innovate and create new knowledge. This way, an organization can become a community of communities, offering space for creating autonomous sub-communities. The different types of technological solutions for managing knowledge should correspond to actual social interactions in KM processes. According to this consideration, technological systems for KM can be classified and inserted in a scheme reflecting the adopted social model. Therefore, on the one hand we have centralized systems that are practically identified with the EKP (Enterprise Knowledge Portal) and, on the other hand, we have DKM (Distributed Knowledge Management) systems. In this chapter, we will focus on the DKM approach since it naturally fits the process of creating knowledge. Following this approach, the individual is allowed to manage his/her knowledge without any superimposed schema. Therefore, he/she can share the individual knowledge by spreading it over the organization and making it an asset of the whole organization.

In particular, distributed applications for KM are based on the principle that different perspectives within complex organizations should not be viewed as an obstacle to knowledge exploitation, but rather as an opportunity to foster innovation and creativity. They are increasingly becoming popular since they permit an easy and quick creation of dynamic and collaborative groups (e.g., CoP) composed of people from a single or different organizations.

Moreover, in today‘s ubiquitous information society an increasing number of people work outside of the traditional office for many hours of the day. Current technologies do not properly support this new style of working and every day it is becoming harder and harder to exchange information in a labyrinth of network connections, firewalls, file systems, tools, applications, databases, voicemails, and emails. Individual Knowledge Workers spend much of their time finding and exchanging information or reaching people, and very limited time is left to actual productive work. To cope with these issues, many companies use technological solutions that include portals, extranets, VPNs, and browser-based application strategies that, at best, have been partially successful.

We argue that IKWs need a virtual workplace where the physical office can be recreated and where everybody and everything is easily available from anywhere at anytime. The *Virtual Office* approach (Marshak, 2004) can solve most of the aforementioned issues. A VO is a work environment defined regardless of the geographic locality of employees. A VO fulfils the roles of the traditional, centralized office although employees collaborate for the most part electronically with sporadic physical contacts.

P2P (Peer-to-Peer) solutions naturally fit the DKM and VO requirements, since they offer autonomy, coordination, and scalability features (Bonifacio et al., 2002). We designed and developed a P2P system named *K-link+* (Le Coche et al., 2006) that implements the VO model and provides users with a collaborative knowledge management environment. In *K-link+*, users can integrate different applications (knowledge sharing, messaging, shared boards, agenda, etc.) within a single environment and enrich the system with new tools that can be added as new components.

In *K-link+*, peers are allowed to concurrently work on the same shared KOs (Knowledge Objects). To foster peers' autonomy, different local replicas of a KO can be created, so concurrent access can affect data consistency if adequate mechanisms are not provided. Since peers can join or leave the system at any time, synchronization is required by peers that reconnect to the network and need to be informed about recent updates made on KOs by other peers. The *K-link+* system adopts a hybrid model to guarantee content consistency and peer synchronization. This model exploits the efficiency of centralized models, but at the same time includes decentralized features that assure scalability properties when the system size increases.

The basic concept under the *K-link+* Virtual Office approach is the workspace. A *K-link+* workspace can be viewed as a work area integrating people, tools, and resources. KOs created and exchanged within a workspace are provided with a semantic meaning through ontologies. In recent years, the knowledge management community has been considering ontologies as an adequate support to harness semantics conveyed by information (Fensel, 2001). An ontology (Gruber, 1993) is an abstract representation of a knowledge domain which allows its modeling in terms of concepts, relationships among concepts, class hierarchies and properties, and permits reasoning about the represented knowledge. Ontologies also offer a way for defining a set of possible instances of concepts and relationships, thus providing links between the model and the modeled reality.

K-link+ is supported by an ontological framework that allows to:

- Give a shared definition of knowledge domains relevant for the organization through the Upper Ontology (UO). So IKWs are provided with a common and well-defined knowledge background on knowledge domains of interest for the organization.
- Provide a shared definition of typical organizational assets (e.g., human resources, knowledge objects, services) within COKE ontologies. This way the retrieval of such assets can be done more effectively.
- Deepen aspects of the organizational knowledge domain in communities through Workspace Ontologies or on a personal basis through Peer Ontologies. Therefore, IKWs are endowed with a certain degree of autonomy in defining their own conceptual schemas (i.e., ontologies).

- Annotate COKE instances and in particular KOs (i.e., textual documents, emails, Web pages) to ontology concepts. Therefore unstructured and heterogeneous information is provided with semantically relevant metadata and can be retrieved on a semantic basis by specifying ontology concepts instead of keywords.

BACKGROUND

Most of the current architectures for content sharing and knowledge management are typically based on client/server architectures in which one or more servers act as central entities. In such architectures, knowledge handled by IKWs must be managed according to organizational guidelines. However, such centralized approaches do not reflect the social nature of knowledge (Bonifacio et al., 2002). As it is argued in (Nonaka & Takeuchi, 1995), the *seed* of new knowledge is *individual (tacit)* knowledge, but the importance of the knowledge increases when it becomes available to the whole organization. Therefore, the *externalization* of tacit knowledge is a quintessential process for creating new knowledge; this typically requires people to interact and collectively reflect on a problem or an idea. Such observations promote the demand for new technological architectures that place more emphasis on collaboration.

We argue that a P2P architecture that implements the VO model fits both the requirements of collaboration (synchronous and asynchronous) and knowledge sharing. In fact, P2P architectures naturally support the creation of communities (e.g., workspaces, peer groups) in which content and conveyed knowledge can be created, shared, exchanged, and transformed.

Content consistency is a fundamental reliability requirement for a P2P system. Current approaches depend on the scale of P2P systems. In a large-scale and dynamic system, it is complex and cumbersome to guarantee full consistency among replicas, so researchers have designed algorithms to support consistency in a best-effort way. In Datta et al. (2003), a hybrid push/pull algorithm is used to propagate updates, where flooding is substituted by rumor spreading to reduce communication overhead. SCOPE (Chen et al., 2005) is a P2P system that supports consistency among a large number of replicas at the cost of maintaining a sophisticated data structure. By building a RPT (Replica-Partition-Tree) for each key, SCOPE keeps track of the locations of replicas and then propagates update notifications.

Conversely, in a small- or medium-scale system, it is possible to adopt centralized schemes to guarantee a strong consistency model, which is often the *sequential* model (Lamport, 1979). In Wang et al. (2006), an algorithm for file consistency maintenance through virtual servers in unstructured and decentralized P2P systems is proposed. Consistency of each dynamic file is maintained by a VS (Virtual Server). A file update can only be accepted through the VS to ensure the one-copy serializability.

The *K-link+* system, which is mostly suited for small/medium enterprises, adopts a hybrid model which exploits the efficiency of centralized models, but at the same time includes decentralized features which assure scalability properties when the system size increases. This is accomplished by using: (i) a unique and stable server to maintain a limited amount of metadata information about shared objects; (ii) a number of interchangeable servers that maintain and manage the primary copy of shared objects; and (iii) a pure decentralized mechanism to allow P2P nodes to exchange up-to-date object copies when only read operations are required.

Another striking feature of *K-link+* is the use of ontologies for supporting OKM both at individual level, by Personal Ontologies, and within communities through Workspace Ontologies. Ontologies allow to “conceptualize” knowledge subjects, externalize them in terms of ontology primitives (e.g., concepts, relationships), and share knowledge through "the establishment of shared understanding" (Becerra et al., 2001). Ontologies can also be used to improve current keyword-based search techniques (Fensel, 2001), since they permit users to semantically annotate contents with respect to concepts. Conceptual search, that is, search based on meaning similarity rather than just string comparison, has been the motivation of a large body of research in the Information Retrieval field long before the Semantic Web vision emerged (Agosti et al., 1990; Järvelin et al., 2001). In the literature there are several approaches to ontology-based search (Guha et al., 2003; Vallet et al., 2005) that rely on queries expressed in formal languages, such as RDQL (Seaborne, 2004) SPARQL (Prud'hommeaux et al., 2006) or on a combination of formal queries with keyword-based queries (Castelles et al., 2007).

The approach we implemented is different from all these since we aim at creating semantic metadata associated to content (e.g., documents) by following the principle of superimposing information (Maier et al., 1999). We do not aim at explicitly populating the knowledge base of each peer with ontological knowledge, but rather at enabling users to quickly assign, by *annotations*, an immediate semantic meaning to both structured and unstructured content.

Concerning semantic-based P2P systems, there are several approaches that share common characteristics with *K-link+*. KEx (Knowledge Exchange) (Bonifacio et al., 2002) is a P2P system aimed at implementing knowledge sharing among communities of peers (called federations) that share interests. The system relies on the concept of context that peers exploit to represent their interests. KEx implements specific tools (e.g., context editors, context extractors) to extract the context of a peer from the peer knowledge (e.g., file system, mail messages). In order to discover semantic mappings among concepts belonging to different peer contexts, KEx exploits the CtxMatch algorithm. CtxMatch associates concepts with their correct meaning with respect to their context by exploiting WordNet and translates concepts in logical axioms in order to discover mappings. The algorithm implements a description logic approach in which mapping discovery is reduced to the problem of checking a set of logical relations. SWAP (Semantic Web and Peer to Peer) (Ehrig et al., 2003) aims at combining ontologies and P2P for knowledge management purposes. SWAP enables local knowledge management through a component called LR (Local node Repository), which gathers knowledge from several sources and represents it in RDF-Schema. SWAP allows searching for knowledge by using a query language called SeRQL, which is an evolution of RQL.

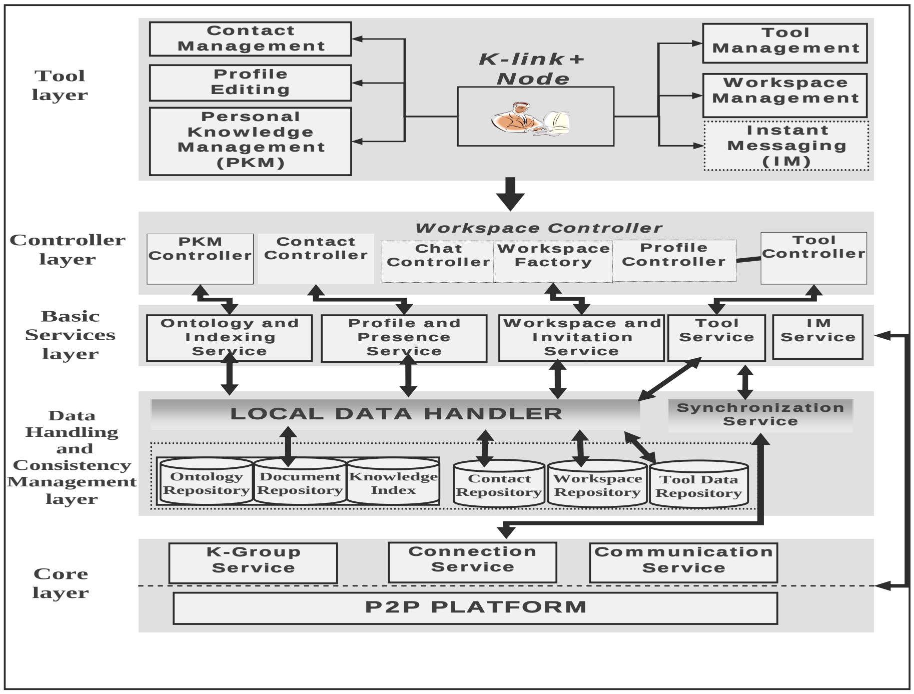
Different from these approaches, *K-link+* does not specifically tackle the problem of ontology mapping, since it can be time consuming thus affecting the requirement of quickness mandatory in a P2P environment. Conversely, we support a "mutual agreement" mechanism among participants since we build ontologies in a democratic way through a distributed voting mechanism.

K-LINK+ ARCHITECTURE

K-link+ is a collaborative P2P system that provides users with a Virtual Office environment in which content can be shared to enable collaborative work, and replicated, to foster peer autonomy. Different applications (document sharing, messaging, shared boards, agenda, etc.) can be integrated within a single environment (a *K-link+* workspace) and new tools can be added as new components to support emerging requirements. In this section, the system architecture is briefly presented. For a more detailed description of the *K-link+* architecture refer to the GridLab website, *http://grid.deis.unical.it/k-link*.

The *K-link+* architecture, shown in Figure 1, is based on five layers including basic grouping and communication services, data handling services, semantics services, workspace management

Figure 1. The K-link+ architecture



services, and a set of high level tools for content sharing and user cooperation.

K-link+ Core Layer

This layer defines the *K-link+* basic services whose implementation can be based on any P2P infrastructure (for the current version of *K-link+*, we use JXTA). Services provided by the *Core Layer* are exploited by higher layers. In particular, the *K-Group Service* allows *K-link+* Nodes (KLNs) to create new *K-Groups*, for example, communities or workspaces. The *Connection Service* allows KLNs to join the *K-link+* network by contacting a *K-link+ Rendezvous*. Features used to send and receive messages are provided by the *Communication Service*.

Data Handling and Consistency Management Layer

This layer is responsible to cope with concurrent access to shared objects, object consistency, and peer synchronization. This layer includes the *Local Data Handler*, which manages a set of local repositories to store information about contacts, workspaces, objects, and so on.

K-link+ Basic Services Layer

The services of this layer manage local and remote operations performed by a *K-link+* user. The *Ontology and Indexing Service* deals with operations involving ontologies (creation, update) that *K-link+* exploits to describe resources semantically. It also copes with the indexing of documents for keyword based searches. The *Profile and Presence Service* manages state check operations and enables users to create and publish their profile within the *K-link+* network. The *Workspace and Invitation Service* handles workspace set up and population by sending invitation messages to other KLNs. The *Tool Service* is used to add new tool instances to workspaces at run time. The *IM (Instant Message) Service* allows KLNs to communicate each other via a chat-like system.

K-link+ Controller Layer

This layer contains a set of controllers through which the system interacts with the *Data Handling and Consistency Management Layer* via a set of services (provided by the *Basic Service Layer*). The *Workspace Controller* manages workspace settings through the creation of *workspace profiles* that contain information about workspace topics, sets of tools, and the IKWs that belong to the workspace. The *Contact Controller* enables IKWs to discover other IKWs on the network and add some of them to a personal *Contact List*. The *PKM Controller* is delegated to manage the *Personal Knowledge* of an IKW. Finally, the *Tool Controller* is responsible for allowing users to handle operations (add, update, remove) on private and shared tools.

K-link+ Tools Layer

This layer enables the user to choose the set of tools to include in a workspace. Basically, *K-link+* enables workspace members to choose among a set of tools (file sharing, shared calendar, contact manager, etc.). Moreover, other tools can be developed and included in the system as components. In fact, the development of a tool in the *K-link+* system can be carried out by third parties with the only requirement that the *K-link+* tool interface must be implemented.

REPLICATION AND CONSISTENCY OF DATA IN K-LINK+

In *K-link+*, several users can work concurrently on the same shared objects. To favor the autonomy of users, the system allows users to create different replicas of the same object, so that they can work on their local copies. As mentioned in the previous section, the purpose of the *Data Handling and Consistency Management* layer is to ensure data persistence, consistency management, and data synchronization. In the context of *K-link+*, we adopt the *sequential consistency* model (Lamport, 1979), which assures that all updates performed on an object are seen in the same sequence by all peers. The model is implemented by associating to each object a KLN (named *Manager*), which is responsible for authorizing object updates and putting them in a given order. In particular, each object is assigned a *VN (Version Number)*, which is incremented after each successful update. To efficiently handle the consistency problem in the P2P environment, *K-link+* defines the following roles that can be assumed by workspace nodes:

- *Creator*. This role is assumed by a KLN that creates a shared object and specifies its *ML (Manager List)*, that is, the list of KLNs that can assume the *Manager* role for this object. Managers are ordered on the basis of their degree of responsibility in managing the object.
- *Rendezvous*. For each workspace, one rendezvous node maintains metadata about all the shared objects in a *Consistency Table* (described below) and provides such information to workspace members. The Rendezvous possesses up-to-date information about objects, in particular the identity of the node which is currently in charge of each object (i.e., the *Current Manager*) and the current VN.
- Manager. An object Manager is a KLN that manages the object life cycle and is contacted by KLNs when they want to propose an object update. An object can be assigned several Managers, but at a given time the *Current Manager*, which is the first online Manager in the ML, is actually responsible for the object. The Current Manager can decide whether or not to authorize an object update, according to the specific set of semantic rules associated to the object. KLNs are informed about the identity of the Current Manager by the Rendezvous.

- Broker. It is a KLN that maintains an updated copy of an object and can forward it to other KLNs. Whereas the Manager is a *static* role (i.e., it is assigned at object creation time), the Broker role is *dynamic*, since it is assumed by a node whenever it maintains an updated copy of the object.
- Worker. It is an ordinary KLN that can operate on an object, and possibly issue update proposals to the *Current Manager*. Workers can obtain an updated copy of an object by a *Broker*.

KLNs, as well as the *Rendezvous*, maintain information about the state of objects in a *Consistency Table*, whose structure is shown in Table 1. Each object is permanently associated to a *Consistency Entry* identified by a unique *ID* which is assigned when the object is created. Moreover, to keep trace of the object state, the Consistency Entry contains the Version Number, which is incremented at each object update, the *ID* of the Current Manager and the *Manager List*.

The definition of the mentioned roles enables three different kinds of interactions as shown in Figure 2. A *static centralized* approach is adopted when Workers interact with the unique and static Rendezvous. The aim of the Rendezvous is solely to provide information about Current Managers and object versions, but the management of each single shared object is delegated to the corresponding Current Manager. Such way of managing objects enables a *dynamic centralized* paradigm because object management can be dynamically switched among different Managers. This way, two common issues are solved: (i) we avoid the presence of a central bottleneck which would be originated if all objects were managed by a single node; (ii) we cope with the volatile nature of P2P networks, in which peers with Manager responsibilities can leave the network at any time.

A *decentralized* model is exploited by Brokers to provide updated object copies to Workers in a P2P fashion. We argue that the use of these three paradigms can represent a valid trade-off among different ways to face distributed object management. A detailed description and a performance evaluation of the consistency protocol can be found in (Mastroianni et al., 2007).

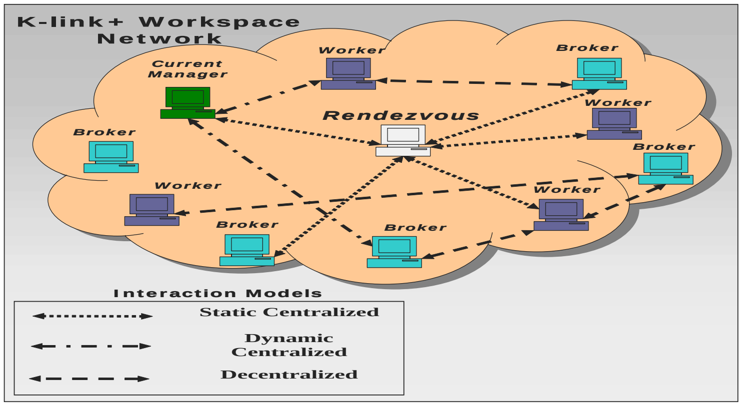
THE K-LINK+ ONTOLOGICAL FRAMEWORK

Most of the current approaches to collaborative work--while being worthwhile--do not take into account semantic aspects of knowledge management. A complete and useful collaborative system should be able to deal with both information and knowledge on a semantic basis. In recent years, the knowledge management community has been considering ontologies as an adequate support to harness semantics conveyed by information (Fensel, 2001). An ontology is an abstract representation of a knowledge domain which allows its modeling in terms of concepts, relationships

Table 1. Consistency table

Field	**Description**
Object ID	A unique ID that identifies the shared object
VN (Version Number)	Object version number, incremented at each object update
Current Manager	The first online node contained in the ML. This node is responsible for the shared object.
Manager List	An ordered list of nodes that can assume the Current Manager role
Creator	The node that creates the object

Figure 2. The K-link approach to data consistency. Different kinds of arrows are used to show the different models of interaction among K-link+ nodes



between concepts, class hierarchies, and properties, and permits reasoning about the represented knowledge. Ontologies also offer a way for defining a set of possible instances of concepts and relationships, thus providing links between the model and the modeled reality. *K-link+* provides an ontology framework organized in two layers as shown in Figure 3.

The first layer contains an UO and a set of COKEs represented as ontology classes.

The UO represents a basic set of meta-concepts relevant for an organization that are defined by domain experts.

Definition 1 (UO) (Upper Ontology)

- An UO is a five-tuple of the form UO=$\langle C,\leq_C, R,\leq_R,\varphi_R\rangle$ where:C is a set of concepts, defined by domain experts, which describe knowledge domains of interest for the organization.
- R:C→ C is a set of built-in relationships among concepts in C (e.g., represents, same-as, different-from, contains, associates, part-of, isa, related-to) arranged in hierarchies by means of the partial orders $\leq_C$, $\leq_R$.
- The function $\varphi R : R \rightarrow C\times C$ associates each relation $r\in R$ to its domain *dom*(r)=$\pi 1(\varphi R(r))$ and range *range*(r)= $\pi 2(\varphi R(r))$. The initial set of relationships included in the UO can be customized according to organizational needs.

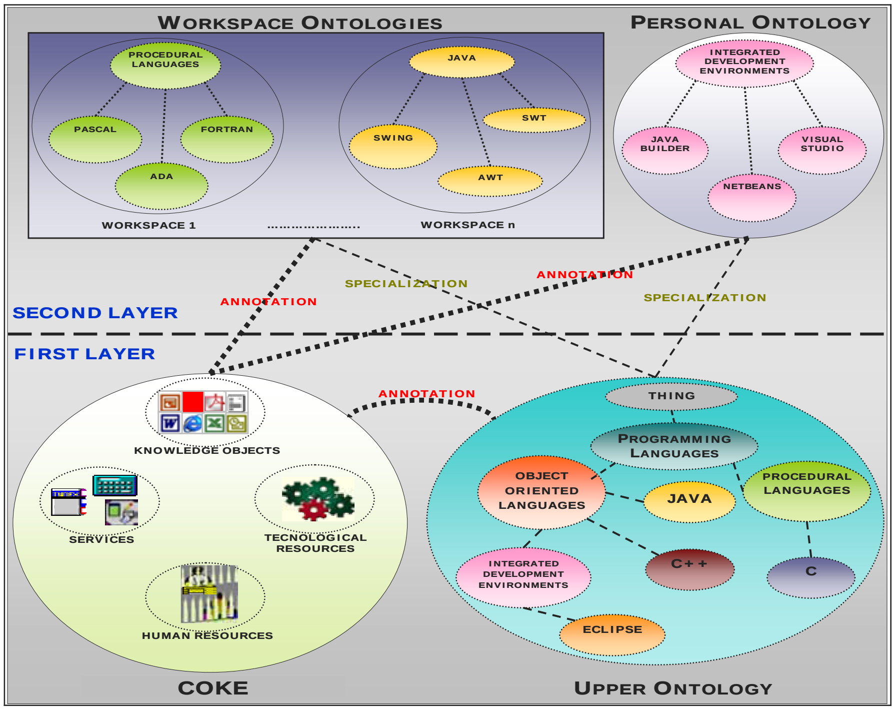
The UO can be viewed as a semantic network of concepts similar to a thesaurus. For instance, the UO for a health care organization will contain concepts and relationships related to diseases, clinical practices, drugs, surgery, and so forth.

COKEs aim at giving a semantic description of some organizational sources of knowledge.

We identified four COKEs:

- *The Human Resource COKE* describes organizational groups (Community of Practices, Project Teams) and individuals. For each IKW, personal data, skills, group memberships, and topics of interest are represented. A group is described through its objectives and topics and contains information about the participant IKWs.
- The *Knowledge Object* COKE describes textual documents, database elements, emails, web pages, through metadata (e.g., data of creation, document type, author, URI). In particular, the framework exploits this COKE for enabling advanced search and retrieval capabilities in *K-link+*.

Figure 3. The user view of the K-link+ Ontology Framework. This figure shows the relationships between ontologies belonging to the two layers. The user's Personal Ontology and the Workspace Ontologies are specializations of one or more UO concepts. For example, the shown Personal Ontology specializes the UO concept Integrated Development Environment. COKE instances are annotated to Upper, Personal, and Workspace ontologies concepts.



- The *Technological Resource* COKE describes tools through which knowledge objects are created, acquired, stored, and retrieved. For each tool, this kind of COKE provides information about version and features.
- The *Services* COKE describes services, provided by IKWs, in terms of provided features and access modalities.

However, each COKE has its own definition also in terms of attributes. For instance, the COKE KO, which describes different types of unstructured textual documents, contains attributes such as *name*, *size*, *author*, and so forth.

Instances of the same COKE share the same structure, so allowing for the management of implicit and explicit knowledge stored in structured, semi-structured or unstructured formats.

The *Annotation* relationships can be defined between the COKEs and the UO, which means that COKE instances can be semantically associated to the concepts of the UO by following the principle of superimposed information, that is, data or metadata "placed over" existing information sources (Maier et al., 1999). For instance, let us consider a human resource skilled in Java. An annotation relationship can specify that this human resource has a semantic annotation to the *Programming Languages/Object Oriented Languages/Java* concept contained in the UO. This way, *K-link+* can exploit this annotation to search human resources skilled or interested in Java. In general, queries can be performed using specific tools able to retrieve COKE instances, belonging to one or more of the four above mentioned classes, which are related to a specific concept.

The second layer of the ontology framework is composed of a set of UO extensions called *Workspace Ontologies*, and one or more *Personal Ontologies* for each IKW.

A PO (Personal Ontology) is the specialization of one or more UO concepts and is used to deepen a particular aspect of the knowledge domain in which an IKW is interested.

Definition 2 (PO)

A PO is a 4-tuple of the form *PO=<UO,UOC', UOP,UOR'>* where:

- UO is the UO as described in Definition 1.
- UOC' is the set of new concepts added by the peer.
- UOP is a set of attributes for concepts in UOC' added by the peer.
- UOR' is the set of relationships among concepts added by the peer.

A PO operates at individual level as semantic support for personal information management of IKWs that use the Organizational Ontology and need to extend it for their specific goals in the organizational activities. The PO can be used to annotate KOs with respect to PO concepts that describe their topics. The creation of an annotation is supposed to reflect the content of a KO and establish the foundation for its retrieval when requested by an IKW. This way unstructured information can be semantically enriched and its retrieving can be performed by specifying ontology concepts instead of keywords. However, it is expected that the annotation process can be automated to decrease the burden of the IKW. For this purpose, a method based on keyword extraction, as in (Popov et al., 2003) can be adopted. For instance, keywords extracted from the text of the KO can be viewed as descriptors of the content of the KO. Therefore, annotations between such descriptors and ontology concepts can be created.

In order to enhance social aspects of OKM, the framework allows users to create WOs (Workspace Ontologies). A WO specializes in one or more UO concepts and is used to support workspaces. IKWs can annotate COKEs instances relevant to the workspace, with respect to WO concepts, and retrieve them by specifying ontology concepts instead of keywords.

Definition 3 (WO)

A WO is a 2-tuple of the form *WO=<WB,WT>* where:

- WB has the same structure of the PO defined in Definition 2.
- WT is a set of basic concepts concerning workspace topics on which there is agreement among workspace members.

The relationships existing between the UO and the Workspace and Personal Ontologies are called *specializations* since such ontologies specialize in one or more UO concepts. For example, in Figure 3 the WO of *Workspace 1*, focused on procedural languages, specializes in the corresponding UO concept (*procedural languages*) by adding information describing further types of procedural languages.

HANDLING ONTOLOGY DRIFT IN *K-LINK+*

Although the structure of the proposed ontology framework has been designed beforehand, static or fully predefined ontologies in a dynamic distributed environment cannot satisfy the ever-changing requirements of an organization.

In *K-link+*, IKWs are allowed to propose extensions or modifications of an ontology according to their needs. Upon acceptance of such proposals, ontologies evolve in a collaborative and emerging way.

Ontology drift, that is, the evolution of an ontology, is managed in *K-link+* through a distributed voting mechanism (Ge et al., 2003). In *K-link+*, for each voting procedure, a *voting chair* is in charge of permitting or denying the voting process, collecting results and propagating them to participants. Before initiating a new voting procedure, an IKW obtains the authorization from the chair if there are no other voting procedures in progress.

An update proposal related to the UO is accepted if, within a specified amount of time, the majority of all the *K-link+* members, regardless of their workspace memberships, agree with the proposal. Similarly, to be approved, an update proposal related to a WO needs to be accepted by the majority of the workspace members.

A voting process within *K-link+* is divided into three phases:

1. *Set up phase*: in this phase the voting initiator contacts the voting chair which, if there are no pending voting procedures, forwards a “request for vote” message to all the involved IKWs. This message contains information about the update proposal along with the voting deadline.
2. *Voting phase*: IKWs vote to confirm or reject the ontology update proposed, and send their vote to the chair.
3. *Scrutiny phase*: when the deadline expires, the chair counts the votes and sends the result to the involved IKWs. If the update proposal has been accepted, the UO or WO is appropriately modified.

When IKWs, which were previously offline, reconnect while a voting procedure is in progress, they are made aware of the voting proposal by the voting chair and can join the voting process. If they reconnect when the voting procedure has terminated, they receive from the chair a notification containing information about the updated version of the ontology.

K-LINK+: A MOTIVATING EXAMPLE

As mentioned before, the Virtual Office environment provided by *K-link+* is based on the concept of *workspace*. A workspace can be viewed as a common *work area* accessible at any time from everywhere and composed by COKE instances (e.g., human resources, knowledge objects) that are annotated to WO concepts. A workspace provides a set of tools for creating and storing knowledge objects and for using services useful for the workspace members. Each KLN can be a member of a workspace under the following profiles:

- A *Workspace Manager* is a workspace administrator endowed with full capabilities for adding tools, inviting other KLNs or modifying the WO settings.
- A *Workspace Participant* is a workspace member with reduced but extensible (under Manager control) capabilities.

A workspace set-up procedure can be performed whenever a new organizational task must be carried out. For instance, let us consider a software company that must develop a graphical interface, written in Java, able to support the design of business workflows in a distributed environment. To deal with this task and fulfill the commitment requirements, the project leader can set up a proper workspace. The workspace must be associated to one or more concepts of the UO, and the WO represents a specialization of these concepts. For example, *Workspace n* of Figure 3 specializes in the *Java* concept by adding child concepts related to some available Java graphical libraries. A workspace creation is automatically followed by the creation of a group ontology instance in the COKE human resources ontology. This instance is semantically annotated to the *Java* UO concept.

Hereafter, by using the *K-link+* functionalities, the project leader:

- Chooses the existing literature and document templates concerning the project topic. In this case, it is valuable to populate the workspace document base with knowledge objects related to the concepts defined in the WO. Interesting knowledge objects can be discovered by the *K-link+ File Sharing Tool* which is able to handle keyword and semantic based searches.
- Defines an appropriate team of IKWs whose skills can be exploited to accomplish the commitments within the deadline. For the above mentioned example, the *K-link+* system should be able to find, through the ontology support, at least the following IKW profiles: experts in Java programming, experts in graphical interface development, and experts in workflow systems. People having the selected profiles become members of the workspace after receiving invitation messages sent by the workspace manager through the *K-link+ workspace and invitation service*.
- Designs an activity plan and assigns single activities to the IKWs by sending proper messages.
- Chooses a set of services for supporting the project. For example, the services ontology should contain a reference to a CVS (Concurrent Versions System) dedicated to the project. Services can be directly embedded in the *K-link+* workspace perspective that provides IKWs with a common work environment which gathers the needed applications.

Finally, the workspace manager or its delegates choose a set of tools through which the workspace members can perform the actual work. Such tools can be selected among a basic set of tools with which *K-link+* is endowed (e.g., file sharing, shared calendar, shared browser, sketch pad, etc.). Through these tools, IKWs can set project deadlines, project meetings, exchange documents, and so on. Furthermore, it is also possible to develop specific tools that can be plugged into the system as libraries at run-time. When a new tool is added to a workspace, the workspace members will automatically be informed and a local instance of the tool will be created. Afterwards, each tool update (e.g., adding a new project meeting to the shared calendar tool) will be forwarded to the workspace members that can store new information locally.

Each workspace is described by a *workspace profile* that includes the UO concept used to specialize in the WO, information about the participant IKWs and services and tools of the workspace. After creating the WO, its concepts can be used for semantically annotating new COKE instances created within the workspace. For example, a tutorial on the use of the SWT Java library can be annotated to the *SWT* WO concept.

K-link+ can be profitably used as an effective cooperative platform in organizations because:

1. It enables cooperation among IKWs by offering them an integrated and shared work environment in which they can concurrently work on the same shared objects and handle different sources of knowledge within the same environment. This way, the system avoids users to run several applications that cannot exchange data.
2. It allows providing contents (described by COKEs) with an immediate semantic meaning, by *annotations*. The principle followed by annotations is aimed at providing information with a sort of superimposed meaning. This aspect is particularly important since today information is for the most part in unstructured form and its retrieval mainly relies on statistical approaches (e.g., Information Retrieval approaches) that are not able to “interpret” its semantic meaning.
3. It fosters the retrieval of contents on a semantic basis by enabling concept based search. This is accomplished by coupling a shared

representation of organizational source of knowledge (e.g., COKE ontologies) with ontologies.

4. It enables the reusability of organizational knowledge. For instance, in the described example, if the company will deal in the future with a similar commitment, such as the development of a new Java application, a search can be issued for a workspace that contains in its profile concepts like *Java*, *SWT, Swing* and so forth. Thereafter the project leader can select the documents, templates and human resource profiles that can profitably be reused for the new project.

The abovementioned aspects make *K-link+* a system very useful for small-medium enterprises composed of different divisions that need to cooperate, share and exchange knowledge.

CONCLUDING REMARKS

This chapter discusses how ontologies can be combined with the P2P computing paradigm to support knowledge management within organizations.

In particular, ontologies have been adopted to define an ontological framework that allows peers to conceptualize knowledge domains in which they are interested, and to semantically annotate COKE instances w.r.t. ontology concepts. The framework has been designed on two levels. Each organization can define its own UO covering the domains of interest for the organization. Moreover, the COKE ontologies aim at representing a "consensus" in defining a structure for several sources of unstructured knowledge (e.g., knowledge objects). This unified view helps managing and sharing both structured and unstructured knowledge.

The second layer represents the part of the framework which fosters the creation of new organizational knowledge since it allows users to specialize in aspects generally covered by the UO. This can be done collaboratively through WOs. Workspace Ontologies allow participants of the same group to adopt the same terminology for describing knowledge of interest. This way, aspects of a particular knowledge domain (covered by a workspace) emerge and are defined on a collaborative basis. To enable more flexibility, the framework also allows individuals to define their own ontologies. Through *Personal Ontologies*, an individual can manage its personal knowledge according to their view on a particular knowledge domain.

A very prominent feature of the defined framework is the *Annotations* mechanism. Annotations allow users to associate COKE instances to ontology concepts. They capture and harness the semantic meaning of a piece of knowledge that can be a Knowledge Object, a Service, and so forth. This feature is very striking since today the main issue related to the retrieval of information comes from the fact that information is for the most part unstructured. The framework allows users to capture and/or update implicit knowledge connected with explicit knowledge contained in unstructured content of COKE instances.

On the other side, the P2P computing paradigm has been shown to be a valuable support for today's IKWs that often work away from their usual workplace. In particular, this chapter describes how the P2P can be exploited to implement a distributed VO whose aim is to support collaborative work within *workspaces*. Within workspaces peers can autonomously manage and share knowledge without relying on any central entity thanks to a hybrid content consistency protocol that guarantees consistency of shared contents and synchronization among peers.

The combination of the two abovementioned technologies (ontologies and P2P) allows users to implement the distributed knowledge management model that naturally fits the process of creating new knowledge by allowing IKWs, on the one side to manage their knowledge without relying on any imposed schema and on the other side to exchange and retrieve knowledge on a semantic basis by exploiting ontologies.

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Chapter 5.12

Organizational Culture for Knowledge Management Systems:

A Study of Corporate Users

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ABSTRACT

Knowledge is increasingly being viewed as a critical component for organizations. It is largely people-based and the characteristics of groups of individuals, in the form of organizational cultures, may play a key role in the factors that lead to either the acceptance or rejection of knowledge management systems (KMS). The primary objective of this research is to explore how dimensions of organizational culture influence factors that lead to the acceptance of KMS. While researchers have agreed that culture plays an important role in KMS, the literature has only recently begun to examine organizational culture within this context. We examined the effects of three dimensions of organizational culture through a research model that was tested and analyzed utilizing a field survey of corporate knowledge management users. Our results indicated that both process-oriented and open communication system organizational cultures significantly influenced the factors that led to the acceptance of KMS.

INTRODUCTION

Organizational culture can either facilitate or be a major barrier to knowledge management system (KMS) acceptance (De Long & Fahey, 2000;

Grover & Davenport, 2001; Ruppel & Harrington, 2001). On February 1, 2003, the space shuttle Columbia was lost during its return to Earth. The Columbia Accident Investigation Board (CAIB) concluded that NASA's organizational culture as well as the piece of Columbia's foam insulation that fell off during launch shared equal blame for the tragedy (CAIB, 2003). According to the CAIB, the prevailing culture at NASA was of a mindset that accidents were inevitable, which led to the unnecessary acceptance of known and preventable risks. Although a KMS to assist with hazard identification and risk assessment was available at NASA (the Lessons Learned Information System), personnel only used that system on an *ad hoc* basis which limited its usefulness (CAIB, 2003). NASA's organizational culture consequently interfered with open communication, impeded the sharing of lessons learned, caused duplication and unnecessary expenditure of resources, and prompted resistance to external advice (CAIB, 2003).

The Columbia incident is an illustration of knowledge management system use failure. The acceptance of KMS, however, is a pressing issue in organizations (Kwan & Balasubramanian, 2003; Money & Turner, 2005). As knowledge is increasingly viewed as a critical activity for decision making (Markus, Majchrzak, & Gasser, 2002; Miranda & Saunders, 2003), organizations are becoming more receptive to using technologies to facilitate knowledge management (Schultze & Leidner, 2002). KMS are often employed to enhance organizational performance (De Long & Fahey, 2000) and are a reason why the KMS market has become one of the fastest growing areas in software development. While it is widely recognized that information technologies have the potential to facilitate knowledge management, the management of knowledge-based systems is an intricate process that involves a complex interplay of technical and social factors.

Recent studies have begun to investigate a variety of social factors and phenomena related to knowledge creation, sharing, and transfer. For example, Wasko and Faraj (2005) studied how individual motivations and social capital influence knowledge sharing in KMS. Ko, Kirsch, and King (2005) found that individual communication capabilities, motivations, and interpersonal relationships affected the transfer of complex enterprise software knowledge. Bock, Zmud, Kim, and Lee (2005) found that subjective norms and organizational climate had a significant impact on people's intention to share knowledge. Kankanhalli, Tan, and Wei (2005) similarly discovered that several social factors, including prosharing norms, influenced knowledge contribution. These studies provided strong empirical evidence of the social influences in knowledge management. Some of the factors that have been examined are conceptually similar to organizational culture dimensions that have been identified in the management literature. A more systematic study of organizational culture on KMS acceptance would provide theoretical congruence to this recent literature.

The primary objective of this research is to explore how dimensions of organizational culture influence the factors that lead to the acceptance of KMS (e.g., perceived usefulness, perceived ease-of-use, perceived behavioral control, subjective norms). In our investigation, organizational culture is postulated as a distal determinant for an employee's intention to use a KMS. In the next section, we present a literature review to support our hypotheses, followed by a discussion of our research methodology. We then empirically test our hypotheses with a field survey of corporate KMS users, discuss the results, and finish with some concluding remarks.

LITERATURE REVIEW

Knowledge Management Systems

Knowledge is information that exists in the mind of individuals (Alavi & Leidner, 2001; Berman-

Brown & Woodland, 1999; Grover & Davenport, 2001; Ruppel & Harrington, 2001). Given the nature of knowledge, which is created and applied in the minds of human beings, it is extremely difficult to manage and control (Alvesson & Karreman, 2001; Grover & Davenport, 2001). Indeed, an organization's efforts to facilitate knowledge sharing can be a "central competitive dimension" for a firm (Kogut & Zander, 1992, p. 384). Consequently, KMS are an organization's efforts to facilitate knowledge sharing through the use of information technology (IT) in order to obtain organizational benefits.

There are a variety of KMS that exist, such as knowledge repositories, corporate directories, and knowledge networks (Alavi & Leidner, 2001; Grover & Davenport, 2001). Knowledge repositories, the type of IT examined in this study, are the most common KMS in Western organizations (Grover & Davenport, 2001). These systems are typically used to capture knowledge from employees for subsequent and extensive use by others within the organization to assist in decision-making. Examples of knowledge that are contained in such systems may range from best practices and lessons learned to organizational strategies and recruitment efforts.

There have been a number of KMS reviews and meta-analyses done in the information systems (IS) domain. Alavi & Leidner (2001) provided a review of the knowledge management literature in different academic disciplines that identified some key areas of research, which included the concept of knowledge in organizations, knowledge management processes (i.e., knowledge creation, storage/retrieval, and transfer), and KMS. They indicated that while the design of a KMS is important, the extent of use by its intended users would also have a significant impact on KMS acceptance. Schultze & Leidner (2002) also examined knowledge management research in the IS area. They identified and classified knowledge management research into four theoretical streams, which are normative, interpretive, critical, and dialogic discourses. Subsequent case-based research (Alavi, Kayworth, & Leidner, 2005-2006; Leidner, Alavi, & Kayworth, 2006) has found that differences in organizational cultural values leads to different uses of KMS. These research efforts demonstrated the importance and saliency of KMS in the IS context.

Organizational Culture

NASA's organizational culture had as much to do with this accident as foam did. Columbia Accident Investigation Report (CAIB, 2003)

As suggested in the quotation above, organizational culture is important and inextricably linked to KMS within organizations (Alavi & Leidner, 2001; Alvesson & Karreman, 2001; Cronin, 2001; De Long & Fahey, 2000; Grover & Davenport, 2001; McDermott, 1999; Tanriverdi, 2005). Organizational culture has been extensively studied in management research, and therefore, it is surprising that the relationship between KMS and an organization's culture has not been more thoroughly explored in the IS literature. Culture has historically been a factor that has received insufficient attention in the IS acceptance literature (Cooper, 1994; Robey, Wishart, & Rodriguez-Diaz, 1995a; Ruppel & Harrington, 2001), but is increasingly being viewed as a key ingredient for an organization's ability to embrace KMS (Cronin, 2001).

Organizational culture is widely believed to be a major barrier to KMS acceptance (De Long & Fahey, 2000; Grover & Davenport, 2001; Ruppel & Harrington, 2001). Without a match between an organization's culture and the cultural assumptions embedded within an IT innovation, costly implementation failures are likely to happen (Ruppel & Harrington, 2001). For example, in organizational cultures that are not suited to share and utilize knowledge (e.g., an organization where miscommunication is common and mistrust is prevalent), acceptance of a KMS can be problematic (Ruppel & Harrington, 2001). Without acknowledging cultural mismatches or modifying the organizational culture to better fit the IT, the impact on the organization could be disastrous, as evidenced in the Colombia tragedy.

Hofstede (1991) views culture as being collective, but often intangible and is what distinguishes one group, organization, or nation from another. There are two main elements of culture: the internal values of culture (invisible) and external elements of culture (visible), which are known as practices (Hofstede, 1991). Practices are particularly important to investigate because they are the most direct means for changing behaviors needed to support knowledge creation, sharing, and use (De Long & Fahey, 2000). Hofstede, Neuijen, Ohayv, and Sanders (1990) measured the perceived practices in employees' work situations in 20 organizational units and discovered six dimensions underlying organizational culture. Contrary to his dimensions of national culture (Hofstede, 1991), these organizational dimensions deal with key sociological issues. In favor of depicting a more manageable research model, we examine three dimensions of organizational culture, process-oriented vs. results-oriented, employee-oriented vs. job-oriented, and open communication systems vs. closed communication systems.

Technology Acceptance

Previous findings from the technology acceptance literature, which has been widely popular in the IS field for the past few years, suggest that for an advantage to be attained, the technology in question must be accepted and used (Venkatesh, Morris, Davis, & Davis, 2003). Organizations typically employ KMS to leverage their collective knowledge for competitive advantage (Alavi & Leidner, 2001). There has been relatively little research, however, that explicitly examines the influence that dimensions of organizational culture have on technology acceptance.

In the technology acceptance literature, a variety of psychological constructs have been examined with the goal of understanding how and why individuals adopt new information technologies. This has generated several competing models of technology acceptance, each with different sets of determinants for acceptance (Venkatesh et al., 2003). The following is a concise review of attributes that have been consistently shown to account for a significant amount of variance in the prediction of intentions and behaviors (Rogers, 2003; Tornatzky & Klein, 1982; Venkatesh et al., 2003).

Attributes of the Acceptance and Use of Technology

Based upon conceptual and empirical similarities across eight prominent models in the user acceptance literature, Venkatesh et al. (2003) developed a unified theory of individual acceptance of technology (the unified theory of acceptance and use of technology or UTAUT). The UTAUT theorizes four constructs having a significant role as direct determinants of acceptance and usage behavior: performance expectancy, effort expectancy, social influence, and facilitating conditions. Although we did not test the full UTAUT because the model was not published at the time of our data collection, each of the constructs that we did examine was conceptually similar. The four constructs that we utilized and their relationships to the constructs of the UTAUT model are discussed next.

The first construct examined in our model is perceived usefulness. Originally proposed in Davis' (1989) technology acceptance model (TAM), this is contained within the UTAUT construct of performance expectancy and is defined as "the degree to which an individual believes that using the system will help him or her to attain gains in job performance" (Venkatesh et al., 2003, p. 447). The second construct examined in our model is perceived ease of use. This construct, originally in Davis' (1989) TAM, is incorporated into UTAUT as part of effort expectancy which is defined as "the degree of ease associated with the use of the system" (Venkatesh et al., 2003, p. 450). Perceived ease of use has a significant direct effect on perceived usefulness (Davis, 1989).

The third construct examined, perceived behavioral control, indicates that a person's motivation is influenced by how difficult the behaviors are perceived to be, as well as the perception of how successfully the individual can, or cannot, perform the activity. Perceived behavioral control, originally in the theory of planned behavior (TPB) (Ajzen, 1985; Ajzen & Madden, 1986), is part of UTAUT's facilitating conditions construct which is defined as "the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system" (Venkatesh et al., 2003, p. 453). Subjective norms, the fourth construct examined in this model, deals with the influence of important others, such as coworkers, supervisors, and top management. Subjective norms, originally in Fishbein & Ajzen's (1975) theory of reasoned action (TRA), are incorporated into UTAUT's construct of social influence, which is defined as "the degree to which an individual perceives that important others believe he or she should use the system" (Venkatesh et al., 2003, p. 451).

RESEARCH HYPOTHESES

Organizational Culture's Impact on Perceived Usefulness

An organization's attitude toward change, often elicited and reflected by the introduction of technology innovations, impacts the adoption of these technologies (Damanpour, 1991). Some organizations are relatively *process-oriented* and may have conservative attitudes toward innovation and its associated risk, exerting minimal effort while preferring the use of existing or well-known methods (Hofstede et al., 1990). Such organizations innovate only when they are seriously challenged by their competition or by shifting consumer preferences (Miller & Friesen, 1982). In contrast, *results-oriented* organizations are risk-oriented and foster an environment that encourages and actively supports the use of innovative techniques for the survival and growth of the organization (Hofstede et al., 1990). As an organization's policies and practices are perceived by employees to encourage, cultivate, and reward their use of a technology (e.g., KMS) the stronger that culture will be for the implementation of that technology (Klein & Sorra, 1996). Organizations that promote innovativeness and a willingness to try new things among their employees have been found to have better success with a KMS implementation (Ruppel & Harrington, 2001). Such organizations and individuals usually try to obtain a competitive advantage by routinely making dramatic innovative changes and taking the inherent risks associated with those innovations. Consequently, employees in a results-oriented organization are likely to believe that using KMS would enhance their job performance. On the other hand, knowledge sharing is risky from an individual employees' perspective because their value depends largely on the knowledge they possess (Stenmark, 2000). A work environment that is more process-oriented, consequently, would view KMS as a threat and to be less useful for making decisions. This leads to the following hypothesis:

H1: *Employees who perceive their work environment to be more* ***results-oriented*** *will have higher levels of perceived usefulness than employees who perceive their work environment to be more* ***process-oriented****.*

Organizational Culture's Impact on Perceived Ease of Use

At one end of a continuum, job roles in an organizational environment are routine and similar from one day to the next (*process-oriented*) (Hofstede et al., 1990). Employees in this environment are resistant to change, new technology, and risk and will only exert minimal effort. At the opposite end of this continuum, job roles bring forth new challenges daily (*results-oriented*) (Hofstede et al., 1990). Employees in this results-oriented environment embrace risk, are comfortable in unknown situations, and are likely to more quickly exploit any opportunity that a technology may offer. These individuals are likely to have more experience using innovative or relatively complex technologies, and as a result, have a relatively high belief that using other complex technologies would not be difficult. In fact, complexity is the degree to which an innovation is perceived as being difficult to use and has the opposite meaning of ease of use (Davis, Bagozzi, & Warshaw, 1989; Moore & Benbasat, 1991; Thompson, Higgins, & Howell, 1991). Therefore, employees who work in an environment that is characterized as a results-oriented organization where using new or complex technologies in their daily tasks is common are more likely to believe that KMS are easy to use. Hence:

H2: *Employees who perceive their work environment to be more* ***results-oriented*** *will have higher levels of perceived ease of use than employees who perceive their work environment to be more* ***process-oriented****.*

Organizational Culture's Impact on Perceived Behavioral Control

When employees are asked to put what they know into a KMS, they tend to feel as if they have lost ownership of the knowledge that they alone had previously controlled (De Long & Fahey, 2000). Individuals tend to resist such systems because when giving up control of their knowledge they may perceive their worth as an employee to be marginal, which is only propagated by the understandable fear that their job position has become interchangeable. In such circumstances an organization's culture is critical for the acceptance of KMS. As stated earlier, *results-oriented* organizations are risk-oriented, fostering an environment of daily challenges where employees feel comfortable in unknown situations (Hofstede et al., 1990). Although employees in results-oriented organizations may encounter more risky events, their capacity to tolerate risks is much stronger. Employees in this type of risk inclined environment would likely have strong beliefs in their ability to control outcomes (Delfabbro & Winefield, 2000) and hence, will be less worried about the potential negative issues associated with sharing knowledge. The more control an employee thinks they possess, the greater should be that person's perceived control over their behavior (Ajzen & Madden, 1986). Therefore, employees that work in an environment that is characterized as a results-oriented organization would believe that they can control the technology they use, which would make them more likely to use KMS. Hence:

H3: *Employees who perceive their work environment to be more* ***results-oriented*** *will have higher levels of perceived behavioral control than employees who perceive their work environment to be more* ***process-oriented****.*

Environments that typically do not favor KMS emphasize unilateral control, have high stakes for winning and losing, and attempt to minimize negative emotions (Ruppel & Harrington, 2001). Competition thrives in such environments and mistrust in others is high as sharing information or helping fellow employees is frowned upon because it creates a disadvantage for the employee being generous. A *job-oriented* environment exemplifies this scenario as it is an atmosphere where employees feel pressured to complete work (Hofstede et al., 1990).

On the other hand, an *employee-oriented* environment is one where individual personal problems are addressed and the organization has a genuine concern for the employee's welfare (Hofstede et al., 1990). This is critical particularly in the acceptance of KMS where employees must be able divulge, support, and trust the knowledge provided by other employees via the technology. The human relations management and job enrichment literatures (Hackman & Oldham, 1980) suggest that intrinsic rewards (e.g., employee of the month recognition) are at times more important than extrinsic rewards (e.g., salary raises, promotion). Resource-based theory also acknowledges the vital role that human assets/resources play in the contemporary hypercompetitive external environments where progressive organizations strive to keep their employees satisfied and thus retain top talent. Indeed, Ruppel & Harrington (2001) found that early adoption of KMS was most likely to occur in organizations where the culture was characterized as having a high concern for its employees and a setting of mutual confidence and trust. Consequently, employees who work in an environment that is characterized as an employee-oriented organization would be more likely to believe that they have access to greater opportunities and resources to perform a behavior than in a pressure-filled, job-oriented environment. Hence:

H4: *Employees who perceive their work environment to be more* ***employee-oriented*** *will have higher levels of perceived behavioral control than employees who perceive their work environment to be more* ***job-oriented****.*

Organizational Culture's Impact on Subjective Norms

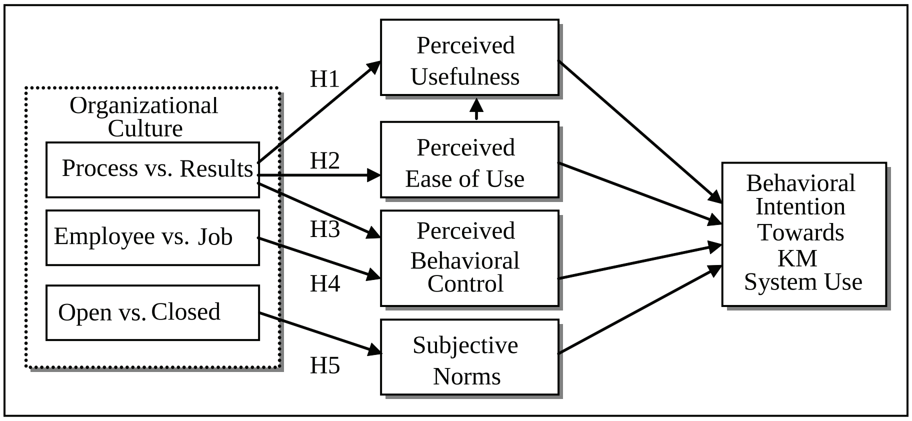
An organizational culture that discourages open communication engenders a context that undermines knowledge sharing (De Long & Fahey, 2000). This is similar to a *closed communication system*, an environment that is secretive and reserved and also one in which it takes a relatively long time for employees to "fit in" (Hofstede et al., 1990). For KMS to be widely accepted within an organization, it should have a culture that supports knowledge sharing from a wide spectrum of coworkers, supervisors, and managers. Without this support, employees may not be willing to share and disseminate their knowledge and experiences, thus making the KMS essentially useless. Indeed, instilling a culture of sharing and maintaining information is critical for KMS acceptance.

An *open communication system*, alternatively, is an environment that is characterized as being open to newcomers and outsiders where it takes a relatively short time for employees to feel comfortable in the organization (Hofstede et al., 1990). Employees in this type of environment are likely to more willingly share their experiences and to support one another when attempting to make decisions on complex and unknown topic areas (e.g., relevance and mastery of new technologies). It is reasonable to expect that users of KMS would be more willing and prepared to assume any challenges posed by the new technology environment in view of the support that they can expect from their colleagues. Employees who work in an environment characterized by an open communication system, therefore, are more likely to be influenced by the opinions of important others and be more likely to use KMS. Hence:

H5: *Employees who perceive their work environment to be more* ***open*** *will have higher levels of subjective norms than employees who perceive their work environment to be more* ***closed****.*

Consistent with the TAM, the TRA, the TPB, and the UTAUT, perceived usefulness, perceived ease of use, perceived behavioral control, and subjective norms are expected to influence behavioral intentions. Following the technology acceptance model, perceived ease of use is expected to influence perceived usefulness. These relationships as well as our research hypotheses are depicted in the proposed theoretical model (Figure 1).

Figure 1. Theoretical model



METHODOLOGY

This research utilized a questionnaire borrowing scales from prior literature. We adopted measures of organizational culture from Hofstede et al. (1990), perceived usefulness, perceived ease of use, and behavioral intention to use from Davis (1989), and perceived behavioral control from Ajzen & Madden (1986). The subjective norms construct contains two dimensions: normative beliefs (similar to the construct developed by Fishbein & Ajzen (1975) and motivation to comply from Bandura (1977). The subjective norms construct was formed by multiplying pairs of items (normative beliefs * motivation to comply). The order of the statements in the questionnaire was scrambled randomly to control for order effects. The dependent variable, behavioral intention was selected as it has been validated in prior literature as a reliable proxy for actual use in behavioral research (Magnus & Niclas, 2003). The questionnaire employed a 7-point Likert-style scale, anchored from 1 (strongly disagree) to 7 (strongly agree).

Data Collection

The instrument was pilot tested using 24 MBA students who were familiar with KMS. The reliability and validity of all eight research constructs were found to be acceptable. A field survey was then administered via two procedures within a 1 week period. We first surveyed KMS users from a leading user group in a major Midwestern U.S. city. The KMS utilized by the users were repository-based and included applications for sharing corporate knowledge, best practices, and lessons learned, among others. We distributed paper-based surveys after briefly explaining our research agenda. There were 64 attendees that were solicited to participate with 41 completing the paper-based survey, yielding a response rate of 64%.

The initial participants in the study were subsequently asked to recruit additional KMS users within their firms via an online Web-based survey, which had the same questions in identical sequence as the paper-based version. The participants represented seven companies from a variety of industries, including manufacturing, finance, consulting, and education. The Web-based survey provided an additional 144 completed surveys from 7 companies, yielding an approximate response rate of 29% (144/500). This resulted in a total sample size of 185 (41 paper and 144 Web). With the exception of a single item, out of 31 total items, there were no significant differences between the paper-based and Web-based surveys after performing a series of t-tests at both the construct and item levels. The single item was not removed from the analysis because dropping it lowered the reliability of its construct. The mean age of the respondents was 38, and 60% of the participants were female and 40% were male. On average, the respondents had 15 years of work experience, 13 years of computing experience, and 2 years of KMS experience.

Consistent with the technology acceptance studies, gender (Venkatesh & Morris, 2000), age (Gist, Rosen, & Schwoerer, 1988; Igbaria, Parasuraman, & Baroudi, 1996), and experience (Venkatesh et al., 2003) were tested as control variables to see if they had a moderating effect on behavioral intention to use. Following Venkatesh et al. (2003), a hierarchical regression analysis was used to test the direct and moderating effects because sample size considerations prevented us from running the interaction terms in LISREL (our primary analysis tool). The moderating effects were modeled as interaction terms between the moderators and perceived usefulness (PU), perceived ease of use (PEOU), perceived behavioral control (PBC), and subjective norms (SN). With direct effects, PU, SN, and PBC were significant. With both direct and interaction effects, PU, PU x gender, PU x age, PU x gender x age, and PBC x experience were significant.

Psychometric Measures

The data were analyzed using the structural equation modeling (SEM) technique, which is suitable because our research model contains latent variables. The model was tested using the two-step approach where the measurement model fit was first assessed followed by the structural model testing in which the path coefficients were estimated (Bollen, 1989). The reliability and validity of the data were tested before model assessment and the results demonstrated acceptable psychometric properties. The reliability coefficients of all eight constructs, with two exceptions, were above .70, which is an acceptable value as stated by Nunnally (1967). The employee-oriented vs. job-oriented and open communication system vs. closed communication system constructs were at .69. They were retained because they were close to the cutoff level1.

Construct validity was assessed by comparing the correlation coefficients within and between constructs. The average within construct correlation was .40, which is higher than the between constructs correlation of .19. The within construct correlations were higher than between constructs correlations, indicating construct validity. In addition, we examined convergent and divergent validity and tested the data for normality. Even though the maximum likelihood estimator performs relatively well under various conditions (Hoyle & Panter, 1995), it assumes the normality of the data. The mean skewness and kurtosis values were -.47 and .33 respectively, indicating that the variables approximate a normal distribution and were acceptable for LISREL analysis (Bollen, 1989; Byrne, 1998; West, Finch, & Curran, 1995).

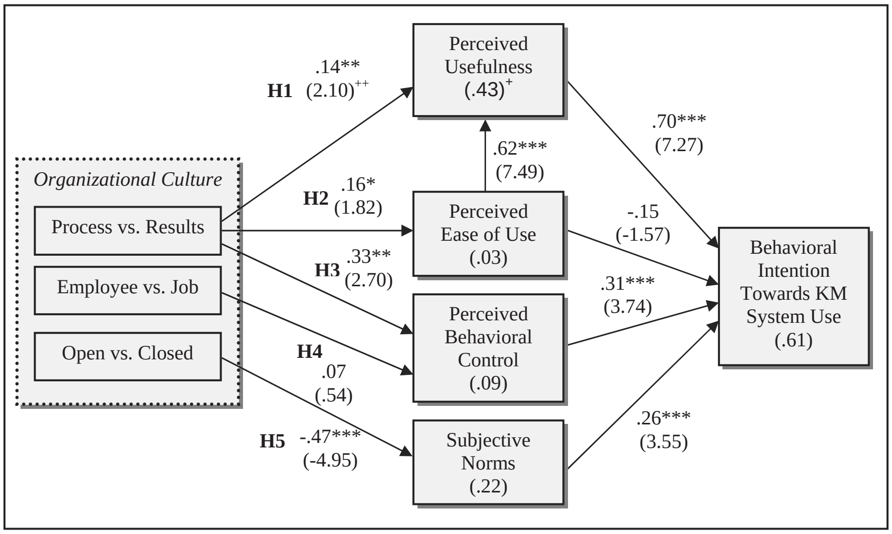
Chi-square goodness-of-fit statistic, comparative fit index, and the root mean square error of approximation were also assessed. Chi-square (χ^2) goodness-of-fit statistic assesses the degree of departure of the sample covariance matrix from the fitted covariance matrix (Hu & Bentler, 1999) . A nonsignificant and small chi-square is desirable. Because the chi-square statistic is a direct product of sample size, when the sample size is large and models contain a large number of indicators, the statistic can often be significant (Byrne, 1998). The comparative fit index (CFI) and root mean square error of approximation (RMSEA), however, are not sensitive to sample size. The comparative fit index is an incremental fit index that measures the improvement in fit by comparing a target model with a restricted, nested base model (Hu & Bentler, 1999). In addition, it is suggested as the best approximation of the population value for a single model (Medsker, Williams, & Holahan, 1994). The general accepted value is above .90. The root mean square error of approximation, a type of absolute fit index, assesses how well sample data are reproduced from an *a priori* model (Hu & Bentler, 1999). The general accepted cutoff is .10.

Using LISREL 8.54, we first tested the measurement model. Its fit statistics were χ^2 (406 df, N = 185) = 685.63, p < .001, CFI = .95, and RMSEA = .061. Overall, the statistics demonstrated good fit and the measures were acceptable for structural model assessment. Good model statistics are indicative of unidimensionality and convergent validity (Gefen, Karahanna, & Straub, 2003). Divergent validity was assessed by comparing the original measurement model with an alterative model that includes all items as one construct (Segars, 1997). The χ^2 was significantly smaller in the original measurement model ($\chi^2_{\text{Alternative}}$= 3234.07, χ^2 difference = 2548.44 with *df* change = 28, *p* = .00) establishing discriminant validity (Segars, 1997).

We assessed 10 paths in the structural model testing. The model fit statistics were χ^2 (421 df, N = 185) = 771.33, p < .001, CFI = .93, and RMSEA = .067. Overall, the statistics demonstrated a good fit of the model to the data. Figure 2 shows the estimated standardized path coefficients and their t-values in the structural model and the variance explained for each of the constructs. The asterisks on the path indicate the significance level and the variance explained are presented below the asterisks in parentheses. All links except those between an employee-oriented vs. job-oriented organizational culture and perceived behavioral control and between perceived ease of use and behavioral intention were significant. The model had adequate predictive power for several constructs, including perceived usefulness (R^2_{PU} = .43), subjective norms (R^2_{SN} = .22), and behavioral intention (R^2_{BI} = .61). However, the predictive power was somewhat less for perceived ease of use (R^2_{PEOU} = .03) and perceived behavioral control (R^2_{PBC} = .09). In regard to the variance extracted in behavioral intention, our model exhibited better predictive power (.61) than that shown in the hierarchical regression with direct effects (.48), as well as direct effects and interaction effects (e.g., age, gender, experience) combined (.58).

The theoretical model was modified to add direct paths of the cultural dimensions influencing behavioral intention. None of the direct paths

Figure 2. Structural path coefficients



* P < .10, ** p < .05, *** p < .001

from the cultural dimensions to behavioral intention were significant. The change between the theoretical model and the modified model in χ^2 was 5.49 with 3 degrees of freedom ($p = .1392$). This suggested that the effects of the cultural dimensions on behavioral intention were mediated and, consequently, the theoretical model was utilized.

DISCUSSION

There was support for four out of the five research hypotheses. These results suggest that the organizational culture dimensions play a key role in the factors that lead to the acceptance of KMS. Our research also examined several prominent technology acceptance relationships and had similar findings to other research that has investigated the applicability of such relationships with the user acceptance of a KMS (Money & Turner, 2005). The relationships between perceived usefulness and behavioral intention to use a KMS, subjective norms, and behavioral intention to use a KMS, perceived behavioral control, and behavioral intention to use a KMS, and perceived ease of use and perceived usefulness were all significant. The relationship between perceived ease of use and behavioral intention to use a KMS, however, was not significant although there was still a significant path through the model incorporating perceived usefulness. These findings are consistent with other studies of extended technology acceptance models (e.g., Adams, Nelson, & Todd, 1992; Hu, Chau, Sheng, & Tam, 1999).

In general, our model explained a reasonable amount of variation of the key variables. The variation in process-oriented vs. results-oriented organizational cultures (as well as the variation in perceptions of ease of use) explained 43% of the variation in perceptions of usefulness. Furthermore, the variability in process-oriented vs. results-oriented cultures explained 3% of the variance of perceived ease of use. Similarly, open communication systems vs. closed communication systems organizational cultures explained 22% of the variance in subjective norms and 9% of the variance in perceived behavioral control. The model accounted for 61% of the variability in behavioral intention to use. Most of the R^2 values are acceptable for technology acceptance research. The large amount of variance in behavioral intention to use is an indication that organizational culture, subjective norms, perceived behavior control, and technology acceptance together are strong factors to study with respect to KMS acceptance.

IMPLICATIONS AND CONCLUSION

In conclusion, our research found that organizational culture does significantly influence the factors that lead to the acceptance of KMS. Our research model was developed using commonly accepted measures from the technology acceptance and organizational culture literatures, tested by surveying corporate KMS users, and analyzed utilizing structural equation modeling. Our results indicated that both process-oriented and open communication organizational cultures significantly influenced factors that lead to the acceptance of KMS.

This research has relevance for both practitioners and researchers. In this article, we examine the influence that three dimensions of organizational culture have on KMS acceptance. It is necessary to examine organizational culture when investigating KMS because such systems are different from traditional information systems. Knowledge, which is information that exists in the minds of individuals, is inextricably linked to knowledge management systems. The emphasis on this human component may not be as prominent in other information systems, and suggests that we incorporate constructs, such as organizational culture, to match the nature of this technology.

This research builds upon the growing IS literature that examines organizational culture, which had historically received insufficient attention (Cooper, 1994; Robey, Wishart, & Rodriguez-Diaz, 1995b; Ruppel & Harrington, 2001). In this study, we have demonstrated that organizational cultural elements are important and should be considered in studies of technology acceptance. For researchers in the culture field, our study extends the importance of examining organizational culture with respect to information systems.

This research also offers several implications for practitioners. We identify different dimensions of organizational culture that lead to greater KMS acceptance. These organizational culture practices are particularly valuable because they are the most direct tools for changing behaviors needed to support knowledge creation, sharing, and use (De Long & Fahey, 2000). Although organizational culture is likely to be inherent in IS practitioner's day-to-day interactions with employees and IT, knowledge of more formally defined dimensions as investigated in this study could lead to better understanding and management of organizational cultural issues, such as office politics. In addition, it has been found that organizations that share common goals, principles, values, and language help facilitate IT relatedness, which can enhance knowledge management capability and ultimately, firm performance (Tanriverdi, 2005). The findings in our research reveal specific dimensions of organizational culture that can influence the knowledge management capability of an organization. Consequently, managers should strive to foster a more results-oriented and open communication system environment in the workplace.

To develop a more results-oriented culture, managers need to encourage behaviors that are less risk averse, such as experimentation and exploration. Instead of a static technology with a limited adaptability, a KMS that has been experimented with by its users will generate new and novel uses of the system. Technologies are often not accepted due to a perceived misfit between the characteristics of the technology and the culture of the organization. Allowing employees the opportunity to adapt to the technology as an outcome of a results-oriented culture can generate a better fit. Consequently, managers should be required to focus more on the goals of job tasks instead of the processes of achieving the outcomes. The schemes for incentives and promotions of KMS users should be compatible with such strategies.

Allowing users time to experiment and explore the features of a new KMS could lead to increased perceptions of usefulness and ease of use, which were also found to influence KMS acceptance. As users experiment and find novel features of the system, they will find it to be more useful. Additionally, the increased time spent on the system would allow for greater perceptions of ease of use. Support for experimentation by management implies a tolerance for mistakes. With the understanding that a certain number of experiments will not have desirable outcomes, users would nevertheless still perceive a greater degree of control over the operation of the system.

Open communication plays a significant role in the acceptance of KMS. To develop a more open communication system culture, a number of strategies can be implemented. Users need to freely interact with their important others (such as coworkers, supervisors, and top management) as well as being included in the design, development, administration, and support of the system. Companies should encourage open communication through the use of forums and newsletters and can even design such features into a knowledge management system. Management can also reward users for openness, such as for voicing opinions regarding the system, and making suggestions for system improvements. These policies will cultivate the tendency to increase subjective norms among users and hence, increase KMS acceptance.

A limitation of our research is that it investigated only a few organizational culture dimensions. We believe that the dimensions most appropriate for KMS were captured in our study and that the germane features of other competing dimensions may be largely encapsulated in the dimensions that we investigated (Chatman & Jehn, 1994; Hofstede et al., 1990). Nonetheless, future research may wish to consider other cultural dimensions to examine the influence that they may have on KMS acceptance. Research can also pursue additional relationships among the cultural dimensions examined in this research, which may provide further insights into the influence that they have on the antecedents of KMS acceptance. The variance extracted for perceived ease of use and perceived behavioral control was less than 10%. It is important to recognize that due to limited variance extracted, the process/result-perceived ease of use and process/result-perceived behavioral control links need to be interpreted with caution and closely examined in future research (Falk & Miller, 1992). Another limitation is that the source of our data may be too limited to claim any universality for our research model. Certain industries, such as health and welfare, government, and retail were not represented in our sample. However, we believe that our research model is robust and will be suitable for testing in other environments and contexts.

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ENDNOTE

[1] An exploratory factor analysis was performed, but not included in this article due to space limitations. These results are available from the third author.

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Chapter 5.13
Organizational Readiness Assessment for Knowledge Management

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ABSTRACT

Implementing knowledge management or knowledge-sharing projects in an organization require significant organizational prerequisites. Lacking proper infrastructures and prerequisite, not only make the knowledge management process unprofitable, but might incur harmful effects as well. To decrease such risks, it is proposed to introduce the readiness assessment, in order to gauge a company's appetite for the work involved in implementing the knowledge management. In this research, critical success factors have been extracted from literature reviews and surveyed through a questionnaire, distributed among 130 knowledge management experts. Then, to validate the measurement of the multi-item constructs, exploratory factor analysis (EFA) was used. Identifying effective variables and their grouping onto related factors, the second questionnaire was employed for readiness assessment of an IT firm working in Iran and its results were presented with Radar diagrams. Finally, promoting propositions were provided based on the firm's current state.

INTRODUCTION

Knowledge management (KM) comprises a range of practices used by organizations to identify, create, represent, and distribute knowledge. In recent decades, there has been proliferation of KM projects in many organizations. Correspondingly, corporate spending on KM projects has increased substantially over the years (Ithia, 2003). The theoretical benefits of KM are clear; hence, in order to maximize internal efficiency, internal coordination, service to clients, and overall profitability, one needs to make tacit knowledge explicit, updated and accessible. Simple one might think but one must go through the reasons as why organizations fail to make KM work possible (Guptara, 2000).

There are several definitions and constructs of the term 'knowledge' and its importance for the firms. Kogut and Zander (1992) for instance, describe knowledge as an embedded resource of the firm. Birkinshaw et al. (2002) see it as 'contingency variable.' Like many other managerial innovations, KM also appears to be adopted first by manufacturing firms, and is beginning now to permeate the service sector, predominantly in professional services such as consulting firms (Hansen et al., 1999). Knowledge, and consequently its management, is currently being touted as the basis of future economic competitiveness. Many large companies have resources dedicated to knowledge management, often as a part of 'information technology' or 'human resource management' departments. Nevertheless, implementing KM projects or knowledge-sharing philosophies in organizations often require significant organizational changes. In essence, assessment of an organization's readiness could serve as a guideline to leaders as they plan and implement KM initiatives (Holt et al., 2004).

System Group Company was founded in 1988 as a small start-up IT company with the vision of establishing IT as an industry in the country. The company is currently the largest private software company in Iran providing IT solutions, specifically integrated business software solutions for vertical markets embodied in different industries. The company has developed a unique combination of the best breed of technology, professional services, and intellectual management in the science of application development. Currently, the company has eight active subsidiaries each specialized in different IT fields, 27 nationwide satellite companies providing after-sales services and 19 licensed companies providing sales and installations across the country. It has grown to become a company of 650 professional staff nationwide to reach its 4,500 customers. The company has received numerous high credentials and awards from Iran's National Council of Informatics and other high-ranking organizations as recognition for its quality software development and contribution to the IT society of Iran.

The firm as a software company faces the challenge of sustaining the level of competence. In fact, the company has problems keeping track of what this knowledge is, where it is, and who has it. A structured way of managing the knowledge and treating the knowledge and its owners as valuable assets could help the company leverage the knowledge they possess. As Rus and lindvall (2002) mentioned, a software organization's main asset is its intellectual capital and the major problem with intellectual capital is that it has legs and walks home every day. At the same rate experience walks out the door, inexperience walks in the door. Based on these facts, the company recognized the need for embarking knowledge management. But based on the dismal success rates of change implementation, managers are being encouraged to be proactive by utilizing change measurement instruments to gauge their organization's demeanor before implementing changes (Simon, 1996; Jansen, 2000) because of changes effect, which imposes risk and uncertainty onto organization.

KM assessment readiness provides thorough answers to two fundamental questions: What is a firm's current KM capability? And what changes must be in place before embarking on a KM initiative? An instrument to assess readiness should be developed based on the premise that KM is enhanced through the critical success factors (CSFs). Before investing scarce resources in such risky projects, corporate leadership is calling for a means to decrease uncertainty surrounding knowledge management.

A failure to assess organizational and individual KM readiness might result significant loss of time and energy of managers dealing with resistance to knowledge management. Knowledge may be accessed at three stages: before, during, or after knowledge-related activities. However, creating KM readiness before any attempt at organizational renewal necessitates later action to cope with resistance. An investment in developing KM readiness—at both individual as well as whole-of-organization level—can achieve double benefit.

KNOWLEDGE MANAGEMENT

As the economy shifts to the post-industrial era, intangible assets (such as knowledge) gain importance over more traditional resources (e.g., land and capital) in organizations (Alavi, 2000). Along with this, KM today emerges as one of the most popular, important areas of inquiry in academic researches and management practices (Ruggles, 1998; Argote, McEvily, & Reagans, 2003). KM first appeared in industries and functional areas that basically sell knowledge—professional services, pharmaceuticals, research, and development functions—in the late 1980s and 1990s. It is now quickly moving into other industries, including manufacturing, financial services, government and military organizations, and even non-government organizations (NGOs) (Grover & Davenport, 2001). Many organizations are increasingly viewed as knowledge-based enterprises in which, formal KM is essential. Being typically tied to organizational objectives, KM is rapidly becoming an integral business activity for organizations as they realize that competitiveness pivots around the effective management of knowledge (Grover & Davenport, 2001).

KM can also be more effective in integrating and administering a firm's information technology base as well as assisting to develop a systemized information model. KM systems (KMS) are becoming increasingly important to organizations, both for their strategic potential and as a crucial resource (Liebowitz & Wright, 1999; Apostolou & Mentzas, 1999a; 1999b; Ahn & Chang, 2004; Wasko & Faraj, 2005). These systems are important for organizations, primarily to help manage a key organizational resource—intellectual capital with the potential to produce a competitive advantage (Rao & Osei-Bryson, 2007).

Although, today there is a great deal of interest in knowledge management, there exists no universally-accepted definition of it (Earl, 1999). KM can be defined as "KM is the practice of selectively applying knowledge from previous experiences of decision making to current and future decision making activities with the express purpose of improving the organization's effectiveness" (Jennex, 2005, p. 15). Also, Alavi and Leidner (2001) defined KM as "managing the corporation's knowledge through a systematically and organizationally specified process for acquiring, organizing, sustaining, applying, sharing and renewing both the tacit and explicit knowledge of employees to enhance organizational performance and create value" (Allee, 1997; Davenport, 1998; Alavi & Leidner, 2001).

One of the key concerns emerging in KM is how to accomplish it. Many companies attempting to initiate KM are unsure of the best approach to adopt (Moffett et al., 2002). Literally, there seems to be general agreement that a combined social and technological approach is ideal one. Davenport and Prusak (1998) believe that KM projects have one of the three aims: a) to make knowledge visible and show its role in an organization, mainly through maps, yellow pages and so on; b) to develop a knowledge-intensive culture by encouraging and aggregating behaviors such as knowledge sharing and proactively seeking and offering knowledgep; c) to build a knowledge infrastructure used not only as a technical system, but also a connecting web of people by giving space, time, tools, and encouragement to interact and collaborate.

Nevertheless, knowledge is not easily measured or audited; therefore, organizations must manage knowledge effectively in order to take full advantage of skills and experiences inherent in their systems and structures as well as the tacit knowledge belonging to the firm's employees. The road to success is eminent. It will certainly go forward, if organizations are aware of the key factors that make its adoption successful.

KM READINESS

This section first deals with literature about critical success factors; then it goes ahead with readiness for knowledge management; and finally it provides measures extracted from the discussions.

Literature Review

The general definitions supplied in the existing literature use the word "readiness" as a necessary pre-condition for a person or an organization to succeed in facing organizational change (Holt, 2000). Knowledge management-readiness is the ability of an organization, department or work-group to successfully adopt, use and benefit from KM. It is important for companies seeking to adopt KM to analysis their businesses to ensure a productive and beneficial implementation of knowledge management. It is worth mentioning that the readiness assessment analyzes the organization's environment and readiness to adopt and support an enterprise-wide project management methodology.

KM strategies are getting mature including their ability to assess an organization's readiness for such systems (Ruppel & Harrington, 2001; Tsai, 2002; Siemieniuch & Sinclair, 2004). Since many KM initiatives did not evolve as successfully as their directors had planned, researchers explored potential barriers and facilitators of KS in organizations (Damodaran & Olphert, 2000; Desouza, 2003; Pumareja & Sikkel, 2005).

Critical enablers of KM have been validated and organized in an integrative framework along with organizational processes and performance (Lee & Choi, 2003). Jennex and Olfman (2000) studied three KM projects to identify design recommendations for building a successful KMS. Jennex and Olfman (2005) summarized and synthesized the literature on KM/KMS critical success factors into an ordered set of 12 KM CSFs. CSFs were ordered based on the number of studies identifying the CSF. There were 17 studies looking at over 200 KM projects. Based on the DeLone and McLean's IS success model, Jennex and Olfman (2006) extended their works with a KM success model and combined and utilized KM and KMS success (Jennex et al., 2007).

Siemieniuch and Sinclair (2004) propose a framework for organizational readiness, by introducing knowledge lifecycle management (KLM) processes. Hung and Chou (2005) give a three-dimensional KM pyramid model (KMPM) for assessing the maturity of its organizational capabilities. KMPM is comprises three components, that is, maturity levels, KM processes, and KM capabilities or enabling infrastructures. Holt et al. (2004) also did a study to develop an instrument for assessing KM readiness. This study draws on the literature dealing with KM and organizational change to propose a synergistic instrument to measure readiness for KM and apply it in an organizational setting. This instrument considers individual, context, content, process measures and KM attitudes.

Further Hung et al. (2006) examined the relationship between KM readiness and intellectual capital while Keith et al. (2006) accomplished a case-based field study from a large Fortune-500 financial firm transitioning its structure to SOE and considering agile software development methodologies. Survey data was collected along with a series of interviews with key managers and developers. Findings indicate significant statistical differences in KM readiness between groups and the need for alignment.

As explained, many instruments purportedly assessed readiness for an organization to embrace changes, but it was not surprising that these instruments were designed to assess readiness from some limited perspectives only, that is, technologic and typical information system, lacking enough considerations on special system and project.

KM Readiness Measures

Based on literature reviews on readiness and success factors in the proposed area, we listed measures influencing on KM readiness. These critical success factors have been extracted from various papers dealing with KM in general, KM success factors and KM readiness, in particular. Hence, this study provides a comprehensive view on KM for firms embarking to KM project. It is shown that firms need to be ready for KM which has specifically essentials with the research objective of identifying factors significantly influencing the KM process. Table 1 shows those extracted measures.

Table 1. KM readiness measures

Measures	Description	Sources
Trust	As maintenance mutual belief with each other based on intention and behavior	Lee and Choi (2003); Davenport et al. (1998); Andersson and Westterlind (1999); Chua and Lam (2005); Allee (1997)
Training	Appropriate training procedures and tools; provide self-training and self-learning environment, Encourage employees to participate in internal and external training	Hasanali (2002); Choi (2000); Chung et al. (2005)
A culture of altruism	Intending to collaboration without compensation	Andersson and Westterlind (1999); Davenport and Prusak (1998)
Open leadership climate	Openly discussion about vision, strategy and procedures and supporting of improvement and democratic leadership style	Chung et al. (2005); Davenport et al. (1998); Taylor and Wright (2004); Andersson and Westterlind (1999); Forcadell and Cuadamillas)2002); Brand (1998); Allee (1997)
Learning from failure	Openly discussing about mistakes and its causes	Taylor and Wright (2004); Soliman and Spooner (2000); Brand (1998)
Knowledge strategy	Specific strategy for knowledge management	Sunassee and Sewary (2003); Taylor and Wright (2004); Snyman and Krugere (2004); Chung et al. (2005)
Management support	The extent that organization's leadership and management were committed to and supported implementation of the prospective change	Davenport et al. (1998); Holt (2000); Chung et al. (2005); Chua and Lam (2005); Ross et al. (2005); Choi (2000); Streels (2000); Hasanali (2002)
Participation	What extent a respondent felt that he or she provided input and was allowed to participate in the change process	Chua and Lam (2005); Choi (2000).
Centralization	The location of decision rights, that is, the level of centralization. The one who makes a decision also has to have access to the right knowledge to make the best decision	Andersson and Westterlind (1999); Lee and Choi (2003); Forcadell and Cuadamillas (2002); Ruikar et al. (2006(; Walczak (2005).
Formalization	Degree that the job relation and decisions managing by standard procedure, policy and formal rules	Taylor and Wright (2004), Lang (2001); Lee and Choi (2003).

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Table 1. continued

Measures	Description	Sources
Quality of information	The extent to which one felt that he or she had useful and meaningful information throughout the change process	Holt (2000); Hasanali (2002); Streels (2000); Davenport and Prusak. (1998); Gupta (2000)
Team work	Encourage knowledge creation teams, concern about teamwork experience and knowledge, evaluation on team coordination, cooperation and efficiency	Chung et al. (2005); Ross et al. (2005); Choi (2000); Soliman and Spooner (2000); Forcadell and Cuadamillas (2002).
Benefit	The extent to which a person feels that he or she will personally benefit from the implementation of the prospective change	Holt (2000); Hasanali (2002); Ross et al. (2005).
Appropriateness	The extent to which one felt that the change effort was legitimate and appropriate for the organization to meet its objectives	Holt (2000); Siemieniuch and Sinclair (2004).
Discrepancy	The extent to which one felt that the organization needed to change	Taylor and Wright (2004); Holt (2000).
Reward system	Is referred to pool of reward like gifts, bonuses or higher salary	Guptara (2000); Chung et al. (2005); Snyman and Krugere (2004); Wiig et al. (1997) Andersson and Westterlind (1999).
Information systems infrastructure accessibility	Referred to software, hardware and network that need to implement of knowledge management projects	Mathi (2004); Taylor and Wright (2004); Ruikar et al. (2006); Macdonald (1998); Hasanali (2002).
Verbal skill	Important factor for knowledge sharing is language that does through narrative and explanation, filtering and organizing information from cultural and physical domain and directing to be meaningful	Polkinghorne (1989); Lang (2001).
T-shape skill	This skill is based on two dimensions, depth (vertically) and width (horizontally) who have this skill can explore specific knowledge domain and application in specific products. They can consolidate knowledge assets. Also they enable to combine theoretical and practical knowledge	Chua and Lam (2005); Lee and Choi (2003).

METHODOLOGY

Sample

There are two basic respondent strategies: sampling and census. However, we decided not to apply any sampling approach or collect data from the whole population, due to required levels of respondent expertise and limited amount of KM expert in Iran as a developing country. The population includes KM experts from academic environment in Iran as well as those working in software companies and has already participated in several KM projects. The academic experts were selected based on teaching and research areas related to KM in various universities and research centers and KMS practitioners in software companies were selected based on experience in KM project implementation. Nevertheless, as discussed later, because expert selection was judicative, it may limit the validity of the findings.

The questionnaires were distributed among 130 experts with 93 surveys completed for a response rate of 71%. The average age and experience of the respondents was 39 years (SD=11 years) and 5.3 years (SD=1.9 years), respectively.

Instrument and Data Analysis

As mentioned earlier, critical success factors affecting KM readiness were extracted from literature reviews and questionnaire-based surveys. The responses about the agreement or disagreement were analyzed using a five-point Likert scale. Further, their reliability or internal consistency was assessed by Cronbach's alpha. It was observed that consistency was above 0.8 (0.86), higher than the 0.7 threshold normally considered as minimum (Nunnally, 1978).

To validate the measurement of the multi-item constructs, we used exploratory factor analysis (EFA), a procedure that allowed us to drop some invalid items from the scale and include valid items to the relevant groups. One variable (knowledge strategy) was deleted in this approach, while 18 variables including five factors remained there.

After identifying effective variables and their grouping onto related factors, the second questionnaire was employed for readiness assessment of an IT firm working in Iran (see Appendix). The questionnaire was designed based on above-mentioned factors and consisting a series of statements (92 statements) relevant to a particular area to which, respondents (or end users) from several functional units may either agree or disagree with varying degrees (using a five-point Likert scale). These questions were extracted from some reliable and valid instruments mentioned in references such as Clark (2003). Nevertheless, managers of the firms were also asked to comment on the questions and their relevance to factors wanted to measure. Assessment relies on the judgment of a respondent (or end-user) as to whether or not he/she agrees with the statement/s in the context of their department or work group. The respondent(s) need to ensure that their responses are consistent with their assumptions, for example, if responses are about the department (and not the organization), then that assumption must be reflected throughout. The extent to which the respondent agrees or disagrees with the statement is graded on a scale of 1 to 5, where: 1= Strongly Disagree, 2= Disagree, 3= Neutral, 4= Agree and 5= Strongly Agree. The statements are orchestrated in a way that a response of "strongly agree" generates the highest score of 5 points. An average score is also calculated for each category. The higher the average score the more likely it is that the firm is ready for knowledge management. Based on Ruikar et al. (2006), an average score greater than or equal to zero and less than 2.5 is weak, indicating that several aspects (within a category) need urgent attention to achieve readiness; whereas, an average score greater than or equal to 2.5 and less than 3.5 is medium, indicating that certain aspects (within a category) need attention to achieve readiness in knowledge management; and, an average score greater than or equal to 3.5 is high, indicating that the firm has adequate capability and maturity in these aspects and therefore has knowledge management-readiness (in those respects). On successful completion of the questionnaire, results are presented with radar diagrams that summarize overall KM readiness in each factor and its related variables. This allows companies to focus on, and improve on, those specific aspects within each category, even if they have achieved knowledge management-readiness in that category.

RESULTS

Factor Analysis Results

The critical assumptions underlying factor analysis were tested using the Bartlett test of Sphericity and the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO=0.65). The independent variables were subjected to exploratory factor analysis using principal components analysis as the extraction method and Varimax rotation with Kaiser normalization. All factors which have the value greater than 0.5 were extracted. This iterative process is recommended as an effective way of deriving a stable factor structure (Sethi & King, 1991; Rai et al., 1996). After five iteration processes, all 18 variables were loaded satisfactorily onto the five latent factors. The factor analysis was also examined to ensure acceptable levels of variable communality and multi-collinearity. The factors are associated with culture, information infrastructure of the organization, vision of change, management support and structure, which explain almost 70 % of the variance of KM readiness. Table 2 shows exploratory factor analysis results.

Empirical Results

This section shows the findings on the KM readiness of a firm based on responses which includes the average scores of the firm in the categories including management support for change, culture of knowledge, structure, infrastructure and vision for change. The evaluations were conducted by managerial staffs (e.g., senior project manager, project director, senior systems manager, etc.) and bottom-line staffs in the relevant departments. Average scores obtained in each category are plotted on a radar diagram as illustrated in Figures 1 to 5. These figures highlight specific points within each category that need attention to achieve knowledge management-readiness.

As seen in Table 3, the firm's state of infrastructure factor is excellent. All measures of this factor are greater than 3.5 (even greater than 4.7) indicating that the firm has adequate capability and maturity. Also, the average scores of each item in change factor are high, that is, the firm can empower or devote the organizational resources on to the other factors.

Table 2. Results of exploratory factor analysis (EFA)

Items	**Factors**				
	Support for change	**Vision for change**	**Culture of knowledge**	**Structure**	**Infrastructure**
Training	0.79				
Management support	0.8				
Participation	0.79				
Reward system	0.78				
Benefit		0.84			
Appropriateness		0.87			
Discrepancy		0.88			
A culture of altruism			0.67		
Open leadership climate			0.87		
Learning from failure			0.82		
Trust			0.86		
Centralization				0.78	
Formalization				0.82	
Team work				0.814	
Quality of information					0.76
Information systems infrastructure accessibility					0.76
Verbal skill					0.73
T-shape					78.8
% of variance explained	14.93	12.81	15.85	12.36	13.75
Cumulative % of variance explained	14.93	27.74	43.59	55.95	69.70

Table 3. Readiness scores of the firm

Factors	Measures	Score	Readiness
Vision for Change	Benefit	3.9	High
	Appropriateness	3.3	Medium
	Discrepancy	3.9	High
Infrastructure	Quality of Information	4.8	High
	Information systems infrastructure accessibility	4.7	High
	Verbal Skill	4.8	High
	T-Shape	4.8	High
Structure	Centralization	3.9	High
	Formalization	3.3	Medium
	Teamwork	3.9	High
Support for change	Education	3.3	Medium
	Management Support	3.4	Medium
	Participation	3.7	High
	Reward system	3.1	Medium
Culture of knowledge	Trust	3.7	High
	Open leadership climate	3.9	High
	Learning from Failure	3.9	High
	A culture of altruism	4.1	High

All items in the management support factor are the least KM readiness with the lowest scores compared to the other four categories. Three measures are in medium state and only participation is high ready. In culture, all the items have high level of KM readiness with scores greater than 3.5. At the same time, verbal skill and T-shape have higher score in readiness assessment.

This firm tried to implement KM in 2004, but its first attempt failed because of its emphasis merely on technological aspects. Project failure caused to managers defines this research project to assess organizational dimensions, needed before embarking on the KM project. After identifying factors influencing readiness as well as weak areas in the firm, all the people involved in the first attempt seem to agree on weakness discovered by this assessment tool. Hence, managers defined projects to improve the current state of the firm to the extent to which all organizational functions and dimensions will be fully ready for this risky project.

CONCLUSION

This study is one of the first systematic studies to determine the KM readiness implementation in firms, especially in the SME[1] sector. This assessment survey profile offers a valuable source of information to firms, which are still lagging far behind when comes to KM practices.

Present research has identified five organizational antecedents to effective KM within the context. We have tried to illuminate the unique challenges managers encounter while implementing KM processes to the aforementioned dimensions. By investigating, managers acknowledge that they have considerable scope to improve current attitudes and practices within these constraints. They can use the developed instrument as a framework in assessing their current readiness in factors influencing on the success of KM project. The instrument in a way provides pointers to what needs to be addressed. The acquired results would help managers to facilitate its adoption and to prioritize its practices. At the same time, academics can use the outcomes to build models that would further expand the KM domain. Although technological infrastructure and KM systems are vital for successful implementation, firms should give more emphasis on soft components of organization such as people and culture because most failure is encountered from narrow view to such a project and a mere emphasis on technology. It causes to ensure the successful implementation of KM as well as to attain full advantages from KM in organization.

Limitations and Suggestions for Future Research

There are some limitations/constraints to this study, including its focus on one enterprise. In addition, self-selection bias not only limits to conclude the results of the study rather it might lead our choice of industry or firm narrow. Although, the instrument can be applied to IT firms, it must be handled prudently while applying in other industries. As a matter of fact, additional research must be carried out to validate conclusions and to add to our understanding about KM readiness in other commercial or governmental enterprises. It is believed that the number of KM experts and their responses was small since it is a new and emerging discipline, and not many SMEs have formally implemented it, especially in a developing country like Iran. Furthermore, we think that there are other influencing factors on readiness that were probably left out, especially environmental ones that were excluded because of difficulty in developing universally-applicable questionnaires, suitable to organizations. Finally, the assessment instrument applied in the firm was attitude-based, that, in reality, may be biased.

However, this instrument needs further improvement and evaluation. The instrument should be less attitude-based and rely more on current documents and statements of firms. Also, researchers are advised to implement those instruments in different areas of industries, in order to determine and enhance their applicability. Also, they should also work on developing comprehensive and integrated maturity model to help practitioners implement knowledge management. To that end, there is a growing commitment by scholars towards empirical and conceptual research especially in knowledge management.

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ENDNOTE

[1] Small-Medium size Enterprise (SME)

APPENDIX

Respondents were asked to rate their agreements with the following statements, on a scale of 1-5.

Benefit	I believe in the value of such knowledge sharing changes.	1	2	3	4	5
	My future in this job will be limited because of such changes.	1	2	3	4	5
	I like the available situation.	1	2	3	4	5
	The time we would spend on such changes should be spent on something else.	1	2	3	4	5
	Such changes give me ability to make decisions as how my work is done.	1	2	3	4	5
	Changes that improve knowledge sharing will make my job easier.	1	2	3	4	5
	Implementation of knowledge sharing changes will disrupt many of the personal relationships I have developed.	1	2	3	4	5
	My past experiences make me confident that I will be able to perform successfully after such changes.	1	2	3	4	5
	I am worried I will lose some of my status in the organization when such changes are implemented.	1	2	3	4	5
Participation	The information I received about such knowledge sharing changes was timely.	1	2	3	4	5
	I am able to participate in the implementation of such changes.	1	2	3	4	5
	I have some control over the knowledge sharing changes that will be proposed.	1	2	3	4	5
	The information I received about such changes, has adequately answered my questions.	1	2	3	4	5
	The information I received about this changes, helped me understand changes	1	2	3	4	5
	When we implement such knowledge sharing changes, I feel I can handle it with ease.	1	2	3	4	5
	Trade planning has been done regularly and each person in the organization participates and includes in this process to some extent.	1	2	3	4	5
Discrepancy	There is a clear need to change knowledge sharing activities.	1	2	3	4	5
	Attempts to make things better are necessary around here.	1	2	3	4	5
	Our organization has problems about knowledge saving.	1	2	3	4	5
T-shape	I have the knowledge of my job.	1	2	3	4	5
	Familiar to other tasks in the organization it is useful for doing my job.	1	2	3	4	5
	I have general understanding of organizational processes.	1	2	3	4	5
Appropriateness	There are a number of rational reasons for such changes to be made.	1	2	3	4	5
	There are legitimate reasons for us to make changes that will improve knowledge management activities.	1	2	3	4	5
	Changes that will improve knowledge sharing, match the priorities of our organization.	1	2	3	4	5
	Managing knowledge is an organizational value.	1	2	3	4	5
	Applying new information technology is appropriate with organizational purpose.	1	2	3	4	5
	Change in information distribution is a major goal of the organization.	1	2	3	4	5
Management support	This organization's most senior leader is committed to such change.	1	2	3	4	5
	Management has sent a clear signal that this organization is going to make changes that will improve knowledge management.	1	2	3	4	5
	The top manager is committed to making such knowledge sharing change efforts a success.	1	2	3	4	5
	Major managers encourage everybody to the changes which improve knowledge management.	1	2	3	4	5
	Managers and leaders put their word into action.	1	2	3	4	5

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APPENDIX CONTINUED

Reward System	Rewards are paid according to the needs of a person.	1	2	3	4	5
	People, who have more roles in the organization, are rewarded more.	1	2	3	4	5
	Rewards are paid according to the needs of a person.	1	2	3	4	5
	Based on experiences, the organization reward system do fairly.	1	2	3	4	5
	Organization has the pool of rewords.	1	2	3	4	5
Verbal Skill	In communication, I use words that others understand easily.	1	2	3	4	5
	My colleagues can understand the words I use.	1	2	3	4	5
Centralization	How much does the major manager of the organization directly control the decisions made by others?	1	2	3	4	5
	How much does your unit headman act freely and independently in employing or firing the personnel?	1	2	3	4	5
	How mach does the major manager of the organization act directly in collecting information for making his decision?	1	2	3	4	5
	Each one can be a decision maker in the organization without being controlled by others.	1	2	3	4	5
	How much does your unit head man act freely and independently in personnel's rewards?	1	2	3	4	5
	How much freely and independently does your unit head man act in evaluating his unit function?	1	2	3	4	5
	How much freely and independently does your unit head man act in evaluating his unit function?	1	2	3	4	5
Open leadership climate	Usually, some meetings are held in manager's presence to hear employees' ideas.	1	2	3	4	5
	Management encourages active participation in expressing ideas.	1	2	3	4	5
	Does the manager pay attention to employees' ideas with regard to work affairs?	1	2	3	4	5
	Do they behave honestly?	1	2	3	4	5
	Do employees express ideas freely?	1	2	3	4	5
	Do employees feel relaxed in expressing their ideas?	1	2	3	4	5
Team work	The organization uses different team in order to solve its problems and requirements.	1	2	3	4	5
	The organization focuses on the team work.	1	2	3	4	5
	To do work, team work is used instead of organizational hierarchy.	1	2	3	4	5
	Every one does his work in the team.	1	2	3	4	5
	Do teams have much power in relation to decision making and performance?	1	2	3	4	5
Formalization	Most will make their regulations on their own.	1	2	3	4	5
	Every one in the organization is permitted to work in the way they are satisfied.	1	2	3	4	5
	In order to deal with any condition, there are special procedures.	1	2	3	4	5
	The situation is available for the personnel to express ideas.	1	2	3	4	5
Trust	My success is important for my colleagues.	1	2	3	4	5
	I am sure my colleagues put their words into action.	1	2	3	4	5
	I am sure my colleagues hand me accurate information.	1	2	3	4	5
	I am sure my colleagues are honest with me.	1	2	3	4	5

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APPENDIX CONTINUED

Learning of failure	The employees can detect other methods to do the affairs, without fear of being reprimanded for previous failure.	1	2	3	4	5
	In case of procedure failure, the organization encourages the employees to analyze it.	1	2	3	4	5
	The organization pays no attention to the cause of failed procedure of other organizations.	1	2	3	4	5
	The organization's patience to making mistakes is high.	1	2	3	4	5
	I am annoyed when others talk about my mistakes over and over again.	1	2	3	4	5
	The organization encourages creative endeavors even when they are not successful.	1	2	3	4	5
	I consider my failures as an educating source.	1	2	3	4	5
Education	In case of encountering questions, they are answered while the new systems are used.	1	2	3	4	5
	The organization holds training and introduction with the new technology courses for the employees.	1	2	3	4	5
	A lot of investment is done to educate the employees.	1	2	3	4	5
Information systems infrastructure accessibility	What extent are software systems of the organization capable of coordinating with the new systems?	1	2	3	4	5
	What extent are the internal nets in the organization capable of supporting the new systems?	1	2	3	4	5
	How is the quality of supporting the systems and the network?	1	2	3	4	5
Quality of information	How much standard is used for planning data in the organization?	1	2	3	4	5
	How is the security strategy to data in the organization?	1	2	3	4	5
	How much do you gain from the required information in the appropriate time?	1	2	3	4	5
	How much access do you have to your needed information?	1	2	3	4	5
	We have a well-defined good policy for using management information systems.	1	2	3	4	5
A culture of altruism	I help my colleagues without any rewards.	1	2	3	4	5
	I try to help others without any compensation.	1	2	3	4	5
	Helping my colleagues is enjoyable for me.	1	2	3	4	5
	Solving the problem of my colleagues is my job.	1	2	3	4	5

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Chapter 5.14

The Impact of Institutions on Interorganizational IT Projects in the Mexican Federal Government

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ABSTRACT

Electronic government has the potential of transforming the way government works and interacts with citizens. However, recent research has found that the promised benefits are rarely completely achieved. Some of these studies highlight the importance of institutions in shaping the development, implementation, and use of information technologies in government settings. Based on a survey of Mexican federal government managers, this article explores the relationships between institutional arrangements, organizational forms, information technologies, and the outcomes of Mexican IT initiatives. Overall, it was found that there are important interactions among these variables and important similarities exist between developed countries and other realities, such as Latin America. The research presented here contributes to the field by testing causal relationships often cited in the digital government literature, but with little empirical quantitative exploration. Moreover, understanding those relationships offers guidance in the implementation of inter-organizational IT applications in government, potentially increasing their probability of success as well as the benefits for citizens and other stakeholders.

INTRODUCTION

According to Fountain (2001, 2004), information and communication technologies (ICTs) are one of the most important advances in this century and have the potential to significantly transform government. In fact, some government structures and processes have changed due to the incorporation of technological innovations such as the personal computer and the Internet (Fountain, 2004). Information technologies create interesting possibilities for government. They are used not only to improve the quality of services, but also to reduce costs and make policies and programs more effective (Gil-Garcia, 2006; Gil-Garcia & Helbig, 2006; OECD, 2003). Information and communication technologies are used as a catalyst for organizational change (Dawes, 2002; Holmes, 2001; Rocheleau, 2003). They are also considered a tool to improve democratic participation in a variety of political topics (Carbo & Williams, 2004; Gil-Garcia, 2005; Hiller & Bélanger, 2001).

The term "electronic government" or "digital government" emerged within this context, and is still evolving (Gil-García & Luna-Reyes, 2006; Schelin, 2003). OECD defines e-government as the use of information and communication technologies for a better government or to improve the quality of its services, especially through the use of the Internet and Web technologies (OECD, 2003). Some general characteristics of e-government are: (1) the use of information and communication technologies, (2) supporting government actions, (3) improving the relationships between government and citizens, and (4) following a strategy to add value for participants in the process. In contrast to electronic commerce, electronic government does not include only the transactional aspects, but also takes into consideration the democratic relationships between governments and citizens (6, 2001; Gil-Garcia, 2005; Scholl, 2002).

The implementation of these technological innovations has been challenging. In Mexico, information and communications technologies were first used widely in government in the '90s. However, it was only in 2001 when the secretary of communications and transportation created the e-Mexico project. The e-Mexico initiative fosters innovation in government through the use of information technologies and also promotes the use of the Internet by certain sectors of the Mexican society. New laws and regulations regarding electronic government in Mexico have supported this initiative. One important example is the Law for Transparency and Access to Government Public Information. The objective of this law is to establish the necessary mechanisms to guarantee any person the access to information from the different branches of government, autonomous constitutional organizations, and any federal agency (Poder Ejecutivo, 2002). The main objective of electronic government in Mexico is to use information and communication technologies to innovate and improve government and its relationships with citizens (OECD, 2005).

Therefore, the implementation of electronic government in Mexico needs to consider different factors such as laws and regulations, organizational structures, and the characteristics of the technologies themselves. This study proposes and empirically tests a model to explore the relationships between some of the factors that have an impact on information and communication technology projects in government. Institutional theory and Fountain's technology enactment framework provide the conceptual basis for this study.

After this brief introduction, the article is organized into five more sections. The following section presents a brief literature review of institutional theory and the technology enactment framework, as well as some of their applications to government settings. The third section describes the research model and hypotheses, and the fourth section includes a description of the research methods and procedures. Finally, the last two sections consist of a discussion of the main results and conclusions.

LITERATURE REVIEW

This study is based on institutional theory, particularly Fountain's technology enactment framework (Fountain, 1995, 2001). The concept of institution is central to these theories. According to North, "Institutions are the rules of the game in a society, or more formally, they are humanly conceived obligations, which configure human interaction" (North, 1999). Another definition says that institutions are the joint group of rules, application mechanisms, and organizations that reinforce each other (Scheela & Van Dinh, 2004). Barley and Tolbert (1997) state that institutions represent obligations created by the options that individuals and groups have, but these obligations are subject to change over time. They define institutions as shared and typified rules with identified categories of social actors, as well as their appropriate activities and relations (Barley & Tolbert, 1997). Institutions can also be seen as guidelines that have been created by society and the individuals who are part of that society (Giddens, 1979, 1984). These guidelines or rules are generated and maintained over time through the micro-activity of social actors. In contrast, for Bansal (2005), institutions include macro-level structures like governments, professional associations, public opinion, and the media. Current institutional approaches recognize the interplay between social structures (macro) and the actions and interactions among individual actors (micro). Therefore, the basic principle of institutional theory is that individual actions and organizations are shaped by institutions, which, at the same time, are either reproduced or modified through the collective action of individuals and organizations (Brinton & Nee, 1998; Giddens, 1984; Scott, 2001).

Institutional approaches have been used to understand a great variety of phenomena in multiple disciplines including economics (North, 1999; Rutherford, 1999), political science (Peters, 2001), and sociology (Brinton & Nee, 1998). Within organizational research, institutional theory emphasizes the social context in which organizations are embedded and highlights the influence of culture or laws on decision making and formal structures (Bansal, 2005; Powell & DiMaggio, 1991; Scott, 2001). It also recognizes the importance of external pressures generated by actors in the social and economic environments and their influence on organizational characteristics and performance (Khadaroo, 2005). Institutional theory has been useful to understand organizational change by identifying relevant aspects of the context in which information technologies are designed and implemented (Bennett, Bouma, & Ciccozzi, 2004).

This theory argues that organizations and individuals are constrained by a series of rules, values, norms, and assumptions, which are created by them through their actions and interactions (Barley & Tolbert, 1997; Giddens, 1979, 1984). These rules and values greatly influence how things should be done, but they do not totally determine human action (Barley & Tolbert, 1997). Therefore, institutionalization is a continuous process that can only be observed over time. It is also a cultural and political process related to legitimacy and power—and not necessarily to efficiency (Powell & DiMaggio, 1991). Organizations adopt business practices that are perceived as legitimate in society as a result of coercive, normative, or imitation pressures (Khadaroo, 2005). Accordingly, there are different mechanisms that influence organizational change—in particular, competition, normative isomorphism, coercive isomorphism, and mimic isomorphism (Bennett et al., 2004; Powell & DiMaggio, 1991). Due to its main focus on institutions, some scholars argue that institutional approaches have not adequately included the material properties of technological artifacts in their analyses (Garson, 2003). Other researchers consider that most studies using institutional theory need to explicitly and clearly explain how they are incorporating the role of human agency and the reciprocal relationships between institutions and individual actions (Yang, 2003).

Based on the institutional tradition and as an attempt to explicitly include the role of technology in a comprehensive approach, Fountain (1995, 2001) develops a framework that "pays attention to the relation among information technologies, organizations, embeddedness, and institutions." Using empirical evidence from government information technology initiatives in the U.S. federal government, Fountain (2001) proposes a new way to conceptualize technology within an institutional theoretical tradition: the technology enactment framework.

The technology enactment theory attempts to explain the effects of organizational forms and institutional arrangements on the technology used by government agencies (Fountain, 1995, 2001; Gil-Garcia, 2006). According to this theory, the "technology is enacted in political, social, economic, and organizational contexts" (Fountain, 2004). Fountain (2004) explains that "two of the most important influences on the enacted technology are organizations and networks," and provides examples of information technologies implemented in comparable organizational contexts but with very different results. The interactions among organizational characteristics, networks, and institutions may explain some of these differences. Based on the institutional tradition (Brinton & Nee, 1998; Powell & DiMaggio, 1991; Scott, 2001), she argues that the embeddedness of actors in social, cultural, cognitive, and institutional structures influences the design, perception, implementation, and use of information technologies. Each project is embedded in a certain organizational environment and is affected by specific institutional arrangements. As a result, each organization uses technology differently and obtains different performance, costs, and results (Dawes, 2002; Fountain, 2001). Therefore, organizational characteristics and institutional arrangements have an impact on the enacted technology (Fountain, 2001; Gil-Garcia, 2006; Luna-Reyes, Gil-García, & Cruz, 2006). These institutions could be seen as guides for action, but also limitations to those actions (Brinton & Nee, 1998; Fountain, 2001; Scott, 2001).

Fountain (2001) proposes an analytical distinction between objective technology and enacted technology. Objective technology is described in terms of its capacity and functionality—that is, hardware, software, telecommunications, and other material characteristics, independently of how people use them (Fountain, 2004). In contrast, enacted technology refers to how users perceive and act upon objective technologies. In this instance, the enacted technology could be conceived as a subset of the objective technology (Puron Cid & Gil-Garcia, 2004). However, social actors can also enact new uses that were not included as part of the original design and functionality (Fountain, 2001; Orlikowski, 2000). Therefore, the technology enactment is flexible and fluid and can be observed as it develops over time through interactions among social actors and between actors and technologies (Gil-Garcia, 2006; Orlikowski, 2000). The enacted technology is affected by social, cultural, cognitive, structural, and political factors, but it also affects these factors in a recursive relationship (Fountain, 2001, 2004). Social actors draw upon institutional arrangements and, therefore, the enacted technology is affected by institutions, organizational characteristics, and environmental conditions (Fountain, 2004; Luna-Reyes et al., 2006).

Fountain's analytical framework explains how social actors enact information technologies in order to adapt them to the existing organizational rules, routines, and relations (Fountain, 2001). These modifications are not necessarily optimal and make clear the influence of organizational and institutional arrangements on the selection, design, implementation, and use of information technologies (Fountain, 2004). In addition, organizational actors tend to enact technologies that preserve the current social order, networks, and structures (Fountain, 2001; Kraemer, King, Dunkle, & Lane, 1989).

In summary, Fountain's technology enactment framework argues that information technologies are embedded in organizational and institutional environments and it is very important to understand these environments (Fountain, 2004). Information technologies have the potential to change business processes, communication patterns, coordination mechanisms, hierarchical structures, and other organizational characteristics. However, information technologies are also affected by organizational and institutional factors (Fountain, 2001, 2004; Gil-Garcia, 2006). The technology enactment framework recognizes this bi-directional and dynamic relationship and suggests alternatives to incorporate relevant variables into analytical models.

RESEARCH MODEL AND HYPOTHESES

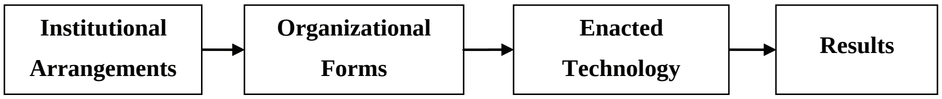
As mentioned before, the research model used in this research is based on institutional theory, drawing specifically on the technology enactment framework (Fountain, 2001) and extending it through a review of current literature on IT in organizations. According to the technology enactment framework, institutional arrangements and organizational forms have an impact on the selection, implementation, and use of information technologies in government.

Institutional theory proposes that the context in which organizations develop has an influence on them (Bansal, 2005). Technology enactment refers to the relationships among institutions (legal, cognitive, cultural, and social), objective information technologies (hardware, software, and networks), organizational forms (bureaucracy, relationships, etc.), and the activities of actors through the selection, design, implementation, and use of information technologies in government settings (Dawes, 2002; Fountain, 2001; Gil-Garcia, 2006).

On the basis of these ideas, Figure 1 shows the research model proposed in this article. In this model, institutional arrangements affect organizational forms and indirectly affect actors' choices about the conceptualization, design, and use of objective technologies, constituting a particular technology enactment. Then, the enacted technology influences organizational results such as efficiency or effectiveness.

In Figure 1, institutional arrangements are represented by procedures, habits, patterns, and regulations that serve as guidelines and constraints for action (Fountain, 2001; Gil-Garcia, 2006). In the particular case of information technology and digital government, the institutional support to IT initiatives and institutional support to a specific project are also being considered as institutional factors. Some of the projects included in the survey are systems mandated by law (such as the law regulating access to government information) or presidential initiatives (like some interorganizational projects conducted by the Ministry of Communications and Transportation). Other projects are also important from a single-agency perspective, but in most cases, decisions about technology not only depend on a single agency, but on several stakeholders, committees, bureaucratic rules, and the relevance of the project itself (Gil-Garcia, 2006). Institutional arrangements guide decisions about IT projects, such as size, goals, objectives, resources, and indicators of success (Fountain, 2001; Gil-Garcia, 2006). Goals, objectives, and resources are important organizational

Figure 1. Research model



characteristics for a particular project. In this way, the first hypothesis of this research relates to the impact of institutional arrangements (laws, regulations, institutional support, etc.) on organizational forms, including goal setting, recognition, or the adequacy of resources to accomplish the goals.

H1: *Institutional arrangements have an influence on organizational forms in inter-organizational IT projects.*

As mentioned before, enacted technology refers to specific choices about design and use of objective technologies, choices that can be observed through characteristics of the project's technology products (Puron Cid & Gil-Garcia, 2004). Enacted technology also refers to the use that different users decide to give to some objective technology (Fountain, 2001). Organizational forms directly influence these choices on design and use, and institutional arrangements also have an impact on the enacted technology, indirectly, through the influence that institutions have on organizational forms (Gil-Garcia, 2006). In this way, systems of goals, recognition, or the adequacy of resources (organizational forms) have a direct impact on specific choices or uses of technology (enacted technology) in a specific project. According to the enactment framework (Fountain, 2001), laws, regulations, institutional support, or other cultural factors (institutional arrangements) do not affect directly the technology choices (enacted technology), but indirectly through their influence on goals, objectives, and other organizational elements. These relationships are reflected in hypotheses 2 and 3.

H2: *Organizational forms affect the way in which technology is understood, designed, and used (enacted) in a particular inter-organizational project.*

H3: *Institutional arrangements have an indirect effect on the technology application and use (enacted technology) in an inter-organizational project through its influence on the organizational forms.*

Particular technology enactments, reflected in the usefulness or how easy it is to use a particular technical solution, are developed and subsequently used in order to have an impact on organizational performance and results. Better systems are designed to improve productivity, service quality, or efficiency (Fountain, 2001). Moreover, the context where a particular enactment takes place is the organization and, therefore, organizational forms also have an influence on the results of using information technologies. That is to say, the specific context (organization) has an influence on IT design, development, and use, but the technology itself also has an effect on performance (Fountain, 2004). In this way, specific enactments of technology have a direct effect on the expected results. The impacts of the organizational forms on the expected results are mediated by the enacted technology according to the enactment framework. Hypotheses 4 and 5 summarize these effects.

H4: *The enacted technology, which is the way technology is interpreted and used, has an effect on organizational results and performance.*

H5: *Organizational forms affect indirectly organizational results and performance through their direct effect on the enacted technology.*

RESEARCH METHODS

The research reported here constitutes the results of the second stage of a multi-method project developed in three stages. The first stage involved a series of interviews with project managers of inter-organizational projects in the Mexican federal government. The second stage encompassed a survey applied to participants in the projects identified during the first stage. The third stage consisted of conducting three case studies, including additional interviews with participants in some projects and document research. This article reports on the results of the survey conducted during the summer of 2006. This section of the article includes a brief description of the subjects, the survey, and the procedures followed in the research to gather empirical evidence for the relations in the hypotheses described in the previous section. It is started by describing the population and the sampling methods, and then the survey instrument and the procedures followed to apply the survey are described.

Sample

As mentioned before, the interest was to explore the effects of institutional arrangements and organizational forms on IT projects involving inter-organizational collaboration. An initial sample of projects was identified during the first stage. The projects were identified using the Internet as a search tool, and asking the project managers interviewed for additional projects to include, following a snow ball approach. In this way, 13 government agencies were identified as involved in inter-organizational projects at the federal level (National Bank for Savings and Financial Services, Ministry of Public Administration, Ministry of Transportation, Ministry of Health, Federal Institute for Access to Information, Mexican Institute for Social Security, INFOTEC, Ministry of Justice, Internal Revenue Service, Ministry of Education, President's Internet Office, Ministry of Economy, and Ministry of Finance). The survey database was put together by compiling names and e-mail addresses of project participants from the agencies Web pages or from lists provided by the project managers interviewed. The database included 1,216 people from federal agencies who participate in 13 inter-organizational projects, and it was decided to include all of them in the sample. Therefore, the study uses a purposive sample of public managers involved in well-known inter-organizational IT projects. Although the population is unknown, which may limit the generalizability of the results, this approach allows establishing a robust sampling framework for this research.

An electronic survey was developed and the usable response rate was 23.2% (n = 282). Forty percent of respondents reported having more than 10 years of working experience in the federal government, and 81% reported having more than 10 years of working experience in general. Fifty-five percent of respondents have experience in the area of informatics, 31% in policy making, and 25% in program development. Most respondents have a college education (97%), while 40% have a graduate-level education.

Survey Instrument

A survey instrument was adapted and re-designed from Fountain's original instrument (Fountain, McKinnon, & Park, 2003). The instrument included questions that sought to understand the effects of institutional arrangements and organizational forms in inter-organizational IT projects. The original instrument was first translated into Spanish and adapted to the Mexican context by the researchers. Then, to ensure content validity and comparability, the instrument was reviewed by two expert translators and four government officials in a two-stage process. Following their recommendations, the research team made adjustments and changes to the survey instrument for both content and format.

The final instrument had 35 questions;[1] five questions were associated with institutional arrangements, six with organizational forms, eight with enacted technology, and 10 with results. The questions related to institutional arrangements include perceptions about influences of government culture, legislation, support from congress, and institutional support for the use of IT. The questions in this scale showed a Cronbach-alpha value of 0.770 (see Table 1).

Organizational questions included aspects related to the definition of goals and performance indicators, adequacy of financial and human resources, and adequacy of recognition from managers. The alpha value for this scale was 0.733. Enacted technology was operationalized in the survey as a series of questions related to the quality of particular technology characteristics enacted in each project. Some of the main characteristics included were ease of use, usefulness, information quality, functionality, personalization, security, and privacy. The alpha coefficient for this scale was 0.932. Finally, results were measured as the level of project success in terms of productivity, cost reduction, transparency, citizen participation, effectiveness of government policies and programs, and quality of service. The alpha value for this scale was 0.905.

Procedures

As mentioned, the survey was administered electronically using a commercial service called SurveyMonkey. Potential respondents (1,216 people) were sent an initial e-mail invitation to participate in the survey during the summer of 2006, giving them the option of declining the invitation. A second e-mail providing the Web address of the survey to complete was sent. A total of three reminders were sent. The first reminder was sent a week after the Web address was sent. The second reminder was sent one week later, and the last reminder was sent a day before the survey was closed.

After the initial e-mail with the survey Web address was sent, 137 answers were received (11.3% response). The first reminder increased the responses to 221 (18.2% response). After the second reminder, the number of responses increased to 273 (22.5% response). With the last reminder, responses increased to 330 (27.1%). Unfortunately, 48 responses were blank with the exception of the first couple of questions, reducing the valid responses to 282. These usable responses correspond to a response rate of 23.2%, which is generally considered acceptable for a Web-based survey. Once the survey was closed, the database was cleaned and analyzed. The following section summarizes the main survey results.

RESULTS AND DISCUSSION

The e-government projects included in the survey are considered successful by respondents (respondents were either participants in the e-government projects or users of the e-government systems associated with the projects). The number of agencies involved in the projects surveyed varied greatly. Many projects involved collaboration between 10 or fewer agencies; three projects involved more than 50 agencies working together. Overall, 88% of respondents believe their project has well-defined goals, 84% believe it is feasible that their project will reach these defined goals, and 75% believe there are clear indicators for success. Most respondents consider that their project is important for the country.

Table 1. Cronbach-alpha values for main constructs in the model

Construct	Items in scale	Alpha value
Institutional Arrangements	5	0.770
Organizational Forms	6	0.733
Enacted Technology	8	0.932
Results	10	0.905

Although respondents consider their projects to be successful and to offer high-quality results, they also mention some problems. Problems are often associated with the lack of human and financial resources and mismatches between project goals and agencies regulations. In addition, respondents consider a variety of political factors, resistance to change, red-tape, and the influence of individual interests as important issues to consider when developing IT projects in government. Only half of the respondents believe the current laws support inter-organizational digital government initiatives, and about one-third (35%) believe legislators support these kinds of projects.

Table 2 includes descriptive statistics for the main constructs in the proposed model. Maximum values in the table coincide with the maximum values of each scale. The relative positions of the means in each scale with respect to the maximum value are in the range from 76% to 86%. The lowest relative mean corresponds to organizational forms, and the highest to enacted technology. Translating the mean values to a 10-point scale to better understand their meaning, respondents assigned an 8.0 to the adequacy of laws, government culture, congress support, and institutional support (institutional arrangements), a 7.6 to the definition of goals and performance indicators, combined with the adequacy of human and financial resources and systems of recognition (organizational forms). They assigned an 8.6 to the current design of the inter-organizational technologies in terms of ease of use, utility, quality, functionality, customization, security, and privacy (enacted technology), and an 8.3 to the success of the projects in terms of success measures such as cost reduction, effectiveness, increased productivity, or improved citizen participation (results).

Pearson correlation coefficients were calculated for all constructs (see Table 3). As shown in the table, the model constructs are moderately correlated. All correlations are significant at a $p<0.01$ level. The highest correlation exists between the enacted technology and the results, while the smallest correlation occurs between institutional arrangements and organizational forms.

In order to test the hypotheses posed by the proposed model, linear regression was used. Equations 1 through 7 show the main regression equations used in this research. Regressions 1, 2, and 3 are used to test hypotheses 1, 2, and 4. To test indirect effects in hypotheses 3 and 5, an approach proposed by Baron and Kenny (1986) was followed.

$$\text{ORG} = \beta_1 \text{ INST} + \varepsilon \tag{1}$$
$$\text{TECH} = \beta_2 \text{ ORG} + \varepsilon \tag{2}$$
$$\text{RES} = \beta_3 \text{ TECH} + \varepsilon \tag{3}$$
$$\text{TECH} = \beta_4 \text{ INST} + \varepsilon \tag{4}$$
$$\text{RES} = \beta_5 \text{ ORG} + \varepsilon \tag{5}$$
$$\text{TECH} = \beta_6 \text{ ORG} + \beta_7 \text{ INST} + \varepsilon \tag{6}$$
$$\text{RES} = \beta_8 \text{ TECH} + \beta_9 \text{ ORG} + \varepsilon \tag{7}$$

where,

ORG = Organizational Forms
INST = Institutional Arrangements

Table 2. Descriptive statistics for the main constructs

Construct	**n**	**Min**	**Max**	**Mean**	**Std Dev**
Institutional Arrangements	215[2]	10.0	35.0	28.08	4.05
Organizational Forms	228	10.0	30.0	22.99	4.19
Enacted Technology	242	24.0	80.0	69.22	8.68
Results	233	26.0	100.0	83.28	12.83

Table 3. Pearson correlations coefficients for main constructs in the model

Construct	Instituti. Arrangmt.	Organiz. Forms	Enacted Tech.	Results
Instituti. Arrangmt.	1			
Organiz. Forms	0.33 **	1		
Enacted Tech.	0.45 **	0.43 **	1	
Results	0.46 **	0.42 **	0.71 **	1

*** p<0.01*

TECH = Enacted Technology
RES = Results

The approach consists of four steps that involve estimating independent regression coefficients to establish mediation. Consider for example the case of hypothesis 3, in which the effect of institutional arrangements on the enacted technology is mediated by organizational forms (see Figure 2). The first stage when testing this hypothesis involves testing relation "c" in Figure 2, showing that the institutional arrangements have an impact on the enacted technology. The second step consists of testing the relationship between institutional arrangements and the mediator, organizational forms (relation "a" in the figure). If any of these two relations are not statistically significant, then the data does not provide evidence of mediation. The third step involves testing the effect of the mediator (organizational forms) on the final variable (enacted technology), controlling for institutional arrangements (the initial variable). If this last relation is statistically significant, and the path "c" becomes zero when controlled by the mediator, then there exists full mediation. If both paths are statistically significant ("b" and "c"), there is partial mediation.

In this way, to test hypothesis 3, regressions (1), (4), and (6) will be used, testing the relation between institutional arrangements and the enacted technology, mediated by organizational forms. Regressions (1) and (4) must be statistically significant. In regression (6), β_6 needs to be statistically significant, and β_7 must be zero to show full mediation. If both coefficients β_6 and β_7 are significant, there will be only partial mediation. To test the relation between organizational forms and results, mediated by enacted technology, regressions (2), (5), and (7) will be used.

Table 4 summarizes the results of the seven regression models described. The first column in the table contains the regression equation number. The second and third columns represent the dependent and independent variables in each

Figure 2. Relations for testing indirect relationships (Baron & Kenny, 1986)

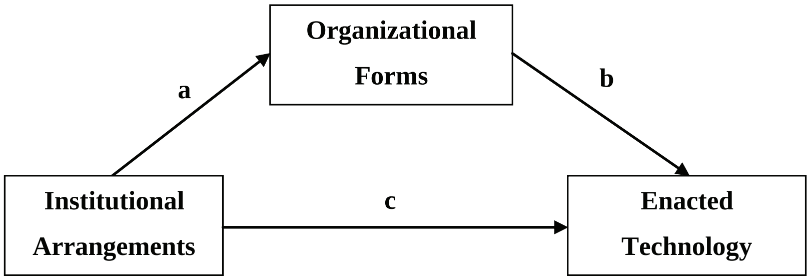


Table 4. Summary of regression results

Dep. Var.	Indep. Var.	B	R^2	F
Organiz. Forms	Institut. Arrang.	0.33***	0.108	24.97***
Enacted Tech.	Organiz. Forms	0.43***	0.183	49.05***
Results	Enacted Tech.	0.71***	0.506	229.8***
Enacted Tech.	Institut. Arrang.	0.45***	0.201	51.97***
Results	Organiz. Forms	0.42***	0.180	46.54***
Enacted Tech.	Organiz. Forms Institut. Arrang.	0.30*** 0.35***	0.278	39.70***
Results	Enacted Tech. Organiz. Forms	0.63*** 0.18**	0.528	114.7***

*** $p<0.01$*

**** $p<0.001$*

regression equation. Column 4 in the table presents the standardized regression coefficients for each model. The last two columns show the R-square value, and the F-test for each model.

Looking at the values in regressions 1, 2, and 3, it can be concluded that the survey data supports hypotheses 1, 2, and 4, finding significant direct relations between institutional arrangements and organizational forms, between organizational forms and the enacted technology, and also between the enacted technology and the results. It is important to notice that enacted technology explains more than 50% of the variance in results.

In the case of hypothesis 3, there is a significant relation between institutional arrangements and organizational forms, and also between institutional arrangements and enacted technology (regressions 1 and 4). Moreover, the relation between organizational forms and enacted technology is significant when controlling for institutional arrangements (regression 6). However, the relation between institutional arrangements and enacted technology is also significant when controlling for organizational forms. Therefore, the survey data supports a partial mediation of organizational forms on the effect of institutional arrangements on the enacted technology. It is important to note that the impact of institutional arrangements on enacted technology is greater than the impact of organizational forms on the same variable.

In the case of hypothesis 5, there is a significant relation between organizational forms and results (regression 5), and between organizational forms and the enacted technology (regression 2). Again, looking at the coefficients of regression 7, it is observed that survey data supports the existence of partial mediation of enacted technology over the relationship between organizational forms and results.

In summary, the regression analyses presented in Table 4 fully support hypotheses 1, 2, and 4, and partially support hypotheses 3 and 5, given that there is no full mediation, but only partial mediation of the relations in those hypotheses and, therefore, direct effects also exist.

CONCLUSION

Given the importance of information and communication technologies in government, it is also essential to understand key factors effecting its use and implementation. Five hypotheses based upon the technology enactment framework were proposed, in order to empirically test the theory, but also to get a better understanding of the relationships among institutional arrangements, organizational forms, enacted technology, and organizational results. In order to test the hypotheses, a survey was administered to participants of inter-organizational e-government projects in the Mexican federal government. Survey results allow to derive implications for both theory and practice.

Survey results suggest that the technology enactment framework (Fountain, 2001) can be potentially enriched with two additional causal relationships (see Figure 3). Although the original enactment framework suggests that the effects of institutional arrangements on the enacted technology are mediated by organizational forms, data from our survey also support a direct effect of institutional arrangements on the enacted technology. In fact, the effect of institutional arrangements is stronger than the effect of the organizational forms. Qualitative data from the survey and interviews to project managers support this additional causal relationship, too.

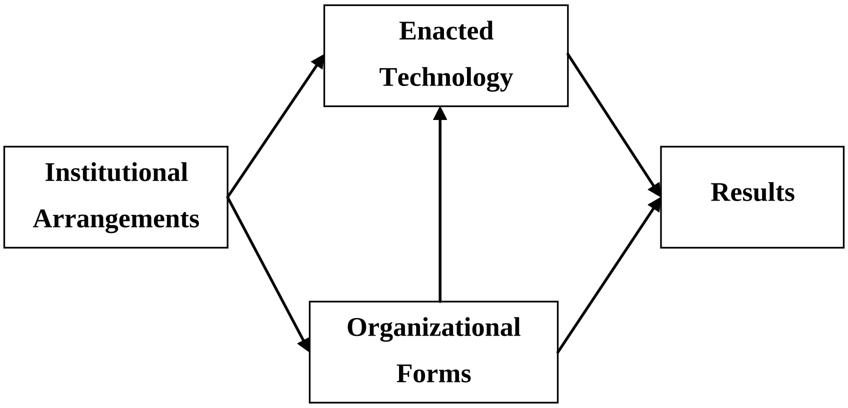
The whole Mexican IT strategy from 2000 to 2006 was driven by a presidential mandate. Moreover, particular technology enactments can be traced to mimetic mechanisms. For instance, many IT-related decisions are driven by best-practices research, or by current practices of a leading agency such as the Ministry of Finance, and sometimes it is difficult to trace IT-related decisions to specific problems or needs. As in many other countries, technology decisions and designs are either constrained or enabled by the legal framework and regulations. Budget cycles, for example, constrain the size of the IT project, which in most cases cannot extend for more than a year.

The second causal relationship suggested by the survey data establishes a significant relationship between organizational forms and results. More concretely, decisions on organizational structures, goals, and performance indicators not only affect a particular enactment, but also affect directly the results of the project. The e-Mexico program, for example, has as a strategic activity the installation of telecenters in the whole country. Accomplishing this task involves collaboration of the Ministry of Transportation, the Ministry of Education, the Ministry of Health, and the Ministry of Social Development, among others. Different organizational forms of these ministries have not only affected the particular enactment of the telecenters sponsored by each of them, but also constrained or enabled the impact of the telecenters in the community.

Thus, institutional arrangements have a direct impact on particular enactments, making lobbying activities even more important to ensure project success. Given that organizational forms constitute a context that also directly influences project results, process redesign is confirmed to be a key activity to succeed in e-government projects.

Additionally, survey data provides support for the direct affects of institutional arrangements on

Figure 3. Revised model as suggested by survey data



organizational forms, organizational forms on the enacted technology, and enacted technology on organizational results. Thus, culture, laws, regulations, and institutional support have an important effect on organizational forms as they are reflected in goals, defining indicators, or during human and financial resource allocation. Moreover, these organizational forms have an impact on the characteristics of particular enactments of technology. For instance, adequacy of human and financial resources, as well as well-defined goals and indicators, have an impact on technological characteristics such as utility, quality of information, or ease of use. Finally, characteristics of a particular enactment have an effect on the results of using technology in government. That is to say, system functionality and quality have a positive impact on the expected results as perceived by the respondents.

Although organizational forms and enactments are under the control of project managers, they usually have more difficulty influencing institutional arrangements in which the project takes place. However, those institutional arrangements effect and constrain the project manager's work. Thus, to be able to manage an effective project, every manager should use at least part of his or her time looking for strategies to promote institutional change. In the case of Mexico and the projects involved in this research, these institutional arrangements are especially important, considering that almost half of the respondents recognized that laws and regulations are in need of improvement. Moreover, intensive lobbying may be an important strategy, given the perception of inadequate support for e-government projects and inter-organizational collaborations from legislators.

On the other hand, survey results are encouraging in the sense that they support the idea that effective technology enactments will deliver results for government organizations. Then, given the adequate institutional arrangements, project managers can make organizational and technology choices to deliver results. Certainly, the promise is apparent if the technical requirements are well identified and proper project management techniques are used.

Finally, this work contributes to the field by providing empirical evidence for important causal relationships often cited in the literature, but with little empirical quantitative exploration. Furthermore, it provides empirical evidence of the existence of such relationships in a context different from the context in which the theory was created, providing evidence of the applicability of the theory in different digital government contexts, particularly in Latin America.

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ENDNOTES

[1] Spanish version of the survey can be obtained from the authors. Other questions in the survey are related to respondents' demographics, and other factors not reported in

this article. Questions used in each construct are listed in the appendix.

[2] Number of observations is smaller than valid response rate because we are not making any imputation to missing values.

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Chapter 5.15

Strategic Alliance Capability:
Bringing the Individual Back into Inter-Organizational Collaboration

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ABSTRACT

Internationalization has accelerated the speed of knowledge generation and innovation. Thus, companies increasingly need to pool and create new resources by engaging in alliances with various partners. However, high failure rates of strategic alliances imply that the degree of a company's collaboration success is related to the level of its alliance capability. While ”alliance capability” has largely been conceptualized from within the resource based and the dynamic capability view, one of the major drawbacks is the lack of micro-foundations, i.e. an explanation of individual knowledge and actions, which drive the development of alliance capability. A modified approach to the capability life-cycle is introduced, which aims at filling this gap. Finally, some implications for managerial practice and for future research are addressed.

INTRODUCTION

In the global marketplace, competitive advantages have become increasingly difficult to realize and many firms strive for new sources of knowledge and corporate growth. For many companies, strategic alliances have become a cornerstone in their expansion efforts because they facilitate access to new resources and wealth creation. Indeed, strategic alliances[a] can be considered a critical issue in the network economy, which is evidenced by both their rise in number and the variety of emerging forms, such as 'value networks', 'alliance networks' or 'alliance constellations' (Gomes-Casseres, 2003; de Man, 2005).

Motives for those 'loosely-coupled arrangements' (Weick, 1976) include easier access to foreign markets, economies of scale, accelerated development of technological capabilities, risk reduction and the acquisition and transfer of knowledge embedded in respective partners (e.g., Hamel, Doz and Prahalad, 1989; Larsson, Bengtsson et al.

1998). Yet, there is also widespread recognition that firms fail with roughly half of the alliances they form and there is considerable heterogeneity in terms of reported performance results (Bleeke and Ernst, 1993). Indeed, the inherent instability of strategic alliances has led both practitioners and researchers to focus on the intriguing question of what firms can do to enhance alliance results (Chang, Chen and Lai, 2008).

Previous research on the success factors of alliances has largely focused on structural and cultural aspects, presuming that these are the major drivers of effectiveness (Cartwright and Cooper, 1993). Only recently has attention been drawn to the fact that some firms are considerably more successful in managing alliances than others and the degree of a company's collaboration success has been linked to specific capabilities involved in managing these relationships (Wuyts, Dutta and Stremersch, 2004). With the recent hype of both the resource-based view (RBV) and the dynamic capability view (DCV) in strategy research, firm-specific factors, such as routines and capabilities, have been highlighted as antecedents of rent differentials (Nelson and Winter, 1982; Barney, 1991).

In this stream of research, the unit of analysis is no longer the relationship between firms, but a distinct organizational-level capability that is subject to dynamic processes of development, change, and improvement. Consequently, subsequent work has emphasized that alliance capability positively contributes to firm-level competitive advantage (Anand and Khanna, 2000).

However, it has also been suggested that the construct of alliance capability should be conceptualized on multiple levels, spanning individuals, groups, and organizations (Blomqvist and Levy, 2006). Unfortunately, studies which refer to *individual* alliance capability, or even comprise multiple level issues, are sparse and firms are left in the dark about adequate action perspectives for the individual manager (Johnson, Melin and Whittington, 2003). Part of the problem is due to the fact that traditional capability research adopts a collectivist focus, while neglecting micro-level foundations (Felin and Foss, 2004; Teece, 2007).

By building on these omissions, a deliberately individual focus is adopted to investigate the micro-foundations of alliance capability. This article provides the following contributions: *First*, a synopsis of previous research on alliance capability is presented and contributions and shortcomings are discussed. *Second*, by highlighting theoretical contributions from the RBV and the DCV, it will be shown that both offer valuable contributions to the conceptualization of alliance capability but do not sufficiently explain how capabilities develop. *Third*, by building on these omissions, a framework is proposed that considers individual contributions to the development of organizational alliance capabilities more thoroughly. *Finally*, some avenues for future research and some practical managerial implications will be suggested.

Strategic Alliance Capability: A Synthesis of the Literature

In this article, the terms of 'alliance capability' and 'strategic alliance capability' are used synonymously to signify those capabilities required to successfully manage a strategic alliance. 'Managing' is used as a generic term to incorporate all activities of an alliance life-cycle (see subsequent paragraphs). This section consists of a literature synopsis of the discourse domain (main terms, constructs, and developments). It further locates an important research gap in the lack of clear interrelations between individual-level origins and organizational-level alliance capability.

Definitions of Strategic Alliance Capability: The Formation of a Research Field

The recent literature on strategic alliances has paid considerable attention to either the very beginning of a collaborative activity and/or the ultimate end of the venture, while managerial issues in-between have been left understudied (Doz, 1996; Kandemir, Ghauri, and Cavusgil, 2002). For instance, Kogut (1988) adopts a life-cycle approach and describes the development sequences of joint ventures as those of creation, institutionalization and termination. Van de Ven and Walker (1984) introduce a stage model that explains the frequent decline of collaborative endeavours. They argue that the reason for the eventual dissolution is implicit in the formation stage, where structures are formalized and control mechanisms agreed. A number of authors have also gone beyond traditional linear stage models by suggesting cyclic relationships. For instance, Zajac and Olsen (1993) relate to the stages of initializing, processing and reconfiguration. During the initializing stage initial conditions are set. In the processing stage, learning takes place and first behaviour patterns evolve. Finally, in the reconfiguration stage, the collaboration is evaluated and this may lead to a revision of the original conditions. While all these research efforts have offered valuable insights into a large task-set associated with collaborative ventures, they fail to provide detailed knowledge of managerial responsibilities.

With the advent of ‘alliance or collaborative capability’, initial efforts were undertaken to fill this void. Focusing on specific capabilities to mange relationships became popular in academic discussion in the mid-1990s (Bucklin and Sengupta, 1993; Simonin, 1997; Lorenzoni and Lipparini, 1999). In the marketing and sales literature, interest concentrates on improving relationships between firms and their customers (Day, 1994; Storbacka, Strandvik and Grönroos, 1994; Crosby, Evans and Cowles, 1990; Sivadas and Dwyer, 2000). With regard to a firm’s business-to-business relations, Håkansson (1987: 124) defines ‘networking ability’ as “a firm’s ability to improve its position in a network (with regard to resources and activities) and its ability to handle individual relationships.” However, the concept remains rather vague and lacks operationalization.

In the management and strategy literature, Simonin (1997: 1151) was among the first to empirically investigate ‘collaborative know-how’, which he measures as the extent to which firms have skills in identifying, negotiating, managing, monitoring, and terminating collaborations. Subsequently, a large array of heterogeneous terms emerged, which amply illustrates the pre-paradigmatic stage of research. Some authors refer to ‘relational capability’ and argue that the ability to interact and share knowledge with other companies is a distinctive organizational competence for firms transactionally intensive in nature (Lorenzoni and Liparini, 1999; Dyer and Singh, 1998). Others use terms, such as ‘network management capability’ (Birkinshaw, 2000), or ‘network capability’ (Ritter, 1998; Walter, Auer and Ritter, 2006), ‘network ability’ (Håkansson, 1987; Hamel, 1991; Hamel, Doz and Prahalad, 1989) or ‘alliance capability’ (Draulans, de Man and Volberda, 2003; Kale, Dyer and Singh, 2002; Kale and Singh, 1999; Khanna, 1998). While the normal convention seems to be that alliances refer to bilateral and networks to multilateral relations, the use of terms has remained rather ambiguous.

Further research referred to ‘learning to manage alliances’ (Anand and Khanna, 2000) as an ability to anticipate and respond to contingencies that cannot be pre-specified in a formal contract. While the learning focus connects to dynamic cycles of alliance development, it has also been related to experience necessary to build alliance capability (Simonin, 1997; Kale, Dyer and Singh, 2002; Heimeriks and Duysters, 2007). Simonin concludes that a firm should first internalize collaborative experience before the lessons learned become useful for a firm’s future alliances. Others also focus on experience and learning effects and their presumed translation into future alliance success (Gulati, 1999; Kale, Singh and Perlmutter, 1999), but do not explain the associated aggregation problem. For instance, Gulati (1995) investigates the importance of prior ties and their influence on future modes of cooperation but does not explain *how* firms can successfully internalize experience. Anand and Khanna (2000) argue that experience plays an important role in the stability of inter-firm collaborations. As firms accumulate experience, their increasing abilities to anticipate and respond to critical contingencies are likely to enhance the chances of success in subsequent alliances.

In short, the majority of studies finds a positive and linear relationship between experiences and alliance performance (Anand and Khanna, 2000; Heimeriks and Duysters, 2007). However, it has also been argued that greater experience may be a necessary but an insufficient condition for firms to build alliance capability. This has been explained by the fact that firms differ in their abilities to appropriate knowledge from alliances (Kumar and Nti, 1998). As Chang, Chen and Lai (2008: 299) argue, “prior experience …may at best be a crude proxy for the precise mechanisms that build alliance capability [and] further alliance capability enhancement may rest upon how effectively a firm is able to capture, share, and disseminate the learnt know-how associated with prior experience”. In a related vein, relations between alliance experience and alliance performance have been found to follow a curvilinear pattern (Deeds and Hill, 1996; Hoang and Rothaermel, 2005) based on increasing conflict-resolution skills (Mohr and Spekman, 1994) and accumulated process know-how (Simonin, 1997).

Taken collectively, previous research has widely contributed to the formation of a new research field but developments have been hampered by scant attention given to precise definitions of alliance capability and its constituting elements. However, minimum consensus exists on the issue of alliance capability as being related to the stages of the alliance life-cycle. As succinctly summarized by Lambe, Spekman and Hunt (2002: 142) alliance capability is the “organizational ability to find, develop and manage relationships”. While this definition is useful because it includes dynamic aspects of change - which preview an investigation from a dynamic capability perspective (see subsequent chapters) - , it does not provide much insight into what *exactly* constitutes the construct of alliance capability.

Elements of Strategic Alliance Capability

What makes up alliance capability has so far remained rather elusive (Gulati, 1998). However, there have been a few selected attempts to more precisely identify its elements. For instance, Ritter and Gemünden (2003) distinguish between the tasks that need to be performed in order to manage a company’s technological network and the qualifications, skills, and knowledge that are required in order to perform these tasks. More precisely, tasks refer to relation-specific (e.g. initiation of first partner-contacts, exchange of products and information, coordination of exchange) and cross-relational tasks (e.g. analysis and planning, organizing and staffing). Network management qualifications involve a complex process, which requires specialist knowledge of the technical side of the relationship and social qualifications. Both types of elements are seen as being highly interdependent. While the authors conclude that their study highlights a firm’s ability to initiate, handle, and use a portfolio of inter-organizational relationships, they seem to confuse the individual and organizational units of analysis. Related research proposes that cooperative competency consists of the ability of the partners to trust, communicate, and coordinate (Sivadas and Dwyer, 2000) with social skills being explicitly emphasized as a complement to structure-related elements of alliance capability (Lawler and Thye, 1999; Prange, Bojkowszky and Wieshofer, 2004).

One of the most comprehensive investigations of alliance capabilities and their elements has been provided by Schreiner and Corsten (2004) and Schreiner (2004), who empirically investigated the components of what they call ‘collaborative capability’. They suggest that capabilities in a collaborative context consist of structural, cognitive, and affective elements.

Structural capabilities, according to their view, include the build-up and maintenance of human resources, partner-specific tangible and intangible assets, as well as time-management and investment strategy (so-called resourcing elements). Further, coordinative elements are subsumed under this category, e.g. partnership and task management, interaction routines, process standardization and personnel continuance. *Cognitive capabilities* refer to the existence of absorptive capacity as the ability to assimilate and exploit new information to foster learning (Cohen and Levinthal, 1990) and the potential to effectively communicate. Finally, *affective capabilities* consist of care-giving and empathic abilities. Again, this study provides important input for a better understanding of alliance capability but suffers from two major drawbacks: It does not clearly link alliance capabilities to the associated alliance life-cycle, and, more importantly, it neglects the linkage between individual skills and organizational routines.

Levels of Strategic Alliance Capability

The previous omissions are also prevalent in subsequent work, where either life-cycle and *organizational* capabilities or *individual* skills are emphasized. The former most often suggests improving specific tasks, such as the codification and transfer of information within ‘dedicated alliance functions’ (Anand and Khanna, 2000; Dyer, Kale and Singh, 2001) or implementing ‘organizing principles’ for the internalization of alliance management know-how (Kale, Dyer and Singh, 2002). These capabilities are seen as being embedded in organizational routines, which are repetitive activities a firm applies in order to deploy its resources available in and through alliances (Nelson and Winter, 1982). In addition, alliance training, alliance metrics and evaluation systems, best practice programmes as well as external support by consultants, lawyers, and financial specialists have been suggested to support those routines (Heimeriks and Duysters, 2007). Taken collectively, the locus of this stream of research remains an abstract phenomenon of alliance capability, which almost completely neglects the concrete contribution of the individual in inter-organizational research.[b]

On the other hand, there is a variety of studies, which places major emphasis on *individual* skills and their impact on collaboration. Scholars have argued that strong interpersonal ties provide channels through which partners learn about other firm’s competencies and reliability (Gulati, 1999). From this perspective, relational capital which rests upon close interpersonal ties at the dyadic level can also play an important role in creating and building larger alliance networks (Kale, Singh and Perlmutter, 2000: 218). Draulans, deMan and Volberda (2003) examine whether it may be useful to concentrate alliance knowledge and experience in certain individuals. While middle management is regarded as potentially suitable for such activities, they focus less on the respective capabilities for managing relations. McGee, Dowling and Megginson (1995) concentrate on experience-based collaborative capabilities and analyze the question as to whether inexperienced managers should cooperate to gain new knowledge or rather avoid it unless they are experienced enough to know what they don’t know.

In short, various research has emphasized elements and levels of alliance capability albeit in a rather disconnected manner. However, preliminary suggestions have been made to consider alliance capability as a *multi-dimensional* and *multi-level construct*, in which elements and levels are closely interlinked and mutually reinforcing (Schreiner, 2004; Blomqvist and Levy, 2006; Dansereau,Yammarino and Kohles, 1999). While studies tend to emphasize single levels of analysis or refrain from clear level specifications, a notable exception is the research by Buckley, Glaister and Husan (2002), who investigate managers' 'partnering skills' in cross-cultural joint ventures and distinguish between national and macro elements, industry or sector level factors, organizational and firm levels, and the perceptions of individual managers.

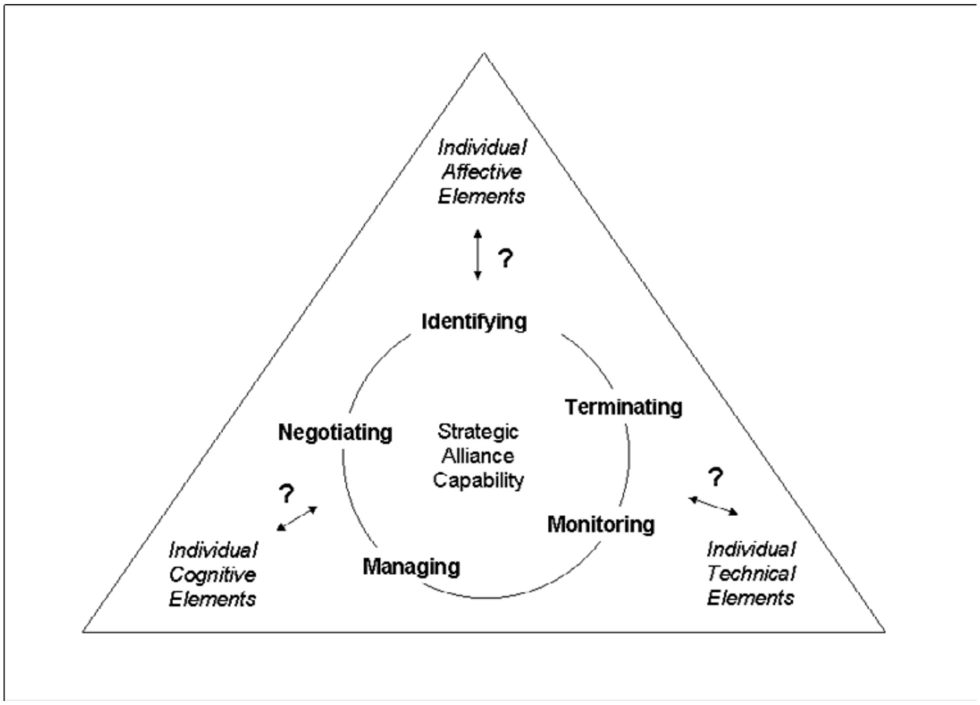
Figure 1 builds on this approach and provides a generic overview of the previous debate with a particular emphasis on the levels of the individual and the organization. Categorical labels for elements are borrowed from Schreiner (2004) but clearly relate to the individual. Further, the notion of structural elements is replaced by 'technical' because the former has too close an association with organizational structures. Arrows in the figure indicate that linkages between individual elements and organizational alliance capability are largely missing in the literature.

Part of the confusion on levels and definitions can be traced back to the theoretical origin of resource and capability definitions within strategic management research. Indeed, as research within the RBV and the DCV itself can still be considered in its infancy (Helfat, 2000), it is not surprising that theoretical contributions lack precise insights into the black box of alliance capability (Priem and Butler, 2001).

THEORETICAL FOUNDATIONS OF STRATEGIC ALLIANCE CAPABILITY

As a theoretical foundation of explaining alliance capability, both the resource-based view and the dynamic capability view of strategy have been suggested (Kale and Singh, 2007). The dynamic capability view extends the argument by departing from the static notion of resources.

Figure 1. Elements of strategic alliance capability



As capabilities for new market entry relate to multiple environments, it is important for a firm to constantly reconfigure its alliance capability. Hence, a dynamic capability view offers a suitable theoretical foundation as it suggests some leeway for learning, integrating, building and reconfiguring internal and external competencies (Teece, Pisano and Shuen, 1997).

Resource-Based View

The RBV considers firms as bundles of resources, which form a prerequisite for achieving and sustaining competitive advantage (Rumelt, 1984; Wernerfeld, 1984; Barney, 1991; Prahalad and Hamel, 1990; Amid and Schoemaker, 1993). The major argument of the RBV is that firms are able to accumulate resources and capabilities that are rare, valuable, imperfectly inimitable and imperfectly substitutable (Barney, 1991; Wernerfeld, 1984). Consequently, a firm's performance is fundamentally due to the heterogeneity of its resources and their persistence over time rather than to industry structure as argued in the market-based view of the firm (Porter, 1980). In exploring this approach, I concur with recent contributors to the literature, who distinguish capabilities from resources (Grant, 1991; Mahoney and Pandian, 1992; Teece, Pisano and Shuen, 1997). *Resources* refer to "all assets, capabilities, organizational processes, information, knowledge, etc. controlled by a firm that enable the firm to conceive and implement strategies" (Barney 1991: 101), i.e. assets pose an input to production. In contrast to resources, organizational *capabilities* refer to an organization's ability to perform a coordinated set of tasks, utilizing and leveraging organizational resources, for the purpose of achieving a particular end result (Amit and Schoemaker, 1993; Helfat and Peteraf, 2003).

The distinction is not completely selective but it has been recognized that capabilities are required to leverage resources and it is therefore capabilities, which provide the essential basis of competitive advantage. As related to alliances, it has been argued that the factual collaborative relationship should be considered a resource, while alliancing as a managerial process has tentatively been mentioned as a capability (Eisenhardt and Martin, 2000:1106). Further, it has been suggested to consider alliance capability as a *meta-capability* (Blomqvist and Levy 2006), directed at improving the lower-order capability of alliancing (Winter, 2000; Kale and Singh, 2007).

According to Simonin (1997), 'collaborative know-how' or 'alliance capability' also fits each of the criteria for turning resources into competitive advantage.[c] Managing alliances is obviously valuable as collaboration enhances a company's flexibility required for building future options. According to conventional logic, it is also a very rare capability given the extensive failure rates of cooperative undertakings. The third criterion, imperfect inimitability, relates to the fact that alliance capability is often complex knowledge rooted in the social fabric of an organization. Finally, alliance capability is difficult to substitute because it is acquired during a period of experiential learning, which is most likely company-specific.

Whether alliance capability is completely experience-based or can be acquired via training (Draulans, de Man and Volberda, 2003) and whether this knowledge can be transferred across companies is an issue which requires further research. This also refers to the nature of alliance capability as related to its transfer among different units within or between companies. The literature is full of classification schemes and examples of both resources and capabilities, which provide helpful guidance. Amit and Schoemaker (1993), for example, refer to capabilities as tangible or intangible assets, which are firm-specific and created over time. Hall (1992, 1993) further distinguishes between intangible/tangible and person-/non-person-based resources and capabilities. Tangible resources include technology, production machinery, facilities, etc. whereas intangible resources range from property rights, trade secrets, public knowledge to know how, organizational culture, etc. (Hall 1992: 135). Intangible resources, in contrast, rely more on a personal momentum whether this be perception, implicit knowledge or person-based learning (Itami and Roehl, 1987). Generally, it has been accepted that the value of a company derives to an increasing degree from its availability of those 'intangible assets' as proven in the difference between market and book value. The related distinction between person and non person-based resources and capabilities resembles the recent discussion in organizational learning and knowledge management. In this stream of research, scholars accept that organizational level constructs rely on individual processes, which have become institutionalized over time (e.g. Kim, 1993; Prange, 1999; Maier, Prange, von Rosenstil, 2001).

Dynamic Capability View

The DVC defines 'dynamic capabilities' as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Teece, Pisano and Shuen, 1997: 516). It is explicitly mentioned that dynamic capabilities consist of specific strategic and organizational processes that create value for firms within dynamic markets by manipulating resources into new value-creating strategies (Eisenhardt and Martin 2002: 1106). Despite slight variations in definitions, consensus has emerged that capabilities are made up of organizational routines, which make use of and deploy combinations of various assets. Eisenhardt and Martin (2002) further argue that dynamic capabilities as such cannot be a source of competitive advantage, instead they need to be applied and the ability to change them quickly is a major asset. Collis (1994) is particularly explicit in making the point that dynamic capabilities govern the rate of change in ordinary capabilities given path dependencies and market positions.

Draulans, de Man and Volberda (2003) present an exceptional case, when they consider alliance capability from a DCV-perspective, emphasizing the development of capabilities by the absorption of inside and outside knowledge. This process supposedly consists of identifiable and specific routines which, at best, are deeply anchored within the organization. At a more strategic level, dynamic capabilities involve those routines that are required to reconnect single relationships into a web of collaborations between alliance partners to generate ever changing resources among businesses. In stable markets, alliance capability resembles the traditional concept of routines, i.e. repetitive action based on sophisticated organizing processes that rely on existing knowledge (Nelson and Winter, 1982; Eisenhardt and Martin, 2000). The situation is different, when firms operate in dynamic markets where capabilities require adaptation. As dynamic markets are not always predictable, these 'routines' are often simple, exhibit experiential components and are situation-specific applied (Eisenhardt and Galunic, 2000). This is why Eisenhard and Sull (2001) introduce the concept of 'simple rules' where competitive advantages come from successfully seizing fleeting opportunities. Guided by a few strategic processes, these simple rules should place a company where new challenges are swiftest and deepest.

This also previews particular developmental processes, which require multiple testing and imply several pathways to successfully creating relevant knowledge.

Figure 2 summarizes the previous discussion and presents some examples, where a distinction is drawn between both an alliance relationship (a resource) and the skills of managing it (a capability). Resource and capability are inextricably intertwined and exhibit both tangible and intangible components.

For instance, alliance mindset incorporates an understanding of alliances as 'first best strategy', which has been regarded as an important precondition for successful collaboration. Similarly, com-

Figure 2. Alliances as resources and alliance capabilities

	Alliances as a Resource	**Alliance Management as a Capability**
Intangible	Culture, alliance strategy, human resources dedicated to the alliance, etc	Alliance mindset (commitment/ trust); implicit and explicit learning about alliances, etc.
Tangible	Structure (nature of contract, governance structure, facilities, IT infrastructure), location, etc.	Codified alliance knowledge (alliance functions, databases, handbooks, guidelines), etc.

mitment and trust are further implicit components of alliance capability. These are complemented by hard factors, such as handbooks, guidelines, benchmarking procedures as to how alliances can best be implemented. These manifestations of alliance capability only contribute to performance outputs if related to the resources of the alliance, which consist of the factual alliance, i.e. its strategies, human resources, structures and governance issues, etc.

The resulting challenge for managerial practice remains how heterogeneous (alliance) capabilities like routines, guidelines or simple rules are supposed to be created by homogeneous individuals in firms - an implicit, but questionable, assumption of resource-based theorizing (Henderson and Cockburn, 1994) - , and how individual action can be transferred into successful organizational behaviour within inter-organizational settings. An answer to these questions is likely to arise from insights into how the collective construct of alliance capability emerges.

DEVELOPING ALLIANCE CAPABILITY: THE CONTRIBUTIONS OF THE INDIVIDUAL

Little is known so far how capabilities arise in the first place. Research from within the resource-based tradition has provided a few hints that, taken together with traditional approaches of knowledge management, present some input into the evolutionary process of alliance capability. Building on these inputs, I suggest a model of alliance capability development, which adds individual knowledge and action as antecedents. I further suggest a more detailed analysis of micro-foundations in order to understand alliance capability differentials between firms.

The Process of Capability Development

The process of capability development can start from different vantage points and often takes unique paths, i.e. it exhibits high degrees of equifinality (Eisenhardt and Martin, 2000). While the literature does not offer straightforward answers to the question of how capabilities are generated, authors seem to agree on repeated practice and experience. Thus, new routines or capabilities build on previous ones, i.e. “firms tend to do what they have done before” (Kogut and Zander, 1995: 425). In a similar vein, Zollo and Winter (2004) argue that ‘experience accumulation’ constitutes organizational routines by skill building based on the repeated execution of similar tasks, an insight shared with the literature on learning curves (Argote, 1999). They further emphasize that experiential learning is largely based on tacit knowledge, which is often applied in a semi-automatic way.

Apart from experiential learning, the authors introduce two further learning processes, borrowed from Nonaka's (1994) conception of knowledge management. First, 'articulation' is seen as a deliberate process by which individuals share their knowledge on what works and what does not. This may be facilitated through collective discussions, debriefing sessions, and performance evaluation processes which help to make implicit knowledge more transparent. Second, 'codification' occurs when individuals transfer their understanding into written tools, such as manuals, blueprints, or decision support systems. Through the co-evolution of these processes capability development is presumed to occur.

One of the few studies, which explicitly refers to alliance capability and its *developmental process* via institutionalizing was undertaken by Dyer, Kale and Singh (2001). The authors empirically investigated 78 companies and indicated that the investment in an alliance function serves as a vehicle for transferring individual into company-based collaborative know-how. Draulans, de Man and Volberda (2003: 152) argue that "like any other competence, the management of alliances is a skill that can be built up and can become a significant source of competitive advantage." Ritter and Gemünden (2003) relate to 'organizational' antecedents of network competence and identify access to resources, network orientation of human resource management and the integration of formal and informal structures as well as an openness of organizational culture as being important.

While there have been several attempts at explaining capability development, there is only anecdotal evidence of the important role of the individual. This is not surprising given the fact that collectivist notions of capability research typically sidestep critical individual-level considerations, including individual action and heterogeneity (Felin and Foss, 2004, 2005). But as the authors remark:

"individuals matter…[and] to fully explicate organizational anything – whether identity, learning, knowledge or capabilities – one must fundamentally begin with and understand the individuals that compose the whole, specifically their underlying nature, choices, abilities, propensities, heterogeneity, purposes, expectations and motivations" Felin and Foss (2005: 441).

The Capability-Life-Cycle Revisited: Towards Micro-Foundations of Alliance Capability

In order to more fully capture the role of individuals in the development of capabilities, the life-cycle approach, as suggested by Helfat and Peteraf (2003), is used as a basic model. Each stage of the original model will be complemented by individual antecedents that help to explain heterogeneity in alliance capability.

The concept of the capability life-cycle "depicts a general pattern and set of possible paths that characterize the evolution of an organizational capability" (Helfat and Peteraf, 2003: 1000), which can be related to the development-cycle of an alliance (see introductory sections) even though the two need not necessarily coincide. Organizations with no heritage in collaboration ('new to the world of alliances') start in the *founding phase* with no previous alliance experience that might influence alliance capability development. However, this stage cannot be seen as a clean slate as individuals may have previous experience with alliances obtained elsewhere.

Individual Level Contributions in the Founding Phase

Before joining an organization, several of the key elements of alliance capability may be influenced by individuals' earlier skills and knowledge related to specific alliance partners and individuals in partner firms. Adner and Helfat (2003) refer to this as 'managerial human capital', i.e. learned skills based on some investment in education, training, or learning. As identified earlier, there may be different types of individual skills, which influence the development of alliance capability. For instance, in a more general way, Castanias and Helfat (1991) distinguish between generic, industry-specific, and firm-specific skills. As shown elsewhere (Prange, Bojkowszky, & Wieshofer, 2004), there are some industries – like biotechnology – where industry-specific skills dominate all other elements of alliance capability. Thus, industry experience may be a selection criterion for prospective alliance managers.

Further, specific alliance roles may exist, e.g. as negotiator or implementer of an alliance, which require some leadership experience or the existence of specific personal traits. Indeed, Rosenbloom (2000: 1102) suggests that leadership by individuals may be a 'central element' in the more general dynamic capability development. There may also be self-selection processes in that only those individuals who have the presumed skills to manage an alliance enter the firm. This initial endowment with skills provides a source of heterogeneity to alliance capability development.

Iindividuals check available knowledge (e.g. via observation) and start a learning process on which they build their action ('learn-act-sequence'). This is the typical incremental and largely cognitive learning approach, which gradually develops knowledge through training and information search. From this initial starting point, two trajectories are possible. First, after reflection and continuous successful action, knowledge is transferred into organizational capabilities by processes of articulation and codification (Zollo and Winter, 2004). Installing these processes adds to the strategic development of knowledge in and about the alliance. As a result, emerging capabilities are made up of routines derived from thorough reflection and stable behaviour patterns. With repeated experience, accumulated knowledge eventually transfers into sedimented knowledge from which quasi-automatic behaviour is generated. In turn, these organizational routines influence individual action.

Secondly, when transferring experience in rather volatile environments, individual experimentation ('act-learn') may also lead to the establishment of simple rules as an expression of alliance capabilities. These are the bases of competitive advantage, where companies simply 'jump' into the market, experiment, test opportunities and shift frequently among partners and businesses as circumstances dictate. Still, there are some principle rules underlying this seemingly chaotic process, which could be the conscious play with market uncertainty, the seizing of several selected opportunities, strategic creativity induced on a permanent basis or the introduction of 'serious play' (Schrage, 2000) as a means of strategy formulation. All these simple rules open up scenarios without limiting a company's future choices by deadlocked routines.

Both reflective action and experimentation lead to different manifestations of alliance capabilities. In the same way as individual learning modes are dominated by one process or build on the logic of both 'thinking and experiencing', these different types of capabilities may interact over time, when flexible rules become more stabilized and stable routines need to be broken up to allow for more flexibility. For instance, when a firm opts to increase the heterogeneity of its alliance partners, past routines may prove detrimental as they do not capture what is new. When firm-level routines turn negative, differing personal endowments can prevent such a lock-in.

Individual Level Contributions in the Development Phase

Pursuing experimental learning processes in order to build 'simple rule-based capabilities' is closely linked to an individual's risk propensity as performance outcomes are highly uncertain. As outputs cannot be anticipated, a tolerance for mistakes is important. Most often, simple rules are tacit and it takes conscious effort to make them explicit and extend them as business unfolds. At the same time, these capabilities consist of a few rules that make them amenable for easy adoption. For instance, CEO Meg Whitman made Ebay's values explicit in simple rules that helped managers to predict what opportunities would work for the company and how they could be adapted (Eisenhardt and Sull, 2001). Given the fact that individuals need to actively engage in the articulation of tacit knowledge, motivational incentives become important (Osterloh and Frey, 2000) as well as cognitive skills, i.e. mental models and beliefs, which determine information search and opportunity seizing in the process of updating existing knowledge components (Hambrick and Mason, 1984).

In contrast, the emergence of stable routines may rather start from initial imitation of already existing capabilities in other organizations (benchmarking of best-practice alliance capabilities), where less individual creativity is required. In order to arrive at sufficient diversity in individual knowledge input, alliance human resource management is challenged to control adequate knowledge inflows. These are presumably tied to different types of motivational incentives.

Reaching maturity with a selected partnership, the development of capabilities may either come to a standstill as there may be satisfaction with what can be achieved, or is deliberately ceased in the process of alliance capability development. While current capabilities may be perceived as influential for performance outputs, this relationship could be blurred by perception gaps or aspiration level definitions. Therefore, complacency with existing capabilities could easily incur lock-in effects, which negatively impact alliance results.

Individual Level Contributions in the Maturity Phase

Individuals may exhibit different levels of skilfulness prior to reaching the full technical limits of capability development (Helfat and Peteraf, 2003: 1002). This may be due to differences in previous education and learning behaviour. Personal satisfaction levels may also differ due to cognitive processes like perception, sensing, opportunity seizing (Teece, 2007). When capabilities consist of simple rules, the problem of causal ambiguity emerges, i.e. comprehensive experiencing activities obscure the fundamental commonalities that drive the effectiveness of the capability. Thus, managers may not know themselves whether and why capabilities are successful and more cognitive effort is required to critically challenge established rules. Also, hierarchical positions in the organization may influence how far capability development is continued. For instance, the strength of influence from the top may have relevant consequences on capability development (Adner and Helfat, 2003: 24). Managers' ability to interpret their company's previous alliance experience also varies profoundly across hierarchical levels, with higher-level actors having more difficulty interpreting feedback from action than lower-level actors (Gavetti, 2005). Thus, variability in decision-making style, speed and implementation act as a driver of heterogeneity in alliance capabilities. Further, aspects of power and incentive systems are supposed to play a crucial role which warrants further attention (Shenkar and Ellis, 1995).

Figure 3 provides a summary of individual actions and some of their micro-foundations that influence the development of alliance capabilities.

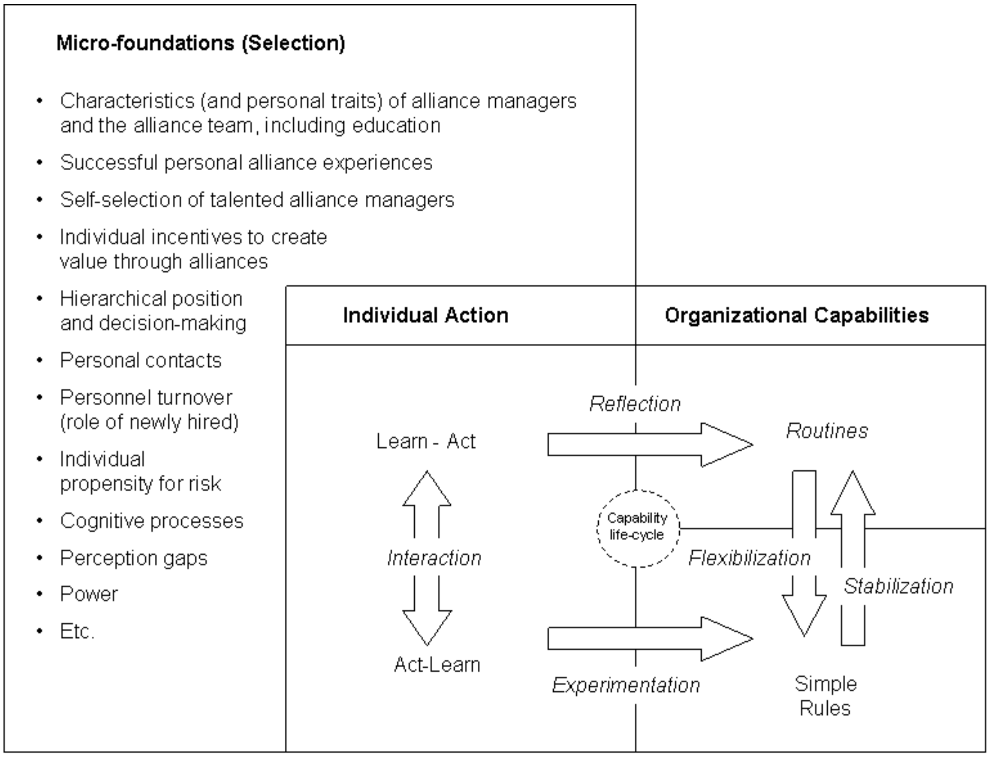
In short, the learn-act sequence pays attention to the fact that there are 'intendedly rational' individuals, who cognitively engage in knowledge generation as a basis for alliance capabilities. With a lower cognitive involvement, experimentation and tacit learning through trial and error contribute to a more flexible type of alliance capability, which is less subject to routine but could be equally effective in turbulent markets. This act-learn sequence can be characterized by an ongoing process of experimentation accompanied by retrospective sense-making and the repetition of successful behaviour sequences. In fact, different learning mechanisms contribute to different manifestations of capabilities (simple rules and routines) mutually related over time to avoid the pitfalls of over- or under-specification. While the role of the individual is emphasized in this figure and attention is directed to several micro-foundations, the opposite process from organizational capabilities driving individual behaviour, as one of the traditional assumptions of resource-based theorizing, still holds true but is neglected in the figure.

DISCUSSION AND CONCLUSION

This article has provided a discussion of the recently fashionable construct of 'strategic alliance capability', its conceptualization and theoretical origin. Resource-based and dynamic capability approaches were used to incorporate 'alliance capability' into the overall framework of resource and capability-based theories. Thereby, an analysis of alliance capability both benefits and suffers from the theoretical promises and pitfalls of resource-based theorizing.

As one of the major difficulties, it has been mentioned that the RBV defines resources and capabilities in a conceptually vague and non-operational way (e.g. Priem and Butler, 2001). Yet, strategic alliance capability exists in several exactly identifiable elements along the cooperative life cycle, which have selectively given rise to empirical studies. Further, the RBV has been criticized as being relevant only for stable markets. This criticism has been encountered by the DCV, which modifies the quest for sustainable advantage into a temporary one as resources and capabilities undergo constant changes. One of the major omissions in both the RBV and the DCV relates to the lack in dealing with individual-level antecedents of alliance capability. In order to fill this void, individual contributions on each stage

Figure 3. Individual foundations and processes of alliance capability development



of the alliance capability life cycle have been introduced.

Several questions can be derived from this model, constituting a future promising research agenda. First, differential learning processes pose several challenges, e.g. how do managers react to environmental turbulences and update their individual knowledge portfolio? Is there an optimal speed for experimental learning and are there given boundaries to the codification of individual knowledge into organizational routines? How do cognitive constraints influence processes like rapid learning, real-time information, multiple options and their impact on existing routines within an organization? When referring to reflective cognitive learning, it would be interesting to know how far previous education or industrial affiliation influences reflection processes? Further, are there previous personal contacts, which facilitate (or impede) the building of social skills as an important element of alliance capability?

As the concept of simple rules illustrates, there are different manifestations of capabilities and further research should more closely match these types of capabilities to specific contingencies. Closely related is the question whether it is generally valid to institutionalize knowledge in rapidly changing environments? Whereas previous studies suggest the implementation of a dedicated alliance function, which coordinates all alliance-related activity within the organization and initiates the transfer of both tacit and explicit alliance knowledge, the flexibility aspect has not been considered. The inherent danger might be inflexibility and overly bureaucratic procedures, which retard or prevent corporate flexibility. Thus, an important research direction is the exact interplay of more stable (routines) and flexible (simple rules) types of capabilities.

Finally, the exact sequence and the particular form of knowledge created and transferred in each step of the cooperative life-cycle both require further empirical analysis. This includes a specific emphasis on the contribution of individual knowledge components and learning processes as well as hierarchical positions and power relations which may have an impact. In more detail, several of the aforementioned micro-foundations pose a research agenda in their own right depending on the research question. For instance, hierarchical roles may serve as an important element of heterogeneity, which may be tailored to specific environmental setting and subsequent performance results. Also, the issue of personal traits offers intriguing challenges for future research, e.g. whether someone is particularly suited for combining different learning processes or whether these should be split between different people in order to guarantee a variety of alliance capabilities at the organizational level.

Also, several managerial implications spring to mind. Once precise micro-foundations of alliance capabilities are identified, human resource practices (selection, incentive systems, motivation) within alliances could be tailored to promote the development of required organizational level routines. As a result, the capability-performance link might be more effectively managed as the relation is highly dependent on environmental conditions and specific types of alliance capabilities. Finally, potential negative effects of (alliance) routines could be avoided by paying attention to those individual antecedents which stir up the system of stable but unproductive capabilities. Thus, management can add more flexibility to the process of capability generation and its dynamic adaptation to changing contingencies.

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ENDNOTES

[a] In this research, 'strategic alliance' is used as a generic term to signify voluntary and planned inter-organizational collaboration between, at least, two partners (e.g. Contractor and Lorange, 1988; Yoshino and Rangan, 1995) and does not consider differences within individual forms, such as joint ventures (JVs), licensing arrangements, partnerships, and others. However, the researcher wants to attract attention to the fact that this is a worth-while effort, which should be undertaken in other studies.

[b] This is a typical approach in inter-organizational research. As Osborn and Hagedorn (1997: 271) in citing Larson (1992) say: "Almost lost in the empirical study of alliances is the importance of the experience and predisposition of the individual using them…The potentially important role of individuals in operating alliances remains virtually unexplored".

[c] Even though he does not further distinguish between resources and capabilities, in principle, I share his argument as applied to alliance management as a capability.

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Chapter 5.16

Product Customization on the Web:

An Empirical Study of Factors Impacting Choiceboard User Satisfaction

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ABSTRACT

Choiceboards are Web-based systems that allow consumers to customize their orders. The study investigated factors that affect consumers' intention to use choiceboards. The research is based on Masons' theory and DeLone and McLean's model of information system use. It was found that intention to use is affected by overall satisfaction. In turn, these two factors are positively impacted by factors such as system quality and information quality. In spite of support from theory, the evidence for the factor, information presentation was weak.

INTRODUCTION

E-commerce is coming of age (Markillie, 2004). Sales in the year 2003 exceeded $55 billion, and revenues in 2004 are expected to be at least 20% higher (Syre, 2004). The total impact of e-commerce, however, cannot be expressed in simple sales figures; rather, it lies in changing consumer behavior. Increasingly, consumers visit the Web site of a company to familiarize themselves with the firm's offerings and prices before deciding to buy. A Web site is becoming the gateway to a firm's brand, even in the case of off-line firms. Companies that realize the importance of their Web sites use technologies such as e-mail, FAQ, online customer support, bulletin boards, and search engines to assist customers in the buying decision process and, obviously, to persuade a purchase of their product.

The choiceboard is a recent addition to this repertoire of technologies, aiding consumers in the decision-making process (Andal-Ancion, Cartwright, & Yip, 2003; Bharati & Chaudhury, 2004a; Collins & Butler, 2003; Liechty, Ramaswamy, & Cohen, 2001; Slywotzky, 2000). A choiceboard is a system that allows customers to design their own products by choosing from a menu of attributes, components, prices, and delivery options (Slywotzky, 2000). For example, in the automobile industry (buyatoyota.com), users can "build" or customize a Toyota and then follow up with a local dealer. In the construction industry (kitchens.com), users can get help to design a kitchen and actually place an order. In the apparel industry (acustomtshirt4u.com), users can select color, fabric, and a suitable logo and lettering. In the entertainment industry (www.apple.com/itunes), customers at the itunes music store can build customized CDs by selecting individual tracks from existing CDs. Finally, in information technology, the Web sites of most computer firms (e.g., www.ibm.com) present individuals with a basic configuration defined by a processor and then flesh out the full configuration with choiceboards, offering hard-drive size, memory, and add-ons such as CD/DVD drive, monitors, and printers.

Although choiceboard technology is being used widely to enhance the customer's experience, very little is known about the actual impact of this technology on overall user satisfaction or on the intention to use the choiceboard. Similar concerns have been expressed for Web-based decision support systems (Bharati & Chaudhury, 2004b). In particular, it remains unclear how the provision of more information, facilitation of decision making through what-if analysis, and choice comparisons through the use of choiceboard technology affects user satisfaction and the intention to use. In this research, the relationships are developed and operationalized between system-level factors (i.e., quality of the system and information in choiceboards and presentation of information) and user's decision making and interface satisfaction. Furthermore, the analysis investigates the relationship between information and decision-making satisfaction, with overall satisfaction and intention to use. The statistical analysis consists of path analysis, assessing a pattern of predictive relationships among the measured variables. This research employs the Structural Equation Modeling (SEM) technique to analyze the data and then to assess the pattern of predictive relationships.

The research views information systems' success in the new domain of e-commerce and, in particular, in the context of choiceboard systems. It attempts to understand how choiceboards facilitate user decision making in the Web-based environment. It then develops a conceptual model that relates system-level factors, user satisfaction factors, and use factors. Specifically, it investigates interrelationships between components of user satisfaction (i.e., interface satisfaction, decision satisfaction, and overall satisfaction) and their combined impact on intention to use.

LITERATURE REVIEW

The research is related to multiple theories such as the consumer decision-making model (Mowen, 1995), consumer information processing model (Bettman, 1979), cognitive decision-making model (Simon, 1955), and information systems (IS) success model (Delone & McLean 1992, 2002). According to Mowen (1995), a consumer transits through several phases, such as problem recognition, a search for alternatives, and an evaluation of alternatives, before making a choice; that is, there is an information-processing phase and then a decision-making one. In this process, a consumer tries to minimize the cognitive effort required to make a decision and yet maximize the quality of the decision reached (Bettman, 1990). Furthermore, Bettman (1990) suggests that because of bounded rationality constraint (Simon, 1955), consumers actually will trade off decision quality for a reduction in information processing effort.

Consumers employ decision aids such as calculators, spreadsheets, consumer guides, and Web-based comparison pricing in order to lessen the impact of bounded rationality constraints on decision quality. E-commerce retailers are incorporating choiceboards on their Web sites in order to assist customers in several phases of the decision-making process (Bharati & Chaudhury, 2004a, 2004b). The information search phase, for example, is facilitated by easy revelation of product alternatives, and the decision-making phase of alternatives evaluation is made easier by price and feature comparison. The IS success model (Delone & McLean 1992), with its focus on issues relating to information processing and decision making and its previous research on Web-based DSS (Bharati & Chaudhury, 2004b), is useful in investigating the role of choiceboards in assisting users. In the recent literature, this model has served as the basis for investigating similar research areas such as IS and service quality (Bharati & Berg, 2003). The research on quality of information systems services (Jiang et al., 2000, 2002; Kettinger & Lee, 1997, 1999; Pitt et al., 1995, 1997; Van Dyke et al., 1997, 1999; Watson et al., 1998) and WebQual (Loiacono et al., 2002) also has attempted to investigate this topic in a slightly different way.

Communications theory (Shannon & Weaver, 1949) was illustrated and modified in Mason's (1978) work to show that classes of information output are at the technical level, semantic level, and influence level. The IS success model (Delone & McLean, 1992, 2002) expanded the concept of levels of output in order to illustrate stages within those levels. Information is communicated to a recipient who either is influenced or not; he or she then impacts organizational performance. In other words, the information flows from its production to influence the individual and then the organization.

System quality and information quality both singularly and jointly impact use and user satisfaction. This research model is based on the IS success model and employs some of the constructs of that model, specifically at the technical level of system quality and information quality, in the context of choiceboards, and in their impact on different components of user satisfaction (interface satisfaction, decision-making satisfaction, and resultant overall satisfaction). User satisfaction then influences the intention to use. The next section explains the research model and hypotheses.

RESEARCH MODEL AND HYPOTHESES

The research model (Figure 1) shows that system and information quality and information presentation impact the different components of user satisfaction and then intention to use. The various constructs and the resulting hypotheses of the model are explained in this section.

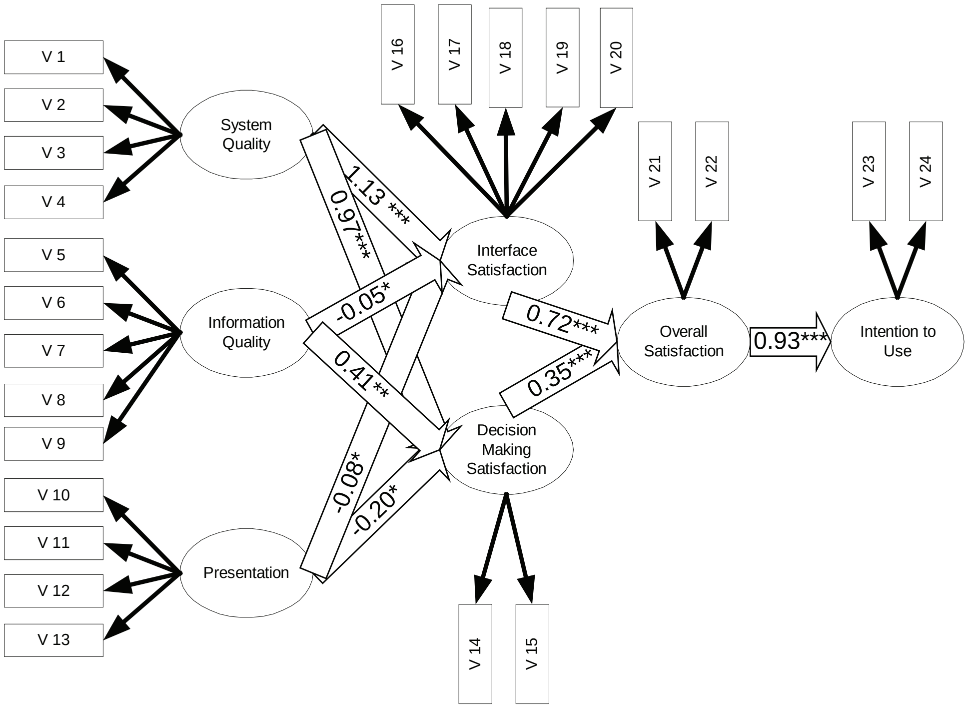
System Quality

System quality is the individual perception of a system's overall performance, which is itself a manifestation of system hardware and software. Ease of use (Belardo, Karwan, & Wallace, 1982), convenience of access (Bailey & Pearson, 1983), and system reliability and flexibility (Srinivasan, 1985) are measures employed for the service quality construct.

Information Quality

The user estimates the value of an information system after evaluating the quality of information it provides (Gallagher, 1974). Information accuracy

Figure 1. Model with results



*** $p < 0.01$; ** $p < 0.1$; * Statistically insignificant

(Bailey & Pearson, 1983; Mahmood, 1987; Miller & Doyle, 1987; Srinivasan, 1985), completeness (Bailey & Pearson, 1983; Miller & Doyle, 1987), relevance (Bailey & Pearson, 1983; King & Epstein, 1983; Miller & Doyle, 1987; Srinivasan, 1985), content needs (Doll & Torkzadeh, 1988), and timeliness (Bailey & Pearson, 1983; King & Epstein, 1983; Mahmood, 1987; Miller & Doyle, 1987; Srinivasan, 1985) are the measures employed in the information quality construct.

Information Presentation

In information presentation, the display of information based on formats, colors, and graphs vs. tables is examined (Vessey, 1994). The interface evaluation has included presentation, format, and processing efficiency characteristics of the interface (Swanson, 1985-1986). The measures used for information presentation construct are graphics, color, presentation style, and navigational efficiency (Swanson, 1985-1986).

Interface Satisfaction

The quality of the information system interface is measured in interface satisfaction. The indicators used to measure interface satisfaction construct are easy to work (Doll & Torkzadeh, 1988; Goodhue, 1990), useful format (Doll & Torkzadeh, 1988; Goodhue, 1990), user friendly (Doll & Torkzadeh, 1988; Goodhue, 1990), does what I want it to do (Davis, 1989; Goodhue, 1990), and clear and understandable (Davis, 1989; Goodhue, 1990).

Hypothesis 1: System quality will contribute positively to interface satisfaction.

Hypothesis 3: Information quality will contribute positively to interface satisfaction.

Hypothesis 5: Good information presentation will contribute positively to interface satisfaction.

Decision-Making Satisfaction

Decision-making satisfaction is the system's ability to support the user's decision-making and problem-solving activities. The system's support to the individual in recognizing problems, structuring problems, and making decisions related to the goal of controlling a business process are part of the construct (Garrity & Sanders, 1998). The construct measures the decision-making satisfaction using decision effectiveness (Chervany, Dickson, & Kozar, 1972) and decision confidence (Goslar, Green, & Hughes, 1986; Guental, Surprenant, & Bubeck, 1984; Zmud, Blocher, & Moffie, 1983).

Hypothesis 2: System quality will contribute positively to decision-making satisfaction.

Hypothesis 4: Information quality will contribute positively to decision-making satisfaction.

Hypothesis 6: Good information presentation will contribute positively to decision-making satisfaction.

Overall Satisfaction

Satisfaction is an important and widely used construct in the IS literature. Numerous researchers have modified the Bailey and Pearson (1983) user satisfaction instrument. The construct of overall satisfaction, a result of interface and decision-making satisfaction, was measured using extremely useful system (Sanders, 1984) and satisfactory in meeting user needs (Alavi & Henderson, 1981; Sanders & Courtney, 1985).

Hypothesis 7: Interface satisfaction will contribute positively to overall satisfaction.

Hypothesis 8: Decision-making satisfaction will contribute positively to overall satisfaction.

Intention to Use

Intention to use a system often has been employed as an important measure of IS success (Chang & Cheung, 2001; DeLone & McLean, 1992; Lucas, 1978; Van der Heijden, 2004; Welke & Konsynski, 1980). Possible to use and intend to use (DeSanctis, 1982) have been employed to measure the intention of the user to use the system construct.

Hypothesis 9: Overall satisfaction will contribute positively to intention to use.

RESEARCH METHODOLOGY

The instrument was constructed based on prior research, and most indicator items were adapted or borrowed from previously validated instruments. The survey was first pretested with a smaller sample and then subsequently refined. The survey was administered to subjects who were undergraduate and graduate students at two universities. They were selected as subjects, because they were users of or familiar with choiceboard systems. The experiment was conducted in a laboratory setting with PCs running on the Windows operating system. In conducting the experiment, the researchers adopted the following procedure.

First, the experimental procedure was explained to the subjects. Then, each subject was randomly assigned a Web site that employed a choiceboard that allowed the user to configure a product. The choiceboard sites were of a very similar nature, despite being owned by different firms. After configuring a product on the Web site, each subject completed a survey questionnaire. The total sample for the experiment was 192 subjects.

Structural equation modeling (SEM) was used to analyze the data. SEM subscribes to a causal indicator model with the operational indicators reflective of the unobserved theoretical construct. It allows the specification of measurement errors within a broader context of assessing measurement properties. Confirmatory factor analysis, content validity, unidimensionality analysis, reliability analysis, convergent validity, and criterion-related validity tests were conducted to evaluate the model and constructs (Anderson & Gerbing, 1988; Bollen, 1989; Chin, 1998).

DATA ANALYSIS

Confirmatory Factor Analysis

The measurement properties of the survey instrument were assessed with confirmatory factor analysis. A measurement model comprised of a weighted linear combination of the items in the scale was analyzed. In confirmatory factor analysis, each theoretical construct is specified and analyzed to assess the fit of the data with the measurement model (Ahire, Golhar, & Waller, 1996; Ravichandran & Rai, 1999; Venkatraman, 1989). For constructs with four or more indicators, these guidelines were followed. As some constructs have fewer than three indicators, these constructs were pooled with constructs having four or more indicators. This was done to ensure adequate degrees of freedom for estimation of the model.

Content Validity

Content validity is ensured when the constructs are defined using the literature. The construct should adequately represent and measure the domain of meaning that it is supposed to represent (Bohrnstedt, 1983). If all the items grouped together for each construct reflect the underlying meaning, then content validity exists (Dunn, Seaker, & Waller, 1994). Since there is no rigorous way to assess content validity, in order to ensure thoroughness, multiple items were used to measure the construct (Bohrnstedt, 1983; Churchill, 1979). The instrument employed in the research used several indicators for each construct that were derived from an in-depth literature review, and thus, content validity was ensured (Bohrnstedt, 1983).

Unidimensionality Analysis

A multidimensional construct helps with content validity and is acceptable as long as the scales are unidimensional. A scale has to be unidimensional in order to have both reliability and construct validity (Gerbing & Anderson, 1988). The condition for a unidimensional scale is that the items of a scale estimate one factor. The goodness of fit index (GFI) measures a good fit of the measurement model, as it indicates that all items load significantly on one underlying latent variable. There is no evidence of lack of unidimensionality when GFI is 0.90 or higher for the model. The GFI indices for all the scales are summarized in Table 1, and the results suggest that all the scales are unidimensional.

Reliability

Reliability of a scale is ensured, if the scale is dependable, consistent, or stable (Gatewood & Field, 1990). Cronbach's alpha coefficient was used to measure reliability, as the items of a scale explain the majority of the variation in the construct vis à vis measurement error (Cronbach, 1951). The results indicate that the scale is reliable, because the alpha coefficient is greater than 0.70 (Table 1).

Table 1. Tests for unidimensionality, reliability, and convergent validity

No.	Construct	No. of Indicators	Unidimensionality: Goodness of Fit Index (GFI)	Reliability: Cronbach's α	Convergent Validity: Bentler Bonnet Δ
1.	System Quality	4	.99	.72	.97
2.	Information Quality	5	.97	.84	.95
3.	Information Presentation	4	.91	.82	.89
4.	Interface Satisfaction	5	.94	.87	.94
5.	Decision-making satisfaction* - System Quality - Information Quality - Information presentation	2	 .95 .96 .91	.83	 .92 .95 .90
6.	Overall Satisfaction* - Interface Satisfaction and Intention to Use	2	.91	.89	.93
7.	Intention to Use - Overall Satisfaction and Interface Satisfaction	2	.91	.74	.93

** A combined model was used for this construct.*

Convergent Validity

Considering each item in the scale as a different approach to measure the construct usually assesses convergent validity. This was measured using the Bentler-Bonett coefficient (Δ)(Bentler & Bonett, 1980). The Bentler-Bonett coefficient (Δ) value of 0.9 or above means high convergent validity. All the scales had a Bentler-Bonett coefficient (Δ) of greater than 0.9 (Table 1).

Criterion-Related Validity

Criterion-related validity tests the degree to which the outcome is predicted by the constructs (Ahire, Golhar, & Waller, 1996; Venkatraman, 1989). Using SEM, the constructs are correlated with outcome constructs. As the correlation of the various constructs are positive and statistically significant (Table 2), criterion-related validity exists for these constructs.

SEM produces parameter estimates of links between the latent variables and so is also called latent variable analysis, or causal modeling. AMOS 4.0 and SPSS 10.1 (Arbuckle & Wothke, 1999) were employed for the SEM analysis.

RESULTS AND DISCUSSION

In summary, this research examined the impact of systems' quality, information quality, and information presentation on user satisfaction and intention to use in the context of choiceboard systems. The IS success model was used as the basis of the research model. The model was based

Table 2. Test for criterion-related validity

No.	Construct	Interface Satisfaction	Decision-making Satisfaction	Overall Satisfaction	Intention to Use
1	System Quality	0.66**	0.65**	-	-
2	Information Quality	0.54**	0.69**	-	-
3	Information Presentation	0.50**	0.44**		
4	Interface Satisfaction	-	-	0.49**	-
5	Decision-Making Satisfaction	-	-	0.51**	-
6	Overall Satisfaction	-	-	-	0.56**

** $p < 0.01$

on Shannon and Weaver's (1949) communication theory, Mason's (1978) theory, and the Delone and McLean (1992) model. The research model employed the constructs at the technical level (i.e., systems' quality and information quality) in the context of choiceboards and finally its impact on different components of user satisfaction such as interface satisfaction, decision-making satisfaction, and resultant overall satisfaction. The path coefficients calculated for the estimated model support the hypothesized relationships in both direction and magnitude with few exceptions. Overall, the statistical conclusions support the research model (Figure 1).

System quality is directly and positively correlated to interface satisfaction (H-1); so, an increase in the quality of the system leads to an increase in satisfaction in using the interface. Information quality is directly and positively correlated to interface satisfaction (H-3); so, an increase in the quality of the information leads to an increase in satisfaction in using the interface. Information presentation is not directly and positively correlated to interface satisfaction; (H-5); therefore, this hypothesis is not validated.

The path coefficients calculated for the estimated model also support the hypothesized relationships in both direction and magnitude in the case of decision-making satisfaction. Most of the hypotheses in the area of decision-making satisfaction have been validated using the data. System quality is directly and positively correlated to decision-making satisfaction (H-2); so, an increase in the quality of the system leads to an increase in decision-making satisfaction. Information quality is directly and positively correlated to decision-making satisfaction (H-3); so, an increase in the quality of the information leads to an increase in decision making. Presentation is not directly and positively correlated to decision-making satisfaction (H-6), as this hypothesis is not validated.

System quality includes system ease of use, convenience of access, and system reliability. Thus, a net positive effect from these factors will result in a positive effect on interface satisfaction and decision-making satisfaction. In choiceboards, as in other systems, the ease of use of the system, convenience of access, and system reliability are important considerations for the user. Information relevance, accuracy, completeness, and timeliness constitute the construct information quality. Thus, a net positive effect from these factors will result in a positive effect on decision-making satisfaction. Choiceboard systems should provide relevant, accurate, complete, and timely information for better decision-making satisfaction.

Graphics, color, presentation style, and navigational efficiency measures information presentation. Therefore, information presentation measures how information is displayed. It was hypothesized that a net positive effect from graphics, color, presentation style, and navigational efficiency would result in a positive effect on interface satisfaction and decision-making satisfaction. The data did not support this hypothesis.

The statistical conclusions support the hypotheses on user satisfaction. Interface satisfaction is directly and positively correlated to overall satisfaction (H-7); so, an increase in interface satisfaction leads to an increase in overall satisfaction. Similarly, decision-making satisfaction is directly and positively correlated to overall satisfaction (H-8); so, an increase in decision-making satisfaction leads to an increase in overall satisfaction. Overall satisfaction also is found to be directly and positively correlated to intention to use (H-9); so, an increase in overall satisfaction leads to an increase in intention to use. The results from the research model also demonstrate the relative weight of system quality compared to information quality. Interestingly, decision-making satisfaction of end users, the quality of the system, is more important than the quality of the information.

As with all regression and structural equation modeling techniques, correlation does not prove the causality of the relation. However, since these causal relationships are based on an established literature, and since the theoretical grounding of the causality is adequate, it is reasonable to concur with the causality, where it has been validated (Gefen, Straub, & Boudreau, 2000).

MANAGERIAL IMPLICATIONS AND FUTURE RESEARCH

The research results empirically demonstrate the relationships between interface satisfaction, decision-making satisfaction, system quality, information quality, and information presentation. It also demonstrates the relationships among variables such as interface satisfaction, decision-making satisfaction, overall satisfaction, and the intention to use. These relationships are useful in influencing the intention to use among users of choiceboard systems. IS professionals need to understand these relationships to help their firms design choiceboard systems that are effective. This research provides an understanding of those interrelationships.

In the context of choiceboards, the quality of information influences decision-making satisfaction. For example, for a choiceboard system that allows users to develop their own holiday itinerary, the research suggests that users would value complete, accurate, and relevant information about holiday sites, weather, local costs, flights, rentals, and hotels. Similarly, users will have better decision-making satisfaction with timely, accurate, and complete information as they develop alternative scenarios for their holidays.

The research suggests that ease of use, convenience of access, and system reliability also influence the decision-making satisfaction of users. A choiceboard, other than just being available and accessible, also should be easy to use. A user should not feel overwhelmed by available choices. The research also suggests that ease of use, convenience of access, and system reliability and flexibility influence interface satisfaction. The quality of the choiceboard system makes an impact if it is user-friendly, clear, and understandable. Interface and decision-making satisfaction influences if the choiceboard has been satisfactory in meeting user needs, which affects intention to use. For choiceboard users, it is not only important that the quality of the choiceboard system and the information it provides be adequate, but also that it provides them with interface and decision-making satisfaction. Thus, they will intend to use the choiceboard if they find it useful and if it meets their needs. This research shows that choiceboard users are deriving satisfaction with the system in a more complex fashion. If the choiceboard provides interface as well as decision-making satisfaction such that there is overall satisfaction, only then will they be a repeat user.

The empirical data suggest that the presentation of information is not important to the user in decision making. Users are not particularly impressed by color, graphics, and presentation style; they are more interested in the pertinent information being provided to them via the system. This is an interesting result, because in the recent past, there has been an increase in color and graphics on Web sites; but this presentation is of limited use if these Web sites are not able to provide the desired quality of information.

This research has examined the perceptions of users relative to their intention to use and how that perception is affected by overall satisfaction, which, in turn, depends on decision-making satisfaction and interface satisfaction. Much of the model has been validated by the data. Even the hypotheses that were not validated provide interesting insights. Studies should be conducted using other Web-based systems to test if the results of the present study can be extended to other situations. Qualitative studies also can be conducted to study choiceboard systems. These studies have the possibility of providing insight about choiceboard system users. These studies will help to build a wider body of research, which is needed for designing effective choiceboard systems.

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Chapter 5.17

Investigating the Impact of Customer Relationship Management Practices of E-Commerce on Online Customer's Web Site Satisfaction:

A Model-Building Approach

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ABSTRACT

This study addresses the effect of customer relationship management (CRM) practices on online customers' satisfaction with their experience in interacting with the company Web sites. Recognizing the importance of maintaining a healthy relationship with customers, companies are actively seeking ways to enhance the customer value of their offerings through relationship marketing. Since effective managing of customer relationships essentially involves managing customer information flow, Internet technologies have become an important element of a firm's CRM program. The company Web site is functioning as the focal point of contact for interacting with existing and prospective customers. An important concern is how the company Web site affects customers' overall perception of the

Web site. Using the concepts of Internet-mediated market orientation in marketing and user satisfaction in information systems, this study formulated and validated a theoretical model to analyze causal relationships between CRM practices, customers' perception of a Web site's online customer orientation and online customer Web site satisfaction. Based on the structural equation modeling analysis of the primary data collected in Taiwan, the study found that CRM practices positively impact online customers' Web site satisfaction through their perception of the Web site's customer orientation.

BACKGROUND

The Internet technology has evolved into a convenient platform for the development of corporate information infrastructures to support a wide range of innovative business strategies. The open and flexible communication protocols that collectively define today's Internet technology are now playing a vital role in processing highly distributed transactions, supporting knowledge-intensive decision making, and facilitating ambitious organizational collaboration (Turban, King, Lee, & Viehland, 2004). The ubiquitous connectivity and user-friendly interfaces have indeed offered a rich set of technological capabilities, allowing for development of value-creating systems to attract customers (Fahey, Srivastava, Sharon, & Smith, 2001).

In the e-marketing discipline, Internet technology is viewed as "a market space where a firm interacts, makes transactions, and builds relationships with suppliers, distributors, competitors, as well as consumers" (Min, Song, & Keebler, 2002, p. 3). In addition to the functional capabilities, the appeal of Internet technology also comes from the rapid growth of consumer acceptance it has enjoyed since the network was made available for commercial usage. An industry research from Jupiter Research (http://www.find.org.tw/), for example, indicates that annual online retail sales in the United States will reach 65 billion dollars during the year of 2004 and 117 billion dollars for the year of 2008 with the composite annual growth rate of 17%. According to this research, although the growth rate of first-time online shoppers in the United States will slow down as the Internet population saturates, the average purchasing amount is expected to increase steadily as a growing number of customers gain and feel satisfied with their experience with Internet shopping. The strategic role of Internet technology becomes even more obvious as one observes how companies in various sectors are integrating sophisticated knowledge management capabilities (e.g., online communities) into their new product development process and other customer-facing functions (Gebert, Geib, Kolbe, & Brenner, 2003).

An important e-marketing area that has received much attention from marketing researchers is relationship marketing. The aim of relationship marketing is to build long-term, mutually satisfying relations with customers, suppliers, and distributors with the objective to earn and retain their long-term preference and businesses (Kotler, 2000, p. 13). Today's highly competitive business environment requires the adoption of both offensive marketing strategy (recruiting new customers) and defensive marketing strategy (retaining existing customers) (Stefanou, Sarmaniotis, & Stafyla, 2003). To implement these customer-centric strategies, companies must have access to information about customers and provide customers with valuable knowledge to help them use the products they purchased from the company. In addition, instead of treating all customers equally, it is essential for companies to understand customers' requirements and customize the product and service offerings accordingly. Maintaining constant two-way communications with customers, therefore, is an important prerequisite for successful management of meaningful customer relationship.

A variety of information systems have been used to help with interactions with the customers. Often referred to as CRM systems, these systems are usually integrated under Internet protocols to provide user-friendly interfaces with customers, usually via a company Web site. From customers' point of view, a company's Web site represents the company itself. Customer satisfaction with or complaining about the ways the company Web site treats customers can lead to brand loyalty, repurchase intention, and repeat sales (Stefanou et al., 2003). An important concern, therefore, is how online customer's Web site satisfaction is affected by the company's CRM practices as demonstrated by its Web site design and management.

In light of the central role played by the Web site in a company's CRM practices, this study was conducted to examine the correlation and causal relationships between the CRM aspect of Web site design and management and online customers' satisfaction with their experience of Web site visits. For the purpose of measurement, the study adopts a framework proposed by Min et al. (2002), labeled "Internet-mediated Market Orientation (IMO)," to measure the construct of CRM practices.

The remainder of the article is structured as follows. The Literature Review section briefly describes the concepts of customer relationship management, Internet-mediated market orientation, and online user/customer satisfaction. This is followed by the section on research method, which includes the description of a theoretical model linking e-commerce companies' Web-enabled customer relationship management practices with the user/customer satisfaction. The section also describes the data collection method and instrument validation. The results of data analysis are then reported in the next section. The conclusion summarizes the study, elaborates on the implication of the findings, and suggests directions for future e-commerce research.

LITERATURE REVIEW

Customer Relationship Management

The theoretical foundation of customer relationship management (CRM) is relationship marketing. Shani and Chalasani (1992) defined relationship marketing as an integrated effort to identify, maintain, and build up a network with individual customers and to continuously strengthen the network for the mutual benefit of both sides through interactive, individualized, and value-added contacts over a long period of time. CRM is an amalgamation of relationship marketing and information technology. Whereas relationship marketing provides strategic foundation for the CRM concept, information technologies are used to automate and integrate marketing, sales, and service activities (Turban et al., 2004). A successful execution of the relationship marketing strategy often requires using sophisticated information systems to move information and knowledge smoothly across multiple complex customer-related processes. These CRM systems create customer value and contribute to company revenue by offering three categories of knowledge: knowledge for customers, knowledge about customers, and knowledge from customers (Gebert et al., 2003). At the core of CRM capabilities are the technological features that promote interactivity and customization (or even personalization). These requirements can be naturally fulfilled with "technology-enabled relationship management" (Schneider, 2002, p.159).

An important goal of CRM is to maximize customer retention. Since the best means to accomplish customer retention is to keep customers satisfied, it is reasonable to use customer satisfaction as an important criterion for measuring the success or failure of a firm's CRM practices (Stefanou et al., 2003). Furthermore, when the company Web site is used as the main interaction vehicle with customers, such as commonly practiced by many e-commerce companies, it is also reasonable to assume that customer satisfaction with Web site visits is a significant determinant of customer retention (Winer, 2001).

A comprehensive set of CRM programs usually consists of customer service, frequency/loyalty programs, customization, rewards programs, and community building (Winer, 2001). From the customer point of view, however, what matters the most is often their perception of the overall interaction experience with the firm. Customers shop for and are attracted to the vendors that maximize customer value. Much of the value-creating activities are related to information and knowledge flows (Winer, 2001). The company Web site, when properly designed and managed, can serve as a flexible and convenient mechanism for satisfying customers' requirements. The information and knowledge-intensive nature of CRM has been actively discussed in both marketing and information system literature (e.g., Gebert et al., 2003; Min et al., 2002; Romano & Fjermestad, 2003; Stefanou et al., 2003). Most discussions about CRM, however, are either conceptual or anecdotal in nature. More empirical studies are needed to verify the concepts and frameworks for the purpose of theory advancement.

Since the concept of CRM is strongly supported by the concept of market orientation, and the practicing of CRM via Web sites can be related to the concept of Internet-mediated market orientation, the following two sections discuss market orientation and Internet-mediated market orientation.

Market Orientation

A well-researched construct, the concept of market orientation is defined by some researchers as a component of organizational culture, consisting of a set of shared values and beliefs that put the customer first in business planning (Deshpade, 1999; Narver & Slater, 1990; Slater & Narver, 1994). The effect of market orientation on a firm's learning capability and innovative activity has been investigated by research in marketing. For example, Jaworski & Kohli (1993) identify market orientation as a significant determinant of overall business performance. Market orientation is also viewed as a fundamental concept underpinning a company's business strategy and innovative operations (Day, 1994; Han, Kim, & Srivastava, 1998; Harmsen & Hensen, 2004; Hurley & Hult, 1998; Farrel, 2000; Matsuno & Mentzer, 2000; Ruekert, 1992; Wu, 2004). Guided by the market orientation concept, companies recognize the value of the activities relating to collection, dissemination, and application of market information as they seek to improve their operational performance and competitive advantage (Kohli & Jaworski, 1990; Morgan & Hunt, 1994; Narver & Slater, 1990).

Market orientation is a composite concept. Researchers identify its components in an attempt to better relate this concept with other marketing concepts. Narver and Slater (1990) suggest that market orientation consists of five components: customer orientation, competitor orientation, functional coordination, long-term perspective, and profit orientation. Kohli and Jaworski (1990) also contend that market orientation is the manifestation of a firm's marketing concept and comprises five components: customer orientation, competitor orientation, intelligence gathering, interdepartmental information exchange, and responses to market intelligence.

In order to bring the market orientation concept to the operational level, Jaworski and Kohli (1993) define market orientation as a set of specific activities a firm carries out to put the marketing concept into practice, and that the concept may be measured by three sets of organization-wide activities: (1) intelligence generation, (2) intelligence dissemination, and (3) response design. These activities involve the collection and distribution of market information pertaining to current and future customer needs, and the use of the information in managerial action. This information usage perspective of the market orientation concept offers a convenient avenue for evaluating a company's marketing activities and thereby examining its impact on the other organizational concerns, such as business performance or learning capability.

Internet-Mediated Market Orientation

The mainstream of marketing research has examined the role of market orientation in the traditional business operational environment. Despite the success of various Internet-centric business models demonstrated by innovative companies, there are few, if any, attempts to examine the significance of the market orientation concept in the context of e-commerce. Min et al.'s (2002) theory of Internet-mediated market orientation represents the first attempt to explicitly take account of Internet technology and examines the role of market orientation in an e-commerce firm's online marketing activities. Internet-mediated market orientation essentially is market orientation in the Internet context.

At the implementation level, a firm's market orientation is witnessed by how it obtains market intelligence from its trading partners and other sources (Evans & King, 1999; Nordstrom & Pinkerton, 1999). As a convenient vehicle for interactive communications, Internet technologies have enabled the inclusion of a variety of forms of electronic communications such as videoconferencing, voice mail, Web casting, usenet, e-mail, bulletin board, and so forth, in a company's marketing activities. These new capabilities have essentially "transformed traditional ways of market information generation, dissemination, and organizational responsiveness to it into a networked computing environment in which a firm interacts and collaborates with end customers as well as suppliers, distributors, competitors" (Min et al., 2002, p. 3). As a result, numerous innovative business models have emerged, including the ones compiled by Turban et al. (2004): online direct marketing, electronic tendering systems, name your price, affiliate marketing, viral marketing, group purchasing, online auctions, and so forth.

Min et al. (2002) proposed the Internet-mediated market orientation theory by extending the concept of market orientation to incorporate Internet services. They defined Internet-mediated market orientation as "the Internet-mediated, information rich, seamless, agile, and boundary spanning process of generating, dissemination, and responding to market information on the Internet" (p. 3). Drawing from the major research literature on market orientation, they developed a conceptual framework to highlight the significant benefits of an Internet-mediated market orientation process: improved customer service, reduced marketing cost, and overall business performance. Hoping to advance the theory to a better maturity level, they call for more systematic inquiries to be conducted in both inductive and deductive manners to challenge or strengthen their framework: "Future research is called for to … empirically test the theory with proper measures for solid deduction" (Min et al., 2002, p. 8).

We contend that, since the three dimensions of the Internet-mediated market orientation (market information generation, market information distribution, and organizational response to market information) are essentially about interacting with customers through information exchange and the subsequent application of the market information, they ought to be investigated within the broader framework of CRM.

Online User/Customer Satisfaction

Customer satisfaction is a perceptual measure of the effectiveness of an organization's customer relationship management. A satisfied customer tends to return for future business and thereby contributes to the retention rate of the existing customers. In addition, a satisfied customer is likely to offer positive word-of-mouth service about the experience of interacting with the vendor. A number of previous researchers have consistently demonstrated that customer satisfaction is an important means for firms to gain an overall competitiveness in today's information and knowledge economy (Berry, 1995), contributes to a firm's profitability, and is increasingly becoming a critical organizational objective in pursuit of a sustainable competitive advantage.

The World Wide Web represents a virtual market space for customers to search for and purchase products and services. Shankar, Smith, and Rangaswamy (2003) investigated the unique characteristics of online shopping and the differences between online and off-line shopping environments. They found no significant difference with regard to customer satisfaction. Szymanski and Hise (2000) conducted focused group studies with selected online shoppers to identify the significant components of the customer satisfaction framework for the online shopping environment. Most of the components they identified are related to the customer relationship management concept, including Web site convenience, provision of product information, Web page design, and security concerns.

In the field of information systems, user satisfaction has been on the research agenda for more than 20 years (Khalifa & Liu, 2004). Early studies examined satisfaction of primary users who dealt with the information products generated by the systems (Davis & Olson, 1985). The target of the study was a specific type of information systems or information technology applications. For example, DeSanctis and Gallup (1987) measured manager (decision maker) satisfaction with a group decision support system. User satisfaction is generally defined as the "multidimensional attitude towards various aspects of MIS such as output quality, man-machine interface, EDP staff and services, and various user constructs such as feelings of participation and understanding" (Raymond, 1987, p. 37). With the subsequent proliferation of personal computing and end user computing, the main focus of user satisfaction research was the individuals who directly interacted with the information system. Several factors have been examined to account for the direct interaction between end users and specific technology applications (e.g., content, accuracy, format, ease of use, and timeliness) (Bollen, 1989).

The recent emergence of e-commerce has further blurred the distinction between end users and online customers due to the use of Web-based user interfaces for both internal and external communications. Not only have customer-facing applications of information technology been constructed to operate under the integrating framework of Internet protocols, back-office applications are also being hyperlinked to Web browser interfaces to provide stakeholders with single user interface. The technological integration is leading to the integration of the information systems and marketing theories. The traditional information system models for user satisfaction research that mainly focused on system/information characteristics are no longer sufficient to explain user/customer satisfaction in the new online environment (Palmer & Griffith, 1998). The traditional focus of marketing on product/service features also must be expanded to incorporate system and content characteristics. Therefore, a growing number of information system studies have adopted the marketing approach to measure online user/customer satisfaction. Many of the recent researchers used the disconfirmation model, a primary theory in marketing literature for explaining customer satisfaction, to examine various aspects of user satisfaction (e.g., Khalifa & Liu, 2004; Mckinney, Yoon, & Zahedi, 2002; Susarla, Barua & Whinston, 2003).

The literature reviewed above led to the conceptual framework for the study, formed by three research constructs (CRM practices, customers' perception of e-commerce firm's customer orientation, and customer Web site satisfaction) and their relationships. Three research hypotheses were formulated to represent these presumed relationships. The conceptual framework, research hypotheses, data collection, and analysis methods, as well as validation of measurement instrument are described in the next section.

RESEARCH DESIGN

Research Constructs and Hypotheses

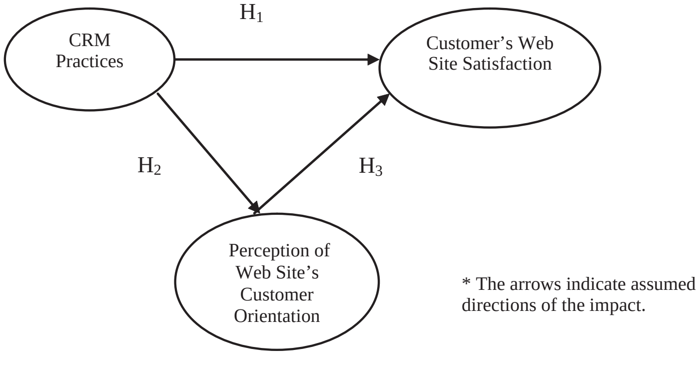
Customers satisfied with their Web site visit experience are more likely to repeat their visits and also more likely to purchase products. The immediate goal of CRM implementation is, therefore, to increase Web site visitors' satisfaction with their visiting experience. E-commerce companies would like to assume that everything they do with their Web site is aligned with customers' characteristics and requirements. Literature has suggested that customer satisfaction might be affected by their perception of the firm's customer orientation. The objective of this study was to clarify these speculations. Figure 1 is a graphical depiction of the relationships between the three research constructs. Following is a list of our three research hypotheses:

- **H_1:** Online customers' Web site satisfaction with their Web site visit experience is positively affected by the CRM practices of the e-commerce firm.
- **H_2:** Customers' perception of customer orientation of an e-commerce firm is positively affected by its CRM practices.
- **H_3:** Online customers' satisfaction with their Web site visit experience is positively affected by customers' perception of customer orientation of the e-commerce firm.

The construct CRM Practices consisted of three dimensions: market information generation, market information dissemination, and organizational responses to market information. All three dimensions were evaluated from the user/customer perspective. Generation of market information represented availability of market information and was gauged in terms of the richness of the information content on the Web site. Dissemination of market information was judged by how rapidly the Web site updated and shared its market information. The organizational response was measured by the Web site's rapidity in responding to customer inquiry or request for information. Each of these three dimensions was addressed by three question items in the questionnaire.

Perception of online customer (or e-customer) orientation was operationally defined as the extent to which an e-commerce company sought to satisfy its e-customers' needs and to enhance e-customer value, and was measured by three question items: (1) "The Web site understands and satisfies customers' needs," (2) "The Web

Figure 1. Research framework



site seeks to enhance customer value," and (3) "The Web site frequently evaluates its customer satisfaction situation." Customer satisfaction with the Web site visit experience was defined as the subjective evaluation of the overall value perception resulting from the interaction experience. Three question items were devised to represent this variable: (1) "I enjoy the experience visiting the Web site," (2) "I am satisfied with the services I received from the Web site," and (3) "I trust the correctness of the content." All variables are subjectively measured using the Likert Scale, with 5 representing "Strongly Agree" and 1 for "Strongly Disagree."

Data Collection and Data Analysis

The primary data were collected from college faculty, staff, and students in Taiwan in the Summer of 2004. The respondents were instructed to use one of their favorite Web sites as they responded to the questionnaires. Most respondents referred to popular local portal Web sites or major global e-commerce Web sites such as www.amazon.com and www.e-bay.com. As noted in Jih (2002, 2003, 2004), e-commerce is a major thrust in Taiwan's economic, educational, and public sectors. Most people in the college population have had some e-commerce experiences. The development of the survey instrument involved three steps.

- **Step 1:** An initial version of the survey questionnaire was designed to identify the question items synthesized from the literature. This version was presented to three practitioners and two academicians in the e-marketing and e-commerce fields. The questionnaire was revised to incorporate their feedback.
- **Step 2:** 100 copies of the revision were distributed to the students in e-commerce and e-marketing classes. This pilot testing resulted in further modification and improvement of the questionnaire.
- **Step 3:** The new version of the questionnaire was then tested online with the college students with e-commerce experience, who were instructed to evaluate a Web site of their own choice. More modifications to the questionnaire were made to accommodate feedback from the online respondents. The final version of the questionnaire was administered to another group of college students and university employees, who were invited via e-mail to participate, during the period of April and May of 2004. A total of 160 effective questionnaires were obtained and used for analysis after removal of the incomplete ones.

Two statistical analysis software packages, SPSS 10.0 and AMOS 3.6, were used to analyze the collected data. The Cronbach's α value was calculated as the reliability indicator for each research variable. The validity of the variable measurements was quantitatively tested using exploratory factor analysis, correlation analysis, and confirmatory factor analysis, in addition to the qualitative assessment of the experts in the field. The validation of the theoretical model was then performed using structural equation modeling analysis. For the model-testing study, Hair, Anderson, Tatam, and Black (1998) suggested an appropriate size from 100 to 200. Structural equation modeling analysis using a large sample (sample size > 200) might result in poor fitness of the model. The sample size 160 used by this study satisfied this requirement. Among the respondents, 43% were males, 57% were females, 30% were ages 19 or below, 37.5% were ages 20-29, 20% were ages 30-39, and 12.6% were ages 40 or above.

Reliability and Validity of Variable Measurements

An exploratory factor analysis was performed to identify the dimensions of the latent variable that represented the research construct CRM practices. The resulting dimensions were then evaluated by a confirmatory factor analysis. As shown in Table 1, the result of principal component analysis identified three factors (dimensions) from the nine question items. The accumulated variance was 72.99%, an indication of high construct validity. The reliability measures of the three factors were 0.835, 0.766, and 0.810, respectively. These reliability measures were greater than the commonly accepted minimum of 0.7, demonstrating a good reliability of our measurement of CRM practices. All factor loadings associated with each of the three factors were greater than 0.7, an evidence that the CRM practices measurement in this study possessed both convergent validity and discriminant

Table 1. Reliability, convergent validity, and discriminatory validity measures of CRM practices dimensions

Construct Dimensions	Measurement Items	Exploratory Factor Analysis	Confirmatory Factor Analysis		Cronbach's α
		Factor Loading	Standardized Structure Coefficient	T value	
Generation of Market Information	The Web site provides detailed product/service information.	0.874	0.838	Fixed*	0.835
	The Web site always has the information I need.	0.834	0.739	9.367	
	The Web site provides plenty of useful information.	0.802	0.806	10.029	
Distribution of Market Information	The Web site frequently mails me information, saving me time and effort.	0.826	0.675	7.539	0.766
	The Web site frequently mails me information on new product, new technology, and something educational.	0.783	0.705	7.800	
	The promotion information from this Web site works for me.	0.767	0.786	Fixed*	
Organizational Responses to Market Information	The Web site responses to competition in the market.	0.836	0.741	9.758	0.810
	The Web site responds to customer complaints and suggestions.	0.792	0.666	8.655	
	The Web site is sensitive to changes of customers' requirements for products and services.	0.700	0.881	Fixed*	

Note: Values on the diagonal are extracted variances. The rest are correlation coefficients.

validity. The convergent validity and discriminant validity of the CRM practices measurement were further confirmed by the fitness indices produced by the confirmatory factor analysis: specifically, the goodness-of-fit index (GFI) and the adjusted goodness-of-fit index (AGFI). The GFI represents the amount of variances and covariances in the sample covariance matrix, which can be used as an estimate of the population matrix. In essence, the GFI is analogous in interpretation to the R^2 in the multiple regression analysis. The AGFI is GFI that has been adjusted for degrees of freedom, and is essentially analogous to the adjusted R^2 in multiple regression. The cutoff value for GFI is usually considered to be 0.9, and for AGFI, it is 0.8 (Sharma, 1996). In this study the GFI value was 0.943, and the AGFI value was 0.893. Additionally, all t-value estimates were significantly greater than zero, with the exception of the reference indicators which were fixed at 1 for each of the latent variables. These characteristics of the measurements allowed for using the mean values of the three question items as the measures of the observable variables for CRM practices.

The factor analysis procedure was applied to confirm the constructs for our theoretical model: CRM practices, perception of online customer orientation, and customers' Web site satisfaction. Each analysis produced exactly one factor, with 1 used as the threshold value of the eigenvalues (Table 2). This result confirmed the single dimensionality of the factors. The high factor loadings and extracted variances of all variables and model constructs indicated a good convergent validity of the variable and construct measurements. Table 2 also showed that, with the exception of CRM, which was close to 0.7, all other constructs had a Cronbach's α greater than 0.7. Our evaluation of discriminant validity of the measurements was based on Fornell and Larcker's (1981) work, who suggested that the discriminant validity between two constructs was good when their extracted variances exceeded the squared correlation coefficient between the two constructs. Table 3 showed that the constructs in our theoretical model passed this test: the extracted variances (values on the diagonal) were all greater than the squared correlation coefficients (the rest of the values in the table).

Table 2. Reliability and validity tests of model constructs

Research Constructs	Measurement Items	Factor Loadings	Cronbach's α	% of Extracted Variance
Customer Relationship Management Practices	Organizational response to market information (crm1)	0.864	0.699	62.62
	Distribution of market information (crm2)	0.771		
	Generation of market information (crm3)	0.733		
Perception of Online Customer Orientation	Web site understands and satisfies customer needs (occ1)	0.890	0.828	74.46
	Web site seeks to enhance customer value (occ2)	0.862		
	Web site frequently evaluates customer satisfaction situation (occ3)	0.837		
Customers' Web Site Satisfaction	I enjoy visiting this Web site (cws1)	0.902	0.870	79.41
	Web site offers satisfying services (cws2)	0.899		
	I believe that I've made the right choice using this Web site (cws3)	0.872		

Table 3. Discriminant validity test of model constructs

Constructs	CRM Practices	Online Customer Orientation	Customers' Web Site Satisfaction
CRM Practices	0.626		
Perception of Online Customer Orientation	0.366	0.745	
Customers' Web Site Satisfaction	0.319	0.454	0.794

Note: Values on the diagonal are extracted variances. The rest are correlation coefficients.

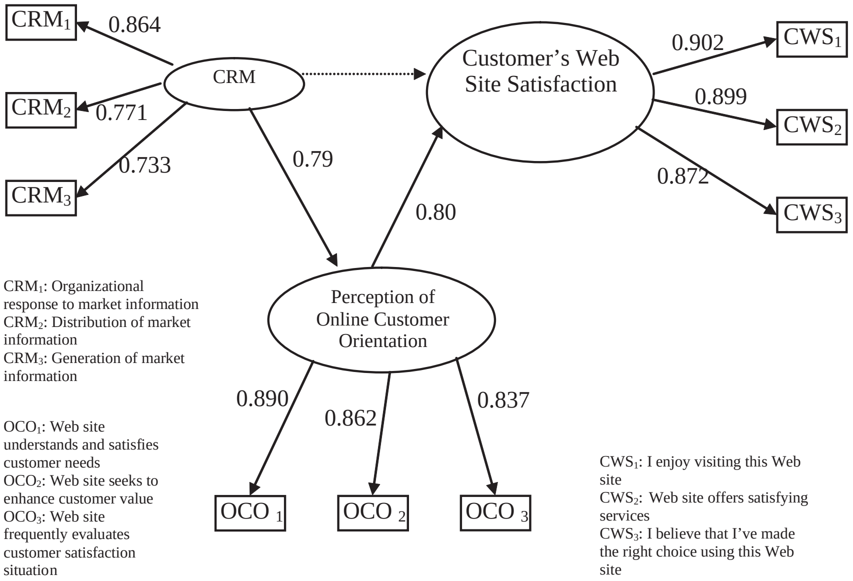
MODEL VALIDATION

James, Mulaik, and Brett (1982) recommended that testing a causal model required a two-step approach: The first step was a confirmatory factor analysis to obtain evidence for determining whether the indicators (or observed variables) appropriately measured the latent variables.

Once an appropriate measure model was identified, items could be combined to form scales of the latent variables. The second step then utilized these scales to test the hypothesized structural models. The theoretical model of this study consisted of three constructs (latent variables), each of which in turn was represented by three observable variables. The latent variables, the relationships to be tested between these three latent variables (expressed as oval symbols), and their corresponding observable variables (expressed as rectangular symbols) are graphically depicted in Figure 2. The factor loadings of the observed variables are indicated on the arrowed lines.

In order to determine the relationships between the three latent variables, the statistical analysis software AMOS 3.6 was used to test the research hypotheses. In addition to the chi-square test sta-

Figure 2. Result of model validation



tistics, six fitness indices were used to evaluate the adequacy of the theoretical model. The χ^2 test evaluated the discrepancy between the theoretical model and the collected data. The smaller the χ^2 value, the better the model fit. According to Carmines and McIver (1981), the χ^2 to degrees of freedom ratios (χ^2 /d.f.) around 3:1 or less were indicative of an acceptable model fit. The χ^2/d.f. in this study is 1.6272, an indication of an acceptable fitness of our theoretical model with the data. The results of testing the three alternative models are summarized in Table 4. Model 1 consisted of all three relationships represented by the three research hypotheses, and therefore was the first one tested. The results showed that both the absolute and incremental fitness indices indicated good fitness of the theoretical model. The absolute indices were GFI (0.945), AGFI (0.898), and RMSEA (root mean square error of approximation = 0.063). Ideally, both GFI and AGFI should be greater than 0.9. The GFI value was greater than 0.9, and the AGFI value was close to 0.9 in this case. The very small value of RMSEA (< 0.08) also confirmed adequate model fit. The incremental indices used in the study included NFI (normed fit index = 0.946) and CFI (comparative fitness index = 0.978 > 0.95). Both values were high enough to present consistent evidences in support of adequate fitness of the theoretical model (Bollen, 1989; Hair et al., 1998).

Table 4 also shows that, of the three research hypotheses in the first alternative model:

Table 4. Validation of three alternative models

path	hypothesis	expected sign	model 1		model 2		model 3 (rival)	
			Standardized Regression weights	t value	Standardized Regression weights	t value	Standardized Regression weights	t value
CRM→ Customer's Web site satisfaction	H_1	+	0.17	1.20	Not Applicable	Not Applicable	0.281	3.31*
CRM→ Perception of online customer orientation	H_2	+	0.78	6.24*	0.79	6.23*	Not Applicable	Not Applicable
Perception of online customer orientation → Customer's Web site satisfaction	H_3	+	0.65	4.35*	0.80	9.29*	0.691	7.62*
χ^2 / d.f.	Acceptable if < 3:1		1.6409		1.6272		4.6999	
Fit index	Critical value		Goodness-of-fit		Goodness-of-fit		Goodness-of-fit	
GFI	>0.9		0.945	good	0.945	good	0.878	poor
AGFI	>0.9		0.898	acceptable	0.901	good	0.780	poor
NFI	>0.9		0.946	good	0.946	good	0.840	poor
NNFI	>0.9		0.967	good	0.968	good	0.810	poor
CFI	>0.95		0.978	good	0.978	good	0.868	poor
RMSEA	<0.08		0.063	good	0.063	good	0.153	poor

**Level of significance = 0.05*

- **H_1:** (Online customers' Web site satisfaction with their Web site visit experience is positively affected by the CRM practices of the e-commerce firm.) was rejected due to the low structural coefficient 0.17 (t-value is 1.20) and was dropped from the subsequent analysis. Both H_2 and H_3 passed the statistical significance test and therefore were accepted.
- **H_2:** The perception of online customer orientation of an e-commerce firm is positively affected by its CRM practices ("CRM --> perception of online customer orientation," structural coefficient = 0.78, t-value = 6.24).
- **H_3:** Online customers' satisfaction with their Web site visit experience is positively affected by the perception of customer orientation of the e-commerce firm ("perception of online customer orientation --> online customer Web site satisfaction," structural coefficient = 0.65, t-value = 4.35).

With H_1 removed from the theoretical model, the second alternative model consisted of only two paths: CRM -> online customer orientation (H_2) and online customer orientation -> online customer satisfaction (H_3). Both hypotheses passed the significance test. In addition, all fitness indices passed the fitness evaluation criteria. The AGFI value (0.901) with this model was better than this value (0.898) with the first alternative model. In short, the second alternative model had a better model fit than the first one.

Despite the acceptance of both Model 1 and Model 2, a theoretical possibility still existed that CRM and perception of online customer orientation individually might directly impact online customer satisfaction. Morgan and Hunt (1994) pointed out the possibility of an antecedent directly impacting a consequence in some structural models and the significance of formulating and testing such a rival model. The rival model tested in this study, as the third alternative model, was formed by H_1 (CRM -> online customer Web site satisfaction) and H_3 (perception of online customer orientation -> online customer Web site satisfaction). However, although the structural coefficients of both hypotheses passed the significance test, the ratio of χ^2 to degrees of freedom (4.70) was higher than 3. In addition, none of the fitness indices passed the evaluation criteria. The rival model was rejected based on these results. The second alternative appeared to be the best theory; that is, CRM practices did not directly impact online customers' satisfaction. Instead, online customers' Web site satisfaction was affected by the CRM practices indirectly through an intervening variable, perception of online customer orientation.

SUMMARY AND CONCLUSION

Following the rise and fall of public expectations for the Internet's revolutionary impact on traditional business models at the turn of the century, researchers have reminded us that the Internet would not render traditional economic and business principles obsolete (e.g., Litan & Rivlin, 2001; Porter, 2001). Rather, the convenient communication capabilities and user-friendly interfaces provided by the Internet technology only represent a collection of technological capabilities that enables the implementation of innovative applications for businesses in all sectors to strengthen their competitive advantage in the knowledge economy. Identifying the synergy between traditional business wisdom and new information technologies is a core organizational competence that can only be learned through aggressive and creative experimentation.

Emerging as a strategic initiative involving the integration of a variety of information technologies with relationship marketing, CRM has received much discussion from both practitioners and academicians. Using various technological tools such as Web site design, database, data mining, software agent, and group work software in their marketing activities, companies are seeking to increase existing customers' loyalty while attracting new customers' attention at the same time. In light of the central role played by the Web site in the CRM practices, this study was conducted in an attempt to contribute to the understanding of the role of e-commerce Web sites in the CRM practices and the customers' satisfaction with their Web site visit experience. We constructed a tentative theoretical model based on the literature in marketing and information systems. The model links three research constructs: CRM practices, perception of the Web site's customer orientation, and customer satisfaction with Web site visits. We then used structural equation modeling analysis to validate the model. The result of model validation generated evidence for rejection and acceptance of the research hypotheses. The first hypothesis, "Online customers' Web site satisfaction is positively affected by the CRM practices of the e-commerce firms," was rejected. The other two hypotheses were both accepted: "The Perception of online customer orientation of an e-commerce firm is positively affected by the CRM practices of the firm," and "Online customers' satisfaction with their Web site visit experience is positively affected by the perception of customer orientation of the e-commerce firm." Interpreted collectively, these results indicated that the customers' Web site satisfaction was not affected directly by CRM practices, and the effect was made indirectly through the perception of online customer orientation. In other words, the perception of a Web site's online customer orientation played a pivotal role in the impact of CRM practices on the customer Web site satisfaction.

An important implication for e-commerce managers may be drawn from the research results. The study confirmed that the traditional wisdom about customer satisfaction is applicable as well to the e-commerce as to the traditional business environment. E-commerce companies must actively engage themselves in interacting with customers to ensure that what they do with their Web sites is all aligned with what the customers want and need. Furthermore, the challenges of time compression in transaction processing and the lack of physical contact in the e-commerce environment require even more careful design and monitoring of customer-facing business processes than in the pre-Internet era. The focus on customer requirements must be emphasized constantly to ensure that the information flows both ways via the Web site in the optimal fashion. After all, the Internet-enabled cyberspace now provides an information-symmetric scenario for both consumers and suppliers. Customers can freely switch between vendors. Customer relationship management is not just a smart business slogan. It must be thoroughly blended into the organizational culture and drives every major business decision made by the organization.

This study contributes to e-commerce research by demonstrating the use of a model-building method to test hypotheses regarding the impact of a major business initiative on customer satisfaction. CRM has received much attention in the management literature. Most discussions are conceptual or anecdotal in nature. Systematic inquiries involving empirical data are needed to verify the relationships between the concepts and, thereby, further this interdisciplinary field to better maturity.

The linkage between CRM and Internet-mediated market orientation is also a new adventure in e-commerce research. Min et al. (2002) proposed the concept of Internet-mediated market orientation to extend the traditional market orientation to the Internet-enabled business environment. They discussed the concept and called for more follow-up research to be conducted to validate their framework. This study built on their framework and used it to measure the information aspect of CRM practices.

Readers are cautioned in generalizing the findings reported herein for several reasons. First, the use of college faculty, staff, and students as respondents limits the generalization power of the research results. Second, the subjective nature of the responses may further pose another limitation on the external validity of the study. Third, since the data was collected in Taiwan, the research must be replicated in other cultures in order to expand the scope of applicability. Despite these limitations, since the study is confirmatory in nature, the significance of the study should not be severely reduced.

Promising directions for further research are suggested in the following directions. For a relatively new theory such as CRM to become well-established, more deductive and inductive inquiries are needed to advance the theory to a more mature level. The specific context of inquiry in this study is general Web site visit experience. Other contexts, such as online purchasing or online auction, may be used to obtain evidence from different angles of observation. Findings from research conducted in a variety of contexts will increase the theory's generalization power. Another area of research is using the controlled experiment approach to investigate issues surrounding CRM concepts. The controlled experiment research methodology complements survey research by keeping irrelevant factors under control in a lab setting. Examples of significant issues for controlled examination are the effects of different personalization designs, frequency of Web site update, and extent of Web site update on customers' perception of market orientation and their Web site satisfaction. The third area for future research concerns gathering data in different cultural settings to allow for cross-cultural comparison. With the global nature of e-commerce, an in-depth understanding of cultural impact on Internet-enabled CRM practices is an essential capability to operate in today's highly global business environment.

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Chapter 5.18

Ethnographic Discovery of Adverse Events in Patient Online Discussions:

Customer Relationship Management

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ABSTRACT

A healthcare provider can extend its customer relationship management program by sponsoring an online, patient discussion group. In those groups, patients may discuss adverse events that are inadequately addressed in the literature. The author, as a cancer patient, joined two online, patient discussion groups and identified four types of such adverse events. For each such adverse event, the patient findings, the medical literature, and the implications are noted. Extracts from the literature that were provided to the patients were welcomed by the patients. A literature review of one of the adverse events has been published in a medical journal. Factors are presented for healthcare providers to consider in deciding whether or not to sponsor an online, patient discussion group.

INTRODUCTION

Customer relationship management (CRM) systems are used in healthcare systems around the world (Alshawi, Missi, & Eldabi, 2003; Calhoun, Raisinghani, Tan, Untama, Weiershaus, & Levermann, 2005; Banaszak-Hol, & Hearld, 2006). A typical approach to CRM is to survey patient satisfaction and to address management steps to improve the results of the next survey (Zineldin, 2006). Data mining of Web information is an alternative way to learn what consumers think. In the financial sector, consumer views on particular investments have been assessed through the comments that those consumers make in online, discussion groups (Antweiler & Frank, 2004).

Many online patient groups are established by volunteers on free sites, such as groups.yahoo.

com (Rada, 2006b). However, some healthcare entities maintain patient online discussion groups. For instance, the Joslin Diabetes Center runs an online, diabetes discussion group for the public, and experts from the Center provide feedback online. Kaiser Permanente Health Plan maintains numerous discussion groups moderated by Kaiser's professionals, but access is restricted to enrollees in the Kaiser Plan.

Healthcare professionals in online moderator roles address adverse events, among other things. An adverse event occurs when some intervention by a healthcare provider produces an unwanted reaction. For instance, radiation treatment for oral cancer can cause obstructive sleep apnea. The literature on adverse events addresses their causes, how to reduce them, and the impact they have on patients, staff, and healthcare organizations (Misson, 2001). Typically, healthcare professionals investigate adverse events through the medical record (Duff, Daniel, Kamendje, Le Beux, & Duvauferrier, 2005).

Listening to patients is a key to reducing adverse events (Cleary, 2003): "by relying on the observations and insights of patients such as Mr. Q., the physicians and staff will be able to close the gap between Mr. Q.'s experience and what they can achieve." The book *Partnering with Patients to Reduce Medical Errors* (Spath, 2004) emphasizes the role of patients in reducing adverse medical events.

Patients in online groups hold a unique and valuable position because of their sheer numbers and an intense focus on their shared illness. Patient groups may have contact with larger numbers of disease-specific patients than many physicians and have the luxury of spending many hours discussing similarities and differences. After hundreds of hours of conversation, patterns can begin to emerge. These patterns might lead to new insights about adverse events. Members of an online patient discussion group explored their treatment and made discoveries that were incorporated in a scholarly journal article (Ferguson, 2002).

This article explores the means by, and extent to, which participants in online patient-patient discussion groups provide useful information about medical adverse events. The hypothesis is that patient online group information can stimulate the discovery of important gaps in the medical literature. More generally, the argument is that these online groups can be an important resource for both patients and healthcare providers.

METHOD

The author is a medical doctor and a head-and-neck cancer (HNC) patient. As doctors become ill and see the world from the patient's side, they often have useful insights to share about the relationship between patients and healthcare providers (Rosenbaum, 1988). This author joined two HNC online patient discussion groups as a patient.

Since an online discussion group is self-documenting by nature, the opportunity exists for a participant in a group to review the discussion and to engage in a kind of retrospective ethnographic analysis. Studying online groups via ethnography is in many ways easier than studying face-to-face groups (Paccagnella, 1997). The term 'netnography' has been coined to apply to such ethnography (Kozinets, 2002): "As a method, netnography is faster, simpler, and less expensive than traditional ethnography and more naturalistic and unobtrusive than focus groups or interviews."

In the context of this research, an online group uses a software system that provides a searchable archive of previous messages. Members of the group create messages and post them to the system, and the system in turn distributes these messages to the group. The system may interface to a group member via an e-mail client or a Web site. The online groups noted in this article may include patients, a patient's family or friends, and others who want to help. This population will be typically represented with the umbrella term 'patients' with its meaning apparent in the context.

The two HNC groups that the author joined explicitly welcomed any group members to use personally de-identified information in the online messages for research purposes. The author read the patient messages, identified messages of interest, studied relevant clinical, journal articles, and where appropriate shared extracts from the literature with the group. The author identified four cases where the information needs of the HNC patients led to the discovery of adverse events and gaps in the medical literature. For each case, the patient findings, the medical literature, and the implications are noted.

RESULTS

The four cases follow:

1. Patients in both groups frequently discussed ways to cope with their fatigue. Many patients reported signs and symptoms consistent with obstructive sleep apnea (OSA) in relation to this fatigue. The literature reveals incomplete information about OSA in HNC patients. Two articles provide interestingly different perspectives on OSA as a complication of the treatment of HNC. In one article, the incidence of OSA is 92% in patients treated for HNC (Friedman et al., 2001), while in the other article, 8% of treated HNC patients develop OSA (Rombaux et al., 2000). The literature at that time provided no mention of a radiated-only patient developing OSA, but one of the patients in the online group developed OSA after only radiation. Extracts of the literature were shared with the online group, and the patients expressed gratitude for that literature information. Furthermore, the observation of a gap in the literature became the basis of a published, medical, journal article (Rada, 2005a) and book chapter (Rada, 2008). In other words, the experience had two positive outcomes: increased patient satisfaction through knowledge gained and contributions to the medical literature.
2. Hyperbaric oxygen treatment (HOT) for osteoradionecrosis (ORN) of the mandible is routine in the United States. A patient in a discussion group presented his concerns about HOT for ORN and said: “Every dentist that I have seen in San Antonio has recommended HOT, but does anyone know if HOT is worth the $50,000 cost?” The patient went to Mexico and was told HOT for ORN was unnecessary. European studies have shown that HOT is not appropriate for ORN (Annane et al., 2004), but the American literature defends HOT (Mendenhall, 2004). Differences in the standard of care in one country versus another and the standard of care versus the ability to pay for the care create a kind of adverse event for the patient. Again, when extracts from the literature about HOT and ORN were shared with the patients, they replied with messages including a ‘thank you.’
3. Multiple participants (all older than 40) had initially gone to the doctor with a lump in the neck and been told that they had a branchial cleft cyst. As the cyst grew over months after the initial diagnosis, each patient sought further medical help and received the correct diagnosis of cancer. The medical literature reports that “80% of so-called branchial cleft cysts in the over 40s’ age group are malignant (Andrews, Giddings, & Su, 2003).” The literature does not address the frequency of misdiagnosis, though this misdiagnosis is an important adverse event. After information from the literature was shared with the patients, some committed themselves to working with their communities to increase awareness of the danger signs of HNC.
4. Two patients reported shock (anaphylaxis) in response to a drug (amifostine) that was first being used during HNC radiotherapy.

> The literature at the time suggested that severe reactions to amifostine were rare in HNC patients: "Amifostine administration was well tolerated, with a low incidence of side effects" (Antonadou, Pepelassi, Synodinou, Puglisi, & Throuvalas, 2002). A year later the results of a clinical trial were published which confirmed what the patients feared (Rades et al., 2004): "Administration of amifostine during radiotherapy for HNC is associated with a high rate of serious adverse effects." When a new drug use appears, detecting uncommon adverse events may be supported by having patient groups monitoring and discussing their reactions to their treatments. Some of the patients took this group information to their doctors and found that their doctors appreciated this information.

These four cases show, at least, three positive outcomes:

- Patients appreciated receiving extracts of the medical literature that pertained to their questions
- Secondary to their online participation, several patients became involved in community initiatives to detect HNC early
- Scholarly reviews of the medical literature have been published based on the gaps in the literature identified by the patients

When patients are confused about an adverse event, the possibility exists that healthcare professionals are also confused about these particular events and are unable to help. In a patient group, the patients may find opportunity to explore these troubling matters at length. From this study, patient groups can promote understanding about topics in which patients felt particularly unable to get adequate explanations from their healthcare professionals. The medical literature shows that these topics were little understood. For example, one journal article said the incidence of OSA secondary to HNC treatment was 92%, while another said the incidence was 8%, and very few other articles addressed this topic.

The majority of the discussion in the two HNC groups was not about the preceding, four adverse events. Much of the discussion was about emotional topics, such as a patient reporting the good news that the latest checkup with the oncologist revealed no progression of the disease and other patients congratulating the patient on the good news. Patients often complained about the loss of saliva (xerostomia) secondary to the cancer treatment. However, this adverse effect is well documented in the literature, and the patient discussion did not shed new light on xerostomia nor suggest a gap in the literature.

CATEGORIES AND PROCEDURES

Each of the preceding adverse events concerned more than one clinical specialty. The adverse events from the HNC groups might be categorized as follows:

- *A diffuse symptom*: OSA secondary to treatment for HNC may tend to be overlooked by otolaryngologists because the symptoms are diffuse and OSA is often addressed by sleep specialists rather than otolaryngologists.
- *Standard of care*: HOT, as part of the national standard of care for ORN, is not supported by clinical trials internationally, but the practicing otolaryngologist is not expected to dispute the national standard of care.
- *Primary care provider misdiagnosis*: A misinterpretation by the primary care provider might not be extensively documented or analyzed by the otolaryngologist.
- *Uncommon reaction to new drug*: When the drug amifostine was initiated for a new purpose, researchers needed further experience to uncover adverse events.

The foremost causes of adverse events as reported by the U.S. Institute of Medicine (Kohn, Corrigan, & Donaldson, 2000) are technical errors, diagnostic errors, failure to prevent injury, and medication errors. That classification is, however, not necessarily the optimal one for understanding what can be gleaned from patient online groups.

If a provider has decided to support an online discussion group and to provide moderators, then it might guide moderators relative to the findings of this study. To find evidence of adverse events that are inadequately appreciated in the literature, a healthcare professional might:

1. *Join an online discussion group for patients with a particular chronic disease.*
2. *Identify a finding that is highlighted by a patient as a problem*. Findings may include symptoms, signs, laboratory or test results, observations, or specific events (such as hospitalization or receiving a bill). A finding is a problem when a patient says so.
3. *Review the medical literature to determine whether a medical intervention experienced by the patient might have a causal relation to the problematic finding.* Relevant PubMed 'Medical Subject Headings' are identified, a query is posed to PubMed, and full-text copies of journal articles are retrieved through membership in a medical library subscription program. Temporal relationship, strength of association, biological plausibility, and other relationships contribute to a judgment of causality (Darden & Rada, 1988).
4. *Determine whether the literature provides conflicting or unclear guidance*. Sometimes the published literature suggests conflicting algorithms for diagnosis or treatment, and more research is needed to harmonize the literature.
5. *Extract information from the literature and return that information to the group.* The extract should be clear to the intended audience, embedded within a personal context, and made as a reply to recently posted message that has not already received a similar response.

If an extract from the literature is simply posted without context or explanation, then the impact, as measured by patient response, is less. Information systems can support this work by parsing patient messages and semi-automatically linking to relevant citations from PubMed (Rada, 2005b).

DISCUSSION

If one takes the preceding categorization of adverse events from online groups and tries to generalize further, one might note that the problems occur where the otolaryngologist's responsibility is blurred because someone else is also responsible. In general, adverse events may be least well understood where 1) the responsibility for the adverse event falls among several medical specialties and 2) the medical specialists inadequately communicate with one another. The four misunderstood topics discovered in this study were about patient conditions that require the coordinated attention of healthcare professionals from different disciplines, and this multi-disciplinary character of the topics may partly account for the relative lack of understanding about the topics.

The data from the online groups leads to qualitative results. For instance, the incidence of OSA in HNC patients is not expected to be the number of patients in the HNC groups that reported OSA because participants may have had OSA and not known it or did not mention it. In online groups, most participants are typically lurkers (Preece, Nonnecke, & Andrews, 2004). To obtain accurate incidence data, clinical trials might be needed. The online patient information supported the identification of a problem which further research might solve.

If a healthcare provider wanted its employees to moderate online patient discussion groups with the intent of also helping identify adverse events, then a proposal to the provider's institutional review board might be in order. The patients joining the group would be provided a consent form that detailed the conditions, the patient alternatives, and other components of a proper consent form. Given that patients had to register to join the group, their successful registration would only occur after they noted online that they consented.

While patients might be asked to sign a consent form, they are not invited to the online groups to get a diagnosis or a treatment. Rather the groups support patient-patient interaction, and the patients are responsible for the content of the message that they share. If a knowledgeable person brings extracts from the literature to the discussion, those extracts cite the original source and are informational only. Responsibility for taking action based on the information rests with the patient.

The Johns Hopkins Department of Pathology hosts some online patient discussion groups. The Department has found that patients may express their gratitude for this service via financial donations to the Department. Thus, the costs associated with maintaining the discussion Web site may be offset by patient financial contributions. This observation links to the economics of religion. Interestingly, online patient groups have some socio-economic characteristics in common with the socio-economic characteristics of religious groups (Rada, 2006b), and the opportunity exists to exploit the literature on the economics of religion (Iannaccone, 1998) in understanding the economics of online patient groups.

A healthcare entity that wants to sponsor an online discussion group has many options. For instance, the entity might or might not assign a healthcare professional as a moderator to the group. Providing a moderator is costly. Healthcare professionals have many demands on their time and often do not see participation in an online patient discussion group as a cost-effective use of their time. For the typical healthcare provider in the United States, efforts invested in an online discussion group cannot be billed to a health insurance company on behalf of the patients in the group. On the other hand, some healthcare entities have found that the goodwill generated by sponsoring an online discussion site stimulates financial donations from patients. A financial cost-benefit analysis that considered a wide range of factors, such as staff cost and patient loyalty, would be appropriate before an entity decided how much, if anything, to invest in online patient discussion groups.

CONCLUSION

Customer (or patient) relationship management is important to healthcare providers, as is minimizing adverse events secondary to healthcare decisions. One source of information that has been largely overlooked by the healthcare industry comes from online patient discussion groups. Online patient groups may provide an opportunity for healthcare providers to both build customer relationships and explore adverse events.

The author participated as a patient, though he is also a doctor, in two head-and-neck-cancer online patient groups. Patients discussed various types of adverse events, but four types were particularly intriguing for the gaps between what the patients needed to know and what the literature offered. These adverse events have been categorized as involving a diffuse symptom, a standard of care, a primary-care doctor's misdiagnosis, and uncommon reaction to a drug. The cases are multi-disciplinary in nature. The gaps in the literature create an opportunity for someone to produce a synthesis of the literature that highlights the gap and to publish that synthesis in a scholarly medical journal.

As measured by their responses, patients appreciated receiving information from the literature about their adverse events. A systematic approach to identifying such adverse events and providing relevant literature to patients is sketched based on the experiences of the author. Software can support the retrieving of relevant literature, but posing the response in the context of the patient's concerns requires human judgment.

One could continue this work in several directions. Patients in online groups typically focus on sharing empathy and information (Ebner, Leimeister, & Krcmar, 2004). Under what conditions do members of a group want primarily empathy or primarily information? What kinds of information are most useful? Some preliminary experimental results on identifying patient groups that prefer information over empathy have been established (Rada, 2006a).

Patients will have questions and comments about the quality of and cost of care from various providers. This kind of information may be comparable to what healthcare entities want from patient satisfaction surveys. To what extent and how can that kind of information be systematically mined from patient online discussion groups?

People seeking health-related information on the Web are one of the most common users of online discussion groups. Healthcare entities might benefit by paying further attention to the content of these discussion groups. This article has presented insights about dealing with adverse events in these groups and, more generally, framed some of the issues that a healthcare provider should consider.

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Chapter 5.19

Capturing and Comprehending the Behavioral/Dynamical Interactions within an ERP Implementation

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ABSTRACT

The behavioral and dynamic implications of an ERP deployment are, to say the least, not well understood. Getting the switches set to enable the ERP software to go live is tedious. But the difficult part is understanding all of the dynamic interactions that accrue as a consequence. Connectionist and causal models are proposed in this article to facilitate an understanding of the dynamics and to enable control of the information-enhanced processes to take place. The connectionist model facilitates the understanding of the dynamic behavioral implications of the larger ERP implementation installation per se. The underlying connectionist model will observe and detect information transfers and workflow. Once maps of the total infrastructure are determined by the models, an analyst can suggest improvements. The models become decision support aids for process analysts in situations where ideal process flows/information transfers are sought. [Article copies are available for purchase from InfoSci-on-Demand.com]

INTRODUCTION

A class of packaged application software called Enterprise Resource Planning systems (ERP) seeks to integrate the complete range of a business's processes and functions in order to present a holistic view of the business from a single information and IT architecture. ERP systems are integrated, enterprise-wide systems that automate core corporate activities such as manufacturing, human resources, finance/accounting and supply chain management (Klaus, Roseman, & Gable, 2000). A brief history of ERP is provided by Jacobs and Weston (2007). Additionally, a discussion of a recent ERP implementation with focus on end-user training can be found at www.diplomica.com (2007).

From a research perspective, several longitudinal studies have been conducted of ERP systems to ascertain how well they achieved their objectives (Holsapple & Sena, 2003a; Holsapple & Sena, 2003b; Lonzinsky, 1998). Other more recent studies have examined research questions such as: (1) how change management issues relate to federated ERP systems (Abels, Brehm, Hahn, & Gomez, 2006); (2) what determinants of ERP implementation success are (Cegielski, Hall, & Rebman, 2006); (3) what factors bring about a successful implementation of a collaborative technology that results in productivity improvements in small businesses (Jones & Kochtanek, 2004); and (4) how organizational knowledge is shared during ERP implementation (Jones & Price, 2004). Hendricks, Singhal and Stratman (2007) provide an excellent discussion of how enterprise systems (ERP) affect corporate performance.

ERP is an important area of study since large organizations world-wide have already adopted ERP and increasingly, small- and medium-sized enterprises (SMEs) too are finding it cost effective and a competitive necessity to follow suit. Current ERP solutions are based on a three-tier client-server architecture, in which the data, the applications and the presentation layers form three logically independent levels, each distributed from the other. Typically, the data management layer contains the database and the applications layer contains the business logic, with each allocated to separate distributed servers. The applications server often contains a portion of the presentation layer in that it serves out Web pages. The final physical component is simply the Web browser which is also a part of the presentation layer, but resides on a different processor—the client.

The comprehensive functionality of any ERP system requires a corresponding reference model for the whole enterprise. In addition to the usual software documentation, the supported processes and organizational structures as well as the structure of the data and objects are usually depicted in a reference model called the Enterprise Model. This model enables rapid access to the functionality and allows navigation through different abstraction levels and between different views in the Enterprise Model.

Enterprise Modeling is the construction of an enterprise model as a limited system that represents the larger system in question. The purpose of Enterprise Modeling is to understand and improve the enterprise, that is, to improve the symbiosis of the individual business processes and objects. In this sense, improvement means any change in coordination among the business processes and between objects that increases the benefits of symbiosis. The methodology of Enterprise Modeling is the construction of a set of views of the enterprise considered as a system. The resulting enterprise model contains business processes and objects and their relationships. Enterprise Modeling is the tool of business engineering and reengineering.

Enterprise Modeling has been one of the main themes of research in ERP, BPR, Software Engineering and IT Project Management areas, and as a consequence there are many different reference models and methodologies for enterprise modeling. Although there are numerous models and methodologies for enterprise modeling, their general structures are all similar and one of the most important components that they usually include is the business process model.

In this article, our purpose is (1) to present an efficient and robust mechanism that can capture the patterns of information transfer between business processing entities and (2) to extract behavioral implications from them within an ERP framework. For the purpose of this research, we integrated existing practice results from ERP enterprise and business process modeling with research we did on CIROS (Connectionist Inexact ReasOning System) for inexact reasoning (Jung, 1990; Jung & Burns, 1993).

This article consists of the following contents: in the next section (section two), we examine business process models for BPR within an ERP framework. In doing so, we focus on the problems and misuses and the possible causes for those problems and misuses in existing ERP systems. Also, we briefly review existing and industry-wide-adopted business process models.

In the third section, we present an information architecture for the prototype system to be proposed and suggest how this system would exist as a software layer juxtapositioned between other software layers so it can capture transaction traffic. We suggest that this layer will serve as a silent observer/recorder of all that goes on in terms of information transfer and workflow within the larger ERP system.

In the fourth section, we present a simplified business process model for our research purpose by modifying existing ones. The result is a Simplified Business Process Model (SBPM). Although it has a simple network structure, consisting of only two components—process nodes and links between nodes—we believe it serves well our research purpose and has enough scale-ability for practical applications.

In the fifth section, we briefly review the CIROS model and its underlying theoretical elements, and then modify the CIROS model to fit our current research concern. We combine the SBPM and CIROS models, and the result is a new connectionist model, called CLEAROS (Connectionist LEArning and ReasOning System), that has the capability of inferencing and learning for BPR[1] within an ERP framework.

In the sixth section, we suggest some further possible analyses that can be done based on the outputs of CLEAROS. In the seventh section, we provide an illustrative scenario of how the methodology could be used. In the final section, we summarize the research concepts and present some further issues extending the research result here.

BUSINESS PROCESS MODELS FOR BPR WITHIN AN ERP FRAMEWORK

The languages and methodologies for describing/modeling business processes are very diverse. [2] The types of models required to design, analyze and operate business enterprises have been discussed by numerous researchers (Jonkers & Franken, 1996; Kettinger & Grover, 1995). The general conclusion is simply that different models are required for different purposes. Thus, a critical research issue is to identify which type of model should be used for what purpose.

As stated previously, business processes can be described or modeled in various different ways for various purposes. However, our primary concern is the patterns of information flow between/among business processes and the behavioral ramifications that are consequences of these patterns, within an ERP framework. For that purpose, we are going to review a real business process model from an ERP software company and then, we build and present a business process model for our research purpose by simplifying it, which is the task described in Section 3. In the following, we briefly review and describe the business process model from SAP R/3 known as Business Blueprint (Curran & Keller, 1998).

SAP R/3 Business Process Model

A tool for business process engineering (and reengineering) in the SAP R/3 system is Business Blueprint. It includes various components for BPR. The language and methodology of Business Blueprint is based on a concept called EPC (Event-driven Process Chaining).

EPC is based on four key elements: events (when should something be done?); tasks or functions (what should be done?); organization (who should do what?); and communication (what information is required to do the right task?). Events are the driving force behind a business process, prompting one or more activities to take place. The EPC provides the interconnections between tasks, data, and organizational units and the logical time sequence involved to define a business process.

An event always triggers a task. It is important for each task to begin with at least one event (the start event) and to end with at least one final event (the finish event). The organizational units (departments, people, etc.) responsible for doing the task are added to the model of the business process to show a complete picture of how the business process is structured and performed.

When companies are faced with the complexities of creating a business information construct, however, different issues require different analyses of aspects of the business. To fill this need, the Business Blueprint of the SAP R/3 system provides the users with the capability of modeling from various viewpoints the business functions and application components, business organizations, data, business processes, and interactions of the various components. Each view answers a distinct question about the interaction of business processes. Accordingly, the users of the Business Blueprint can produce different models from each view, (i.e., application component model, organization model, data model, process model and interaction model). Among these the process view is the central view, and hence the process model incorporates the other models to give the users an integrated view of the whole enterprise under consideration.

Problems with Existing ERP Systems for BPR

ERP software projects often deliver disappointing organizational results, even if the information systems work well technically. One explanation is that companies use technology to automate old, ineffective processes. Moreover, BPR has had a high failure rate with consultants estimating that as many as 70% of BPR projects fail (Hammer & Champy, 1993).

It is well known that the implementation of any ERP software system will drive changes to existing processes. Necessarily, those business processes must morph to accommodate the new software system. The real question is, did the changes required result in any improvement in overall performance? A study described in Gattiker and Goodhue (2002) suggests that the process changes necessitated by the implementation did NOT result in any improvement in overall performance, in spite of the fact that the ERP-imposed processes were supposed best practices. The study rejected the hypothesis that ERP-driven changes in business practices resulted in positive performance impacts from using the software. These results illustrate just how much more work needs to be done to truly discover how to maximize the potential benefits of ERP systems.

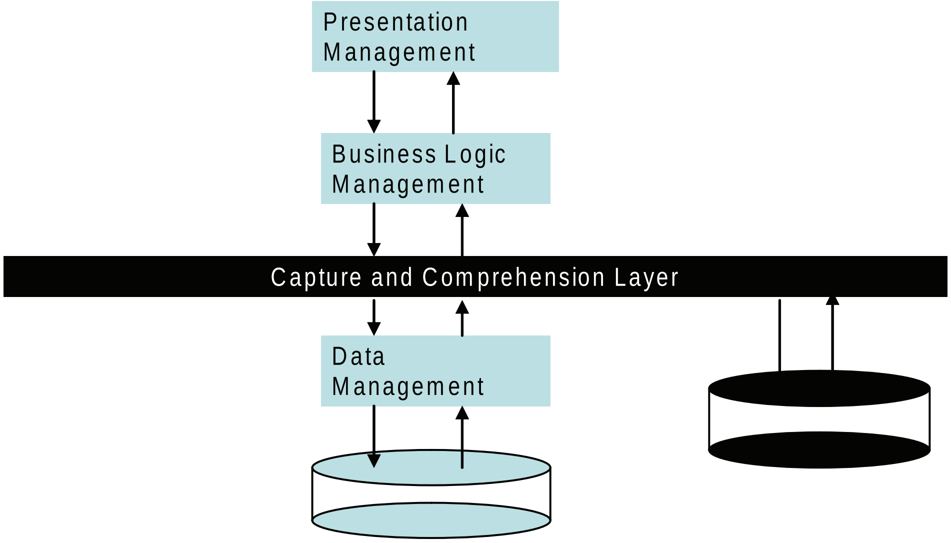
Research in artificial intelligence and expert systems (Holsapple &Whinston, 1996, pp. 462-490) suggests that if one were to ask managers how they react to a given scenario or situation, they could tell you, albeit incorrectly. It becomes necessary, therefore, to observe the managers at work and to record their responses from what is observed rather than from what they might say. This becomes even truer when more than one human decision maker or manager is involved in making a complex, chain-of-organizational decisions. Such "distributed human organizational knowledge" can only be captured through repeated observation. The concept of using artificial intelligence to comprehend the collective decision-making paradigms of an entire organization has yet to fully emerge as a discipline. In this work, we propose a mechanism for doing just that—undoing the reductionist approach to distributed decision-making by capturing the actions of every decision-making node in the entire process and performing analysis upon those actions. By examining the actions of the whole process, the collective behavior and dynamics of the whole process can be understood. In the next section, we present an architecture for capture and comprehension of the individual actions/decisions leading to an understanding of the organizational performance as a whole.

An Information Architecture for this Research

We are proposing that a connectionist model and its data-capture/storage module exist as a "layer" of software that interoperates between the business logic and the data management components of any ERP application. The layered information architecture for the system is exhibited in Figure 1. The dark layer, labeled the "Capture and Comprehension Layer" in Figure 1, is placed between the data management and business logic management layers of the traditional ERP architecture so that it is in a position to observe all the transaction traffic. Transaction traffic would include all client-initiated queries, all e-mails and their attachments, all purchase orders/invoices as well as other business documents, all "pushed" as well as "pulled" content.

The Capture and Comprehension Layer exhibited in Figure 1 observes all of the transaction activity and records the origin and destination of every such transaction, the time and date of the transaction, while classifying the transaction as to type and content. Each transaction is seen as an output from an origin node and as an input to a destination node. From these output/input records involving a pair of nodes, the proposed "system" will infer input/output records for any given process node. Moreover, input/output records are constructed for an entire network of nodes (to be defined subsequently). It is these collections of input/output ((or stimulus/response)

Figure 1. Location of the capture and comprehension layer (black) within the ERP architecture (grey)



records that the "system" uses to create a picture of what is related to what and who is making what decisions in terms of stimulus/response. How the collective decision-making is affecting the overall dynamical behavior of the organization in question is discussed next.

A Business Process Model for this Research

In this section, we define a generic business process, identify some important components of a business process, and then present a Simplified Business Process Model (SBPM) for our research purpose. The SBPM is based on SAP's Business Process Reference Model and the definition/characteristics of the prototypical business process as specified in the next section.

Definition: Business Process. A business process is a specified activity in an enterprise that is executed repeatedly. Business processes have the following characteristics (Martin, 1993; Taylor, 1996; Scheer, 1992, 1994).

- Business processes have definable beginning and end points, called nodes.
- Nodes exist wherever processing takes place; the nodes pass information to each other vis-à-vis a network.
- Business process nodes have inputs consisting of information, material, energy, and so forth, which they transform into outputs that also consist of information, material, energy, and so forth The transformation adds value to the outputs.
- Business processes are created by higher level business processes that monitor and control their operation (i.e., business processes are structured in hierarchical organizations).
- Business processes consume resources that are allocated to them by their higher level controlling business processes.
- Business processes report their status to their higher level controlling business processes.
- Business processes consist of sequences of events—instants in time at which the process undergoes state change

Accordingly, a business process model should incorporate a network structure and include process nodes and the relationships between the process nodes as a minimum. In addition, events, resources such as information, actor or owner, and information storages can be included as the modeler requires.

Process structure. A given business process can be thought of as a network of processing nodes. The process dependency model shows how business processes relate to each other and how they are dependent on each other. A given process is dependent on another process in the sense that the process in question cannot take place until the other process has completed for whatever reason. Basically, process dependency is determined by the business rules of the enterprise. Because business rules are very important in building the business process model, a thorough explanation will be given next. For the description of the process dependency, we use an example of a business process diagram shown in Figure 2.

There can be several forms of process dependency. In Figure 3, the single arc proceeding from process node 2 to process node 3 exhibits one-to-one process dependency. Node 5, with its many inputs from Nodes 1, 2 and 4, exhibits many-into-one dependency. Node 2 initiates nodes 3 and 5 and thus exhibits one-into-many dependency. We will visit Figure 2 again when we discuss a possible scenario involving our system in the last section.

What we wish to propose in this article is mechanisms to capture and comprehend the transaction traffic between the nodes.

Figure 2. A business process diagram

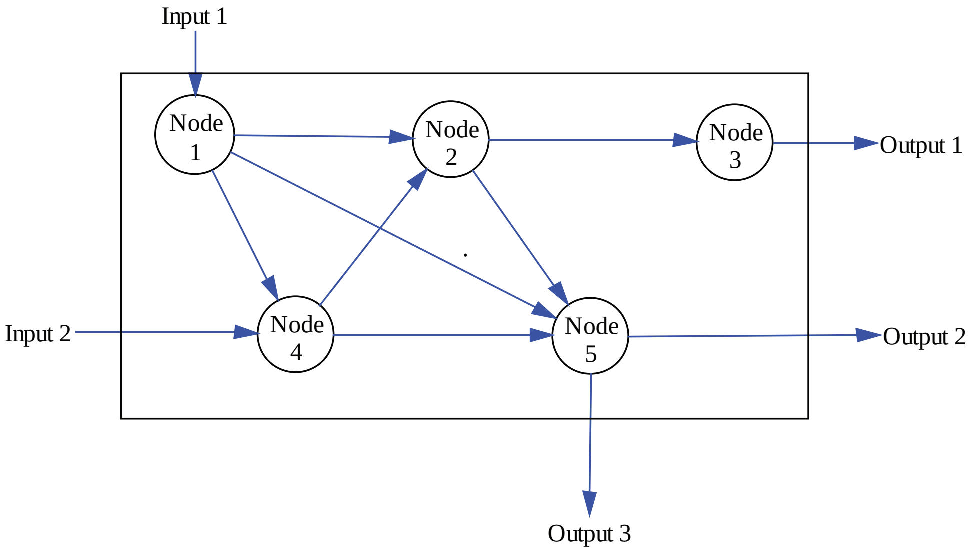
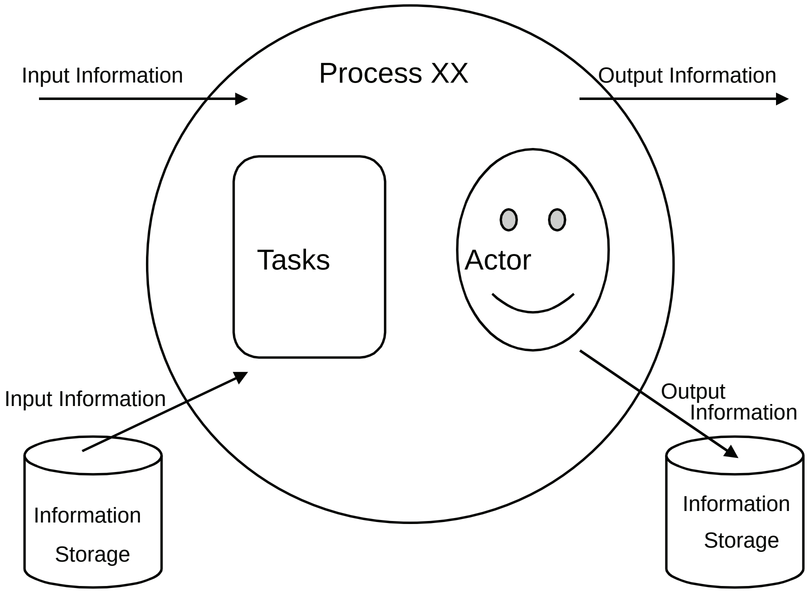


Figure 3. Process node architecture



The business rules. The enterprise has a set of business rules representing the conditions, constraints, and policies that control its organization, direction, and operation. Business rules are, in a sense, a shorthand language for expressing the business knowledge. One place business rules can be found is in the policy and procedure manuals of the organization. Such manuals contain the written operating policies of the firm. Carried to its logical extreme, the set of business rules of an enterprise can act as the declarative script of the enterprise. No matter what happens, one or more business rules would control what happens after that (Gale & Eldred, 1996). A contemporary discussion of business rules can be found in Von Halle, et al. (2006). Debevoise (2005) provides an excellent discussion of business process management utilizing a business rules approach.

The enterprise is an example of a general system. Any general system can be analyzed in terms of three perspectives: a structural perspective, a functional perspective, and a behavioral (or dynamical) perspective. Business rules apply to any or all of the enterprise perspectives. Thus, a given business rule may roughly be classified in one of the three perspectives.

Structural business rules are related to the structure of the enterprise. The structure of the enterprise is its set of entities and their relationships at a specific point of time. Structural business rules maintain the integrity of enterprise entities. Examples of structural business rules are as follows:

- The enterprise should consist of: marketing department, personnel department, finance department, accounting department, and customer service department. (Organization rule)
- Annual Total Profit = Annual Total Revenue – Annual Total Expense (Entity definition)

Functional business rules are the business rules that specify the goals and objectives of the enterprise. Basically, they collectively define the "what should be done (by whom)". Examples of these rules are:

- The marketing department should maintain at least 35% of the domestic market of product A.
- The management of human resources is the responsibility of the managers throughout the company (as opposed to being established as a separate organizational unit).

Behavioral business rules are used to control the preconditions and post-conditions of the state changes of the enterprise. A typical behavioral business rule has the following form: when certain events occur and certain conditions hold true, then the system states change. Behavioral business rules are closely related to the business process chains. In fact, the relationships between different business processes and chaining of the business processes are solely determined by the behavioral business rules of the enterprise in our Simplified Business Process Model (see the following subsection).

A Simplified Business Process Model (SBPM)

A simplified business process model that is sufficient for our purpose can be constructed as follows. The whole business process under consideration consists of smaller (sub) process nodes and relationships between them. The relationship type between two process nodes that is captured in this model is the triggering control sequence. That is, there should be an event or a set of events between the two process nodes that satisfy some predefined (according to some business rules) pre- and post-conditions for the relationship between the two nodes.

Moreover, because the relationship type is a kind of triggering control sequence, it should have some temporal sequence (i.e., the process node before the occurrence of the event (or transaction) originates the event and then the other process node after the occurrence is the destination) and therefore can be represented as a directed link. If we represent the process node as a circle and the relationship between two nodes as a directed link, a typical business process can be diagrammed as in Figure 2. We shall refer to this as a "knowledge network" and it is logically structured to cohere with our knowledge of the physical system that it represents. Thus, every transaction will have an origination node and a destination node.

Each process node must have as its components a task function that is basically a set of services that are expected to be done at this node: an actor who is in charge of or responsible for the task of this process node (an actor may be a person, an organizational unit, or an artificial software agent), and information storage(s) to read input information from or to store output information in. Here, the output information simply means the information resulting from the execution of the node's task (or function). The information storage(s) and the information stored in the storage(s) may be owned (or used) by the process node only, but is usually shared by other process nodes.

The input information may be an input from another node (or from outside of the whole business process in consideration) or read-in records or documents from the permanent storage(s) used by the node. The output information may be some temporary results to be delivered to the nodes that are linked to this node, or some permanent results that should be recorded and kept in a database as a record of a table or a document. Therefore, output information of a process node can be either temporary or permanent and, if permanent, must be deposited in the information storage. The structure of our Business Process Model is shown in Figure 2. Additionally, each business process node will have a very simplified internal architecture as shown in Figure 3. This figure shows us where we can insert a monitoring mechanism that will capture the transaction traffic; clearly, this will occur at the points where we see an input or output arrow. Software that can capture this traffic works as follows; the transaction is sent, not only to its destination but also to a system that records the origin and the destination of the transaction. The software is also capable of detecting the type of transaction as well as important content within the transaction. Additionally, each transaction is date-stamped and time-stamped so that durations can be determined. Of interest would be the length of time an information packet spends in some non-value adding activity such as in storage. All of this data would be placed in database tables, as suggested in Figure 1, utilizing standardized records. This concludes our discussion of the detection and capture mechanism; we describe next several possible comprehension mechanisms.

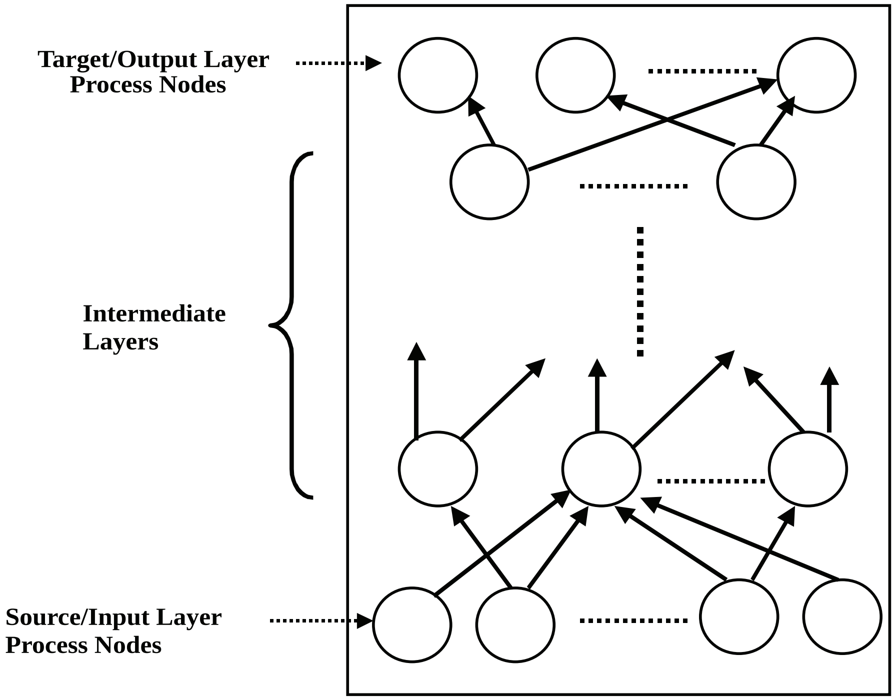
A Connectionist Approach to Business Problem-Solving and BPR

In this section of the article, we consider the network structure (topology) of the whole business process. Usually, this network of process nodes will have a mesh topology and might contain loops or cycles. We use the term "loop" to mean the link starts from a node and comes back directly to the same node. On the other hand, a cycle is a path (a sequence of links) on the network that starts from a node and ends with the same node but with at least one visit to another node. These definitions are used in the material to follow.

The fundamental structure of CLEAROS is exhibited in Figure 4. It is basically a layered, acyclic knowledge network. At the bottom is the input layer that represents the collection of source or input process nodes. The top layer is the output layer that represents the collection of target or output process nodes. Between the two layers are one or more intermediate layers that represent various classes of intervening process nodes. ERP process analysts will decide upon the initial structure of CLEAROS, in which each node represents a process of interest, possibly through use of SAP Business Blueprint and commercial tools like it. The structure must be acyclic because the learning (training) and inferencing algorithms require acyclic networks.

To capture and represent knowledge about the behavior of the ERP system, CLEAROS uses a connectionist model (Waltz & Feldman, 1988—see Appendix I for further discussion of connectionist models and of how CLEAROS works operationally) that makes the following assumptions:

Figure 4. Connectionist structure of CLEAROS



1. The domain knowledge (K) consists of two components, the set (V) of business process nodes and the set (E) of relationships (links) among the business process nodes. Mathematically, K is a diad of V and E (K = <V, E>). The links of the digraph may represent any natural cognitive ordering that is consistent, meaning each link must represent the same relation.
2. The whole node set consists of three mutually exclusive subsets: input (or source) process node set, output (or target) process node set, and intermediate process node set. A process node in CLEAROS should belong to exactly one of these subsets at a time (or in a session of running). See Figures 4 and 7 for depictions of how these nodes interact.

   An input (or source) process node represents a business process that captures or generates ultimate source information in the ERP system. Ultimate source inputs are generated and captured inside of the whole business process under consideration. One possible source input would be POS (Point-Of-Sale) data; another is EDI (Electronic-Data-Interchange) data that is transported across organizational boundaries.

   An output (or target) node represents a point at which transactions leave the system of interest. It is a point where measurements are taken because managers or analysts have concerns. It may also be a "natural" output of the collection of processes networked together—the end product of a supply chain, for example.

   An intermediate process node represents one of the middle steps to reach the target process node from the input nodes. Since there are usually many intermediate nodes by which to reach the target, they collectively determine the behavior of the target.
3. The relationships taken into account in CLEAROS may represent information transfers or actual flows or money, material

or product. The relationship between two process nodes in CLEAROS represents a triggering (or "invoking" in programming terminology) sequence (i.e., if the preceding process is finished and a certain condition holds true then the (directly) succeeding process should follow):

As we have seen in the BPM section of this article, the relationship between two process nodes is determined by the business rules of the enterprise. In fact, the whole business process dependency structure of an enterprise is determined by the whole set of business rules of the enterprise and represented as a network topology (See the item (1) in the following description).

Based on the fundamental assumptions about the knowledge of enterprise business processes, CLEAROS represents its knowledge as follows (design constructs of CLEAROS).

1. Network representation of knowledge

Knowledge about the enterprise's business processes may be represented in a network of process nodes and directed links (some other authors use the term "arc" or "connection" or "edge" instead of "link," but in this article, the term link is used consistently). The process nodes and their links constitute the network topology. The knowledge network initially constructed within CLEAROS is patterned after the enterprise's actual business process network as discerned by use of SAP's Business Blueprint.

2. Representing the influence of a link by weight values (learning)

Associated with each link is its value from the continuous range of [0, +1], called the "weight value" or WV. The weight of a link in CLEAROS measures and reflects the relative degree of influence by the preceding process node on the succeeding process node. The weight value +1 of the link from the preceding process node to the succeeding process means that the preceding process node has the maximum degree of influence on the performance of the succeeding process node. Zero weight means that the preceding process node has no influence on the succeeding process node.

3. Representing the relative importance of each process node (inferencing)

Associated with each node is its value taken from the continuous range of [0, +1], that represents the degree of the importance of the process node in terms of its relative criticalness over the whole business process (under consideration), where the value +1 means that it is a process with the highest degree of importance over the whole business process under consideration, and where the value 0 means that the process has no contribution (no value addition) to the whole business process under consideration. This number will be called the "PF" (Performance Factor) of the process node and will represent the degree of the contribution (value addition) to the whole business process under consideration.

4. Acyclic layered network

As discussed in the BPM section of this article, the original business process diagram under consideration, if represented in a network, might involve loops or cycles, and thus violates the assumptions made in CLEAROS. So it will be assumed, initially, that our business process model does not involve any loop or cycle. If a business process appears to involve loops or cycles, this concern can be addressed by consideration of the abstraction level of the process nodes. A method that can resolve the problem of loops is suggested in (Jung & Burns, 1993) and in the Appendix to this article. By picking a high-enough abstraction-level, the loops and cycles disappear as they are contained within the process nodes. In any case, the knowledge network in CLEAROS will be assumed to be an acyclic network. Causal models of the enterprise will, however, contain the cycles and loops, thereby enabling analysis both with and without loops. This approach offers the best potential for fully understanding the interactions between nodes.

5. Knowledge update by inferencing (update of fact-type knowledge)

CLEAROS changes (or updates) its knowledge in two ways: (1) by learning, and (2) by inferencing. Knowledge updates by inferencing in CLEAROS mean changing (or updating) the PF values of its nodes.

6. Knowledge update by learning (update of rule-type knowledge)

CLEAROS can modify its pattern of connectivity as a part of its learning process. Modifying the pattern of connectivity (thus learning) means changing (or updating) all or part of the weight WV values associated with the links in CLEAROS.

Initialization of the CLEAROS Knowledge Network

For CLEAROS to do its main job, inferencing, its knowledge network (knowledge base) should first be structured and then initialized. The starting rule used for structuring the knowledge network is to use a separate node for each process and/or processor in the real network. Once the node structure is determined, the initialization of the CLEAROS knowledge base is just the initialization of all its weight values. The weight values initialization in CLEAROS can be done basically in three ways.

One way is assigning a weight value for each link. The initial weight value of each link may be supplied by human experts who are in charge of the process. Another way is that we calculate the data traffic rate for each link between two process nodes and normalize it, and then assign the normalized value to the weight. The last method is by using the CLEAROS learning mechanism. To use the CLEAROS learning system, we should have enough learning records. The specific learning method of CLEAROS is explained next.

Learning

Learning requires building and updating the knowledge structure. Because CLEAROS represents its knowledge structure as a network of process nodes and relationships between these nodes, its structural change assumes adjustment and update of relationships between the process nodes. In CLEAROS, this is done by adjustment of weight values between the nodes in different layers. Therefore, learning in CLEAROS requires updates of its weight values. These adjustments permit CLEAROS to perform correct inferencing.

Learning in CLEAROS takes place as follows. Once the structure of the knowledge network has been determined and initialized, learning is required to establish the weight values of the links. Learning requires a table of input/output records. CLEAROS is exercised by exposing it to each set of inputs in a single record, one record at a time. The outputs produced by CLEAROS are then compared with the actual outputs contained in each record. Learning takes place through adjustment of the weight values so as to minimize the error between the predicted outputs of CLEAROS and the actual outputs.

There are many theories, methods and algorithms for learning in the connectionist paradigm. The learning method adopted in CLEAROS is the Generalized Delta Rule or back-propagation algorithm as suggested in Rumelhart, Widrow and Lehr (1994). Back-propagation is currently the most important and most widely used algorithm for connectionist learning. It is an algorithm for learning in feed-forward networks (like CLEAROS) using MSE (Mean Squared Error) and gradient descent. For a detailed introduction to the back-propagation method, readers may consult chapters 11 and 12 of Gallant (1993). For a detailed explanation about the application of the back-propagation method to reasoning system designs, readers are referred to Jung (1990). A thorough illustration of initialization, learning and usage of connectionist models like CLEAROS is found in Jung and Burns (1993).

Inferencing

This step can be applied after initialization and learning have been undertaken. One of the main purposes of CLEAROS is to find the relative degree of performance (i.e., the PF) of a business process node and the relationships among different process nodes in terms of contribution or value addition (again, the PF). In other words, managers or analysts who are concerned about the overall performance of the whole business process (under consideration) may want more detailed information about the relative performance or contribution of each component process and once they get this information, they can do whatever they think appropriate based on the information.

The inferencing mechanism of CLEAROS can provide that kind of information that managers or analysts need. There are basically two types of inferencing tasks that are possible in CLEAROS. These inferencing tasks in CLEAROS can be grouped into two groups. The first group involves forward-chaining computation and the second group involves backward-chaining computation. For fundamental computational mechanisms of connectionist models like forward- and backward chaining and for various learning models, readers may consult Gallant (1993). For hyper-fast inference engine architectures see Burns, Winstead and Hayworth (1989).

1. Forward-chaining computation:
    - Find the effect of input/source process nodes;
    - Calculate the Performance Factor of the target process nodes;
2. Backward-chaining computation
    - Find the causes or paths for a target process node; and
    - Produce justifications/explanations for the conclusion.

Finding the effect of input/source process nodes means finding the paths from a given source process (or set of source nodes) to the target process nodes. This task is needed when managers or analysts want to understand the exact (partial) process chain and the effect of change in some processes. Calculating the effect of input/source process nodes is needed when a manager or analyst wants to get information on the effect of the source process' PF (or the change of their values) on the target process.

Finding the causes or paths for a target process node is similar to the task of finding the effect of input/source process nodes but, in this case, search direction is the opposite one (from target/top to source/bottom). This task is needed when managers or analysts want to find an answer to the question such that "Given a process with a problem, what process chain do I need to address to resolve the problem?" Producing justification/explanation is similar to the task of finding the causes or paths but during learning, CLEAROS calculates the weight values WV of all the links and the performance factor PF values of all the nodes along the chain and shows them to the users. For a more detailed explanation about each of the inferencing tasks presented in this article, readers should consult Jung and Burns (1993).

Analysis of the Discovered Knowledge Network

Three-pronged analyses of the knowledge network created by CLEAROS are possible. First, through the use of simulation and system dynamics (see Sterman (2000), Senge (1990)), the performance and behavior of the associated processes will be assessed. The assessment begins with a determination of the criteria by which performance is assessed (what is the bottom line)? Once the criteria are known, a performance criterion can be constructed. The basic causal structure of the system dynamics model can be discerned from the density/character of the transaction traffic between the identified nodes. A stock-and-flow diagram and subsequent simulation model could then be constructed, tested and utilized to comprehend the underlying dynamics. Are there other networks/rules that might achieve better performance? What is the bottleneck or impediment that prevents performance from being better? Are there networks that might perform equally well at considerably less cost? This analysis type would address such questions.

A second possibility is to perform value analysis[3] on the implied value chain embedded within the knowledge network. Nodes with low PF's and/or links directed toward or away from them with low WV's would be good candidates for elimination. Such an analysis might reveal that a particular node adds no customer-perceived value and thence can be removed. Another possibility might reveal that a simplified knowledge network will achieve the same result, reducing process cost, cycle time while improving quality. Value analysis can contribute significantly to the simplification of the knowledge network. The problem of complexity in large ERP systems is a huge one and this analysis type alone can have a significant impact on the bottom line. It is complexity that adds so much cost and time to the testing and debugging effort. As the ERP software system increases in complexity, the expected time to find a bug increases from days to months.

Still, a third possibility is to perform carbon/silicon replacement analysis on the network. Such analyses might reveal where an expensive carbon-based processor (i.e., a human) or node could be replaced with an inexpensive silicon-based one (i.e., a computer). This might be possible when the business rules of a carbon-based processor are observed to be deterministic and programmable.

THE METHODOLOGY IN PRACTICE: A STEP-BY-STEP EXAMPLE

In what follows, we shall use the word "training" to connote learning as discussed earlier. The basic steps of the methodology would be the following:

1. Determine the structure of the knowledge network and initialize all of its WV's and PF's
2. Monitor the transaction traffic for at least a month
3. Study the transaction traffic and create input/output records for training
4. Layer the knowledge network based on the transaction traffic
5. Train the connectionist network to the transaction traffic using CLEAROS so that values are established for all WV's
6. Perform inferencing on the trained network so as to find all of the PF's
7. Analyze the fitted network using the analyses suggested (system dynamics, value analysis, carbon/silicon replacement)
8. Propose a simplified/restructured knowledge network
9. Test the simplified/restructured knowledge network in off-line simulative fashion
10. Implement the simplified knowledge network
11. Monitor and measure the simplified/restructured knowledge network to ascertain if it achieves goals

We will begin with the process diagram shown in Figure 2. Assume that the knowledge network exhibited in Figure 2 produces the following record of transaction traffic shown in Table 1 next.

The nodes correspond to the following functions. Node 1 receives returned items. Node 2 does all manufacturing and rework. Node 3 ships returned items back to customer. Node 4 receives incoming purchase orders. Node 5 does all outgoing new order shipping.

In analyzing the transaction traffic, we learn that a rework item was inputted to Node 1. Node 1 logs in the item, examines the item and decides whether the item can be reworked or not. If the item can be reworked, it is transferred to node 2, where manufacturing reworks the item. If the item cannot be reworked, it is discarded and a notice is sent to Node 4 resulting in the manufacture of a new item as a replacement. Once reworked at Node 2, the item is transferred to Node 3. At Node 3, the reworked item is then packaged and shipped back to the customer.

In Table 1, we also see that a purchase order was entered at Input 2. This resulted in orders being transmitted to Nodes 2 and 5. As can be seen, the knowledge network processes returns and purchase orders coming in from customers. However, it does not do it efficiently. For example in Table 1, we see that more than a month was required to process order #21345 (from 8/15/2007 until 9/26/2007) and roughly three weeks were required to process the returned item (from 8/13/2007 until 8/29/2007). Most of that time is consumed at Node 2. Thus, there is clearly a bottleneck at Node 2.

Next, we examine the transaction counts for a period of a month, as shown in Table 2 (step 2).

We learn that there were 395 product returns during the month and 1945 purchase orders. We also observe that of the 395 returns, 295 were reworkable and 100 had to be discarded, resulting in new products being built for the customer. We can discern this by observing that Node 1 transferred 295 transactions to Node 2, and 100 transactions to Node 4. We also notice that during this month, only 90 reworked items were returned to their owners, while 1788 new items were shipped out. Clearly, there is a significant number of orders-in-process as well as rework-in-process, but we cannot tell how much. It is impossible to tell from the transaction counts how much product is currently “in the system” because we don”t know how many transactions were in the system to begin with.

Table 1. Transaction traffic for simple knowledge network exhibited in Figure 2

Input Node	Output Node	date	time	Urgency	Content	Order #
Input 1	1	8/13/2007	8 a.m.	Expedite	Rework	225
Input 2	4	8/15/2007	9 a.m.	Normal	Purchase Order	21345
1	2	8/16/2007	8:10 a.m.	Immediate	notice	225
1	4	8/17/2007	2:00 p.m.	Normal	notice	None
1	5	8/16/2007	8:15 a.m.	Normal	notice	None
2	3	8/29/2007	4:30 p.m.	Normal	notice	225
2	5	9/5/2007	4 p.m.	Normal	notice	21345
3	Output 1	8/29/2007	5 p.m.	Normal	Rework Returned	225
4	2	8/19/2007	1:30 p.m.	Normal	order	21345
4	5	8/19/2007	1 p.m.	Normal	order	21345
5	Output 2	9/26/2007	4:30 p.m.	Normal	order filled/shipped	21345
5	Output 3	9/16/2007	5 p.m.	Normal	adj AP & Cash	21345

Table 2. Transaction counts for all arcs in Figure 2 over the period of a month

ARC	Input Node	Output Node	Traffic/mo
Input 1 to 1	Input 1	1	395
input 2 to 4	Input 2	4	1945
1 to 2	1	2	295
1 to 4	1	4	100
1 to 5	1	5	10
2 to 5	2	5	1895
2 to 3	2	3	92
3 to Output 1	3	Output 1	90
4 to 2	4	2	1822
4 to 5	4	5	25
5 to Output 2	5	Output 2	1788
5 to Output 3	5	Output 3	1788

Training the connectionist model CLEAROS with an identical network topology to that of Figure 2 yields the result shown in Figure 5 in which the thick, bold arcs/nodes show us what arcs/nodes received the most weight as a result of the training and inferencing. The training (step 5) utilized the data in Tables 1 and 2 after that data had been reorganized into input/output pairs (step 3). This picture, again suggests that Node 2 is a bottleneck as it is given the highest weight among all of the nodes. Evidently, CLEAROS ignores transaction counts of 25 or less as being too insignificant to be considered here, eliminating arcs 1 to 5 and 4 to 5. CLEAROS would tell us (step 6) that purchase order transactions starting at Input 2 result in shipped orders coming out at Output 2 about a month later. CLEAROS also tells us that rework transactions result in reworked product being shipped back to the customer 75% of the time (at Output 1) and in new product replacements 25% of the time, coming out at Output 2. Further, observations at Node 2 revealed that rework jobs essentially brought the line to a halt while technicians diagnosed and then repaired each reworked unit. The rework jobs were curtailing throughput of the new orders.

Based on the information highlighted in this example, process analysts would decide (step 7) to separate the Rework from the Purchase Order Fulfillment and simplify the total process, as shown in Figure 6. In Figure 6, Nodes 1, 2 and 3 do all of the Rework processing while Nodes 4, 5 and 6 do all of the purchase order processing. Obviously, Nodes 1 and 3 would do the receiving, Nodes 2 and 4 the rework or manufacturing, while Nodes 3 and 6 would do the shipping. This improved knowledge network (step 8) would then be tested in an off-line, simulative fashion (step 9).

By comparison with Figure 5, Figure 6 is referred to as “layered”. Layering often helps process analysts to gain additional insight, to see their processes in a whole new way. Algorithms for layering are discussed in Jung (1990) and Jung and Burns (1993) as well as the Appendix.

Simulation studies of the reengineered processes shown in Figure 6 might suggest that purchase order cycle time could be reduced from one month to three days, mostly as a result of eliminating the bottleneck at Node 2. Substantial improvements in throughput would then be realized as well. The simulation studies also might suggest that increases in the capacity at Node 2 would further reduce purchase order cycle time without creating too much resource idleness. In addition, improvements in outgoing quality would be significant now that manufacturing has segregated its rework from its primary responsibility of filling orders. Finally, by placing the Receiving (Nodes 1 and 4), Manufacturing (Nodes 2 and 5) and Shipping (Nodes 3 and 6) nodes in close proximity, it is possible to utilize sharing of resources. The revised, simplified knowledge network would be implemented (step 10) and monitored to ascertain that it achieves its objectives (step 11).

Figure 5. Result of applying the connectionist model to the data in Tables 1 & 2

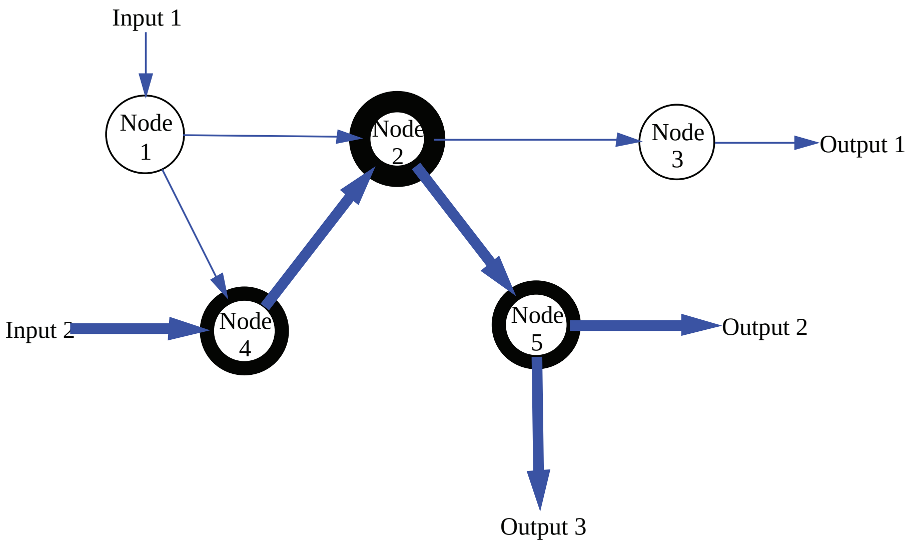
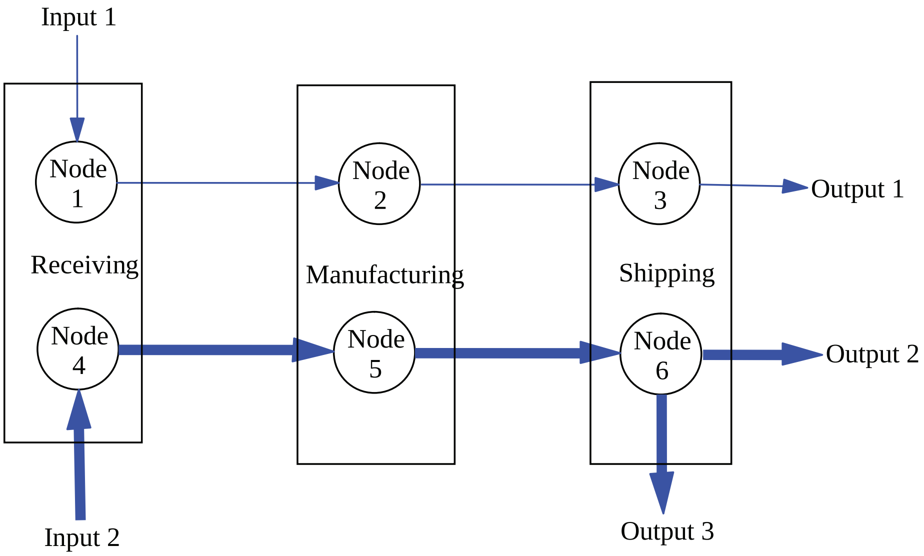


Figure 6. Re-engineered processes to accommodate shortened cycle times, increased throughput and improved product quality



SUMMARY

In this article, an enterprise architecture that automates the process of capturing what information/data professional people and managers are using, and comprehending how they are reacting/responding to that information, is described. The basic idea is to (1) capture all of the transaction traffic between and among the nodes of an ERP system and then (2) to use various models including a connectionist model as discussed in Jung (1990) and Jung and Burns (1993) to "comprehend" the structure of the interactions that exist within the process. The Capture and Comprehension Layer exhibited in Figure 1 observes all of the transaction activity and records the origin and destination of every such transaction. The transaction is seen as an output from an origin node and as an input to a destination node. It is thus able to construct input/output records for any given node. Moreover, input/output records are constructed for an entire network of nodes as defined by CLEAROS. It is these collections of input/output ((or stimulus/response) records that CLEAROS uses to create a picture of what is related to what and how the collective decision-making is affecting the dynamical behavior of the organization in question.

With regard to process structure, the unknowns are the human information processors in terms of what information they take in as inputs and the information they put out as outputs. The rest is reasonably well known; specifically, the business rules are known. Once the process structure is known, there is opportunity to understand why the total process behaves as it does and why performance is less than desirable, as well as how performance can be improved.

Analysis of the process begins once the total process is known. Three-pronged analyses are possible in which overall process performance is assessed first. First, process dynamics can be understood using system dynamics. Alternate process structures can be modeled and tested for possible improvements in performance. Then, value analysis of the implied value chain is possible, revealing where processing at certain nodes adds no customer-perceived value. Finally, carbon/silicon replacement analyses can be performed, resulting in substantial reductions in cost as carbon-based units are replaced with silicon ones.

Overall, it is hoped that this article has highlighted the challenges associated with ERP implementation. Additionally, it is hoped that the ideas developed in this article aid researchers and managers in better understanding how to successfully implement ERP in organizations.

Finally, this article launches an entirely new discipline, which we refer to as distributed natural/artificial intelligence. By our definition, distributed natural/artificial intelligence studies the collective performance implications coming forth from a network of intelligent nodes, each making decisions that affect the overall performance of the larger network as a whole. In this way, we hope to comprehend why certain behaviors, dynamics are being observed in the system.

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ENDNOTES

[1] Business Process Re-engineering—a topic about which much has been said and studied during the last two decades.

[2] See Koulopoulos (1995); Linzinsky (1998); Martin (1993); Rohloff (1996); Scheer (1989); Taylor (1996); and van Es, R. & Post, R. (1996)

[3] Industrial engineers call this “value stream mapping.”

APPENDIX I

The generic structure of CLEAROS follows that of a connectionist model. CLEAROS uses a connectionist model rather than a neural model because synapse firings do not contribute to our understanding of the process being modeled.

As mentioned in the main body of this article, two steps are required to formulate the CLEAROS connectionist model. A third step is the one that actually uses CLEAROS to model/simulate the distributed infrastructure. The steps are: (1) initial structure and weight values WV; (2) learning; (3) inferencing. We discuss each of these in turn.

Initial Network Structure and Weights

The initial structure of the acyclic knowledge network is determined by process analysts who may use commercial products like SAP's Business Blueprint. Additional input to this process is the expert knowledge of the process analysts. The output of this process is a knowledge network that is free of loops/cycles and is a layered network. The network structuring and initial weight determination process consists of three tasks: structuring the initial network, removing all loops/cycles in the initial network, layering the network and establishing the initial weights.

Next, the structure must be examined. The original knowledge structure, if represented in a network, might involve loops of cycles. In CLEAROS, it is restructured to resolve the abstraction level imbalances of the variables that are represented by cycles or other contradictions to the assumptions before it performs any inference or learning process. Thus, cycles/loops must be removed by "condensing" them down to a single node. Layering the network means (1) that all layers have the same number of nodes and (2) no link extends for a distance longer than the next succeeding layer. Thus, links cannot extend to nodes that are not in the next immediate layer, if the structure is to be "layered." This is the way we have drawn the structure in Figure 7.

Figure 6 would be considered "layered" but Figure 5 would not be. Actually, layering is optional, but for large networks becomes necessary in order to keep the computational time for learning and inferencing within reasonable bounds. Assume a structure with L layers and N nodes. Without layering, the computational complexity is of the order of O[N(L-1)], whereas the computational complexity of a layered network is of order O[N]. Layering frequently results in additional nodes being added. As was observed in the main body of the article, layering actually helps analysts to gain additional insight into their processes as each layer is given meaning in the context of the entire knowledge network. Thus, new perspectives and perceptions can be gained from this step. In summary, what the initial structuring step does is to take unstructured, messy managerial knowledge and arrange that into a logical, sound, layered hierarchical structure that facilitates computerized learning and inferencing.

Learning

Learning involves finding the weight values WV through fitting to input/output records of data. Based on these values, a new structure may emerge. Structural change involves adjustment and update of the relationships between variables. In CLEAROS, this is done by adjustment of weight values between cells in different layers (recall that weight values are associated with the links in the knowledge network). The learning method adopted for CLEAROS is the generalized delta rule or back-propagation algorithm as suggested in Rumelhart et al. (1986). This algorithm finds weight values WV that enable the outputs of the knowledge network to match the outputs in the input/output records when the knowledge network is stimulated with the corresponding inputs. Associated with each link is a weight value from the continuous range of [-1, 1]. The value 1 means a perfect (positive) correlation between the two variables that are connected by a link and -1 means a perfect (negative) correlation between the two variables. Zero weight means no correlation (or independence) between the two variables. By weight, we mean that strength of connection of the degree of belief in the (causal) relationship between two variables that is represented as a link in network representation of knowledge.

Inferencing

The main purpose of CLEAROS is to find causes within the frame of discernment for the observed symptoms. In pursuit of this purpose, CLEAROS infers the performance factors (PF) associated with the nodes, especially those nodes representing causes. Each node or cell in CLEAROS represents a single process or processor (silicon or carbon). It does not incorporate distributed representations of a process or processor. The inferencing is actually a computational algorithm for finding the ultimate causes. The task is the following. In the Cartesian space S x C, where S is the space of all possible symptom elements and C is the space of all possible cause elements, find a subset of S x C that correctly captures the symptom/cause pairs. This task is a problem of graph search, involving either breadth-first or depth-first search. Both algorithms have the same computational complexity: O(max[n,e]), where n is the total number of nodes and e is the number of links in the digraph. Both lines of reasoning can be pursued in parallel because of the natural parallel computational structure employed by CLEAROS. For the calculation of performance factors, it is computationally more convenient and efficient to use a completely layered knowledge network like that shown in Figures 4, 6 and 7. In what follows, a mathematical formulation of the computation process is presented, followed by an example.

The inference computation process can be mathematically expressed as a system of equations that involve a weight matrix $\mathbf{W_k}$ for each layer k. In addition, the inference algorithm also needs as input, an activation level for each cell, represented by y_{ki} of the *i*th cell in the *k*th layer. The standard graph-theoretic formula (Harary, Norman, & Cartwright, 1965) is known to be

$$y_{ki} = \sum_{j=1}^{N_{(k-1)}} w_{kij} y_{(k-1)j} \qquad k = 1, \ldots, L,\ i = 1, \ldots, N_k, \tag{1}$$

where w_{kij} is the weight of link ij directed from the jth cell in the (k – 1)th layer to the ith cell in the *k*th layer, and $y_{(k-1)j}$ is the output level of the jth cell in the (k – 1)th layer. If vector/matrix notation is used, Eq. (1) becomes

$$\mathbf{y}_k = \mathbf{W}_k \mathbf{y}_{k-1},\ k = 1, \ldots, L, \tag{2}$$

where $\boldsymbol{y}_{k-1}$ is the activation vector of the k-1th layer, $\mathbf{W}_k$ is the weight matrix, and $\mathbf{y}_k$ is output vector, both for the *k*th layer

For a computational example, we shall consider the knowledge network depicted in Figure 6. In this case, the input set Y = {returns, purchase orders}. Assume that the input vector is

$\mathbf{y}_o = [\ 100, 500]^T$。

These values connote weekly returns and weekly purchase orders. Then, iteratively and successively, the activation level of layer 1 is $[100, 500]^T$. This can be interpreted as the net influences of the input set on the two receiving nodes (see Figure 7), nodes 1 and 4. For simplicity, the output values coming out of Nodes 1 and 4 are simply the input values going into nodes 2 and 5; thus, $\mathbf{y}_1$ is a function of $\mathbf{y}_o$, $\mathbf{y}_1 = \mathbf{f}(\mathbf{y}_o)$, and we will assume that function to be simply a linear function. Thus,

$$\mathbf{y}_1 = \mathbf{W}_1\, \mathbf{y}_0 = \begin{bmatrix} .99999 & 0.00001 \\ 0.00001 & .99999 \end{bmatrix} * \begin{bmatrix} 100 \\ 500 \end{bmatrix} = \begin{bmatrix} 100.004 \\ 499.996 \end{bmatrix}$$

Assume that learning (back propagation) has found weight values for $\mathbf{W}_1$ to be

$$\begin{bmatrix} .99999 & 0.00001 \\ 0.00001 & .99999 \end{bmatrix}.$$

Next,

$$\mathbf{y}_2 = \mathbf{W}_2 \mathbf{y}_1 = \begin{bmatrix} .75 & 0.00001 \\ .25 & .99999 \end{bmatrix} * \begin{bmatrix} 100.004 \\ 499.996 \end{bmatrix} = \begin{bmatrix} 75.008 \\ 524.992 \end{bmatrix}.$$

Assume that learning has found weight values for $\mathbf{W}_2$ to be

$$\begin{bmatrix} .75 & 0.00001 \\ .25 & .99999 \end{bmatrix}.$$

Notice, in Figure 7, that learning has found a relationship between node 1 and node 5 of weight .25. Next,

$$\mathbf{y}_3 = \mathbf{W}_3 \mathbf{y}_2 = \begin{bmatrix} .99999 & 0.00001 \\ 0.00001 & .99999 \end{bmatrix} * \begin{bmatrix} 75.008 \\ 524.992 \end{bmatrix} = \begin{bmatrix} 75.0125 \\ 524.9875 \end{bmatrix}.$$

Assume that learning has found weight values for $\mathbf{W}_3$ to be $\begin{bmatrix} .99999 & 0.00001 \\ 0.00001 & .99999 \end{bmatrix}$.

It should be apparent from the earlier that, in the manufacturing stage, it is discovered that roughly 1 out of 4 returned items cannot be repaired, so that customer gets a new one. The result is, an initial order vector of 100 returned items and 500 new orders actually results in 75 returned items being repaired and returned to customers and 525 new items being sent out. Clearly,

$$\mathbf{y}_3 = \mathbf{W}_3 \mathbf{y}_2 = \mathbf{W}_3\, \mathbf{W}_2 \mathbf{y}_1 = \mathbf{W}_3\, \mathbf{W}_2\, \mathbf{W}_1\, \mathbf{y}_0 = \mathbf{W}\, \mathbf{y}_0.$$

When we carry out the indicated multiplications in $\mathbf{W}_3\, \mathbf{W}_2\, \mathbf{W}_{1,}$ we get the following result:

$$\mathbf{y}_3 = \mathbf{W}\, \mathbf{y}_0 = \begin{bmatrix} .7499875 & 0.000029999 \\ 0.250012 & .99997 \end{bmatrix} * \begin{bmatrix} 100 \\ 500 \end{bmatrix} = \begin{bmatrix} 75.01375 \\ 524.9863 \end{bmatrix}.$$

The same result is obtained for the output vector $\mathbf{y}_3$.

What we conclude from this series of vector/matrix multiplications is that reworked returns are strongly influenced by the number of incoming returns and the number of manufactured products is strongly determined by the number of incoming purchase orders. Further about 25% of returned items cannot be reworked, so they are replaced with a new one. Notice, though that the relationships are not perfect in the sense that very weak connections of the order .000001 were found. These are just computational errors.

Functional Comparison of CLEAROS with Other Analysis Tools

The overall architecture of CLEAROS resembles causal diagrams used in system dynamics or other causal modeling methodologies. However, there are a number of important differences between CLEAROS and these causal models: (1) the main purpose of building CLEAROS is to capture unknown organizational knowledge (that is heuristic and experiential) and then do subsequent inferential computation on it. On the other hand, the principal purpose of casual models is to capture the causality inherent in systems; (2) CLEAROS is designed to handle a large number of relevant variables, and more importantly the relationships between these variables need not be limited to causal relationships, while those in causal models are; (3) CLEAROS assumes hierarchical, layered and acyclic network structures with synchronous timing in updating their status. On the other hand, causal models assume general network structures with asynchronous timing in updating their status; (4) CLEAROS supports weighted relationships (representing degree of influence) whereas the signed digraphs utilized in causal models do not.

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Chapter 5.20

Enterprise Information Systems Change, Adaptation and Adoption:

A Qualitative Study and Conceptualization Framework

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ABSTRACT

This article introduces and discusses the process and system conceptualization framework for adoption and ongoing evaluation of enterprise information systems, based on the series of recursive high and base-level conceptualizations of organization's existing (as-is) and desired (to-be) processes and systems. The motivation for the framework is provided by a qualitative study that reveals two distinct approaches to the organizations' systems adoption and change. The approaches are labeled as systems view and process view, centered on organizations' processes and systems respectively; where process oriented approach is more likely to result in better fit between the adopted systems and corporate needs. Consistent with this finding, the purpose of the introduced framework is to guide organizations toward embracing the process-centric approach to the adoption of enterprise information systems, by placing particular emphasis on processes' and supporting systems' fit with organization's strategic goals.

INTRODUCTION

Continuous pressures to cut costs, increase productivity and capture a competitive edge in global markets are among the main drivers of ongoing investment in change and adoption of information systems and system components in many enterprises. Nevertheless, the success rates of enterprise systems implementation have been fairly low with respect to a variety of evaluation criteria, such as on-time and on-budget completion, system match with functional requirements, and cancellation rates (Hong & Kim, 2002; Legris, Ingham & Collerette, 2003). Reported failure-rates vary somewhat, but typically are estimated at 30-50% (Surmacz, 2003). Consequently, a great deal of research has explored the factors influencing the effectiveness of managerial decisions about information system adoption, as well as the quality of the implementation of these decisions.

This problem has been approached from many perspectives using a host of methodologies. Many different empirical models have been published, including cognitive models at an individual level such as the Technology Acceptance Model (TAM) (Davis, 1989), behavioral models such as the Theory of Planned Behavior model (Ajzen, 1991), and firm resource-based models (Srinivasan, Lilien & Rangaswamy, 2002). This large and diverse body of research has added much to our understanding of technology adoption on an organizational level, especially in the identification and classification of a variety of factors according to their source (internal vs. external to the organization), size, explanatory power, and level of managerial control in influencing their size and impact (Champy & Hammer, 1993).

Some empirical research has recognized the importance of organizational contexts in determining the success of information systems planning. A study (Hong & Kim, 2002) has concentrated on the influence of organizational fit on success of system implementation. In this study, organizational fit was defined as the degree of alignment between the existing software package and organizational needs in terms of data, processes, and users. The authors recommended that the implementation team as well as top managers should undertake this assessment of fit, ahead of the actual adoption process, with continuous measurements during the implementation phase. This, and similar, studies touch on the issue of alignment among organizational strategy, business processes, and enterprise systems.

In addition, recent published work investigated the relationships among strategic goals of an organization, its business processes and structure, and its information systems. According to Attaran (2004), the role of information technology capabilities is emphasized in process planning and redesign. Information technology is described as a critical enabling tool to advance firm performance through business process reengineering by facilitating communication across functions, improving process performance, and by helping management to model, optimize, and assess the consequences of business process change. In Attaran (2004) these processes were described as tools for organizations to achieve success.

Given the known connections among strategies, processes, and systems, why is change and adoption failure still common? Perhaps there are additional factors that have not yet been widely recognized and accepted by the industry. In particular, the importance of the conceptualization of processes and systems at multiple levels of complexity is an important, but often underappreciated, factor in system change and adoption. The conceptualization process can often be a moderating factor in success, in that other established success factors are enhanced by the organizational commitment to conceptualization of processes and systems. This article introduces a framework that outlines, in an increasing level of detail, the recommended flow of conceptualization efforts in an organizational system change and adoption process, the constituencies involved in the different stages, and appropriate methodologies. Our framework complements and extends the conceptual models of process and systems planning and implementation that exist in the research literature by binding them together in an ongoing organizational practice of continuous reexamination of processes and systems in a non-disruptive, constructive manner.

The arguments for our framework start with a brief discussion of business and systems architecture, their interdependence and the need for a comprehensive view that accounts for both. Next, the actual change planning and decision making process is delineated, and observations about corporate practices are presented based on qualitative research. Thirdly, a simple competitive space matrix is presented to clearly identify the issue of fit among organizational strategies, processes and systems. We propose and address four questions that address key aspects of this fit at different stages of system planning and deployment. The conceptualization framework based on the four questions is then presented. This framework is designed to facilitate the organization-wide commitment of planning for the change of information systems. It is presented as an important component of a multi-level effort that encompasses strategic goals, business processes, and information systems planning. The presentation of conceptualization framework is followed by the discussion of different modes of conceptualization. Finally, a comparison between the conceptualization framework and the existing approaches is presented, followed by the summary and conclusion.

BUSINESS AND SYSTEMS ARCHITECTURE AND BUSINESS PROCESSES

The architectural components of a modern enterprise are defined in the literature in many ways. An important distinction is the differentiation between *business* and *system* architectures. Architecture is defined as the fundamental organization of a system embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution (IEEE, 2004).

Business architecture, specifically, defines the business system in its environment of suppliers and customers, and, if applicable, taking into account the regulatory and legislative policies. According to Aerts, Goossenaerts, Hammer, and Wortmann (2004), the business architecture consists of processes, organizational rules, people, and resources, while Herman (2001) defines business architecture as consisting of processes, technology resources, governance structure and information flow. The architecture of a business captures its major components (and their responsibilities and relationships) as well as its major mechanisms and processes that enable the firm to collaborate to meet the requirements of the business enterprise (Firesmith 2005). The common thread among the various definitions of business architectures is the recognition that business processes often cut across traditional functional boundaries. This recognition of process centrality with respect to business architecture is common across organizational functions, roles, and relationships, including day-to-day operations, transactional systems infrastructure (such as production, logistics, and customer service), or managerial processes dependent on information and decision making infrastructure (such as communication, coordination and planning).

System architecture describes the information system in terms of its logical (e.g., functional) and physical (component) architecture. While some definitions are limited to software and hardware architecture, we argue that architecture is more complex in terms of its components and their relationships. In Aerts, Goossenaerts, Hammer, and Wortmann (2004), two types of system architecture were defined: application architecture, describing the application components and how they interact with each other, and information and communications (ICT) architecture, which was defined as a generic resource layer describing hardware (computers, networks, peripherals) and software (operating systems, DBMS) infrastructure. Another layer of system architecture, suggested by Firesmith (2005), includes the database components describing type, location, overall content, and usage. Finally, Firesmith (2005) suggests additional layers of architecture of application data components, labeling this as information architecture, as well as a distinctly defined user interface architecture, including type, technologies, structure, and navigation.

The empirical studies on individual and organizational adoption of information technology often have had a much narrower view of system architectures, dominated by only one of its components. For, example, studies concentrated on verification of TAM and similar models often focus on the user interface architecture, taking into account only the components that are directly exposed to the end user, without accounting for the value of the enterprise architecture. Another narrow view of corporate information resources is centered on the hardware and communications architecture. This focus has driven an opinion, as stated by Carr (2003), that since information resources can be easily commoditized, they are devoid of strategic importance. This impression, if widespread, can lead to the view that information systems planning, implementation, and deployment efforts should be evaluated strictly on the basis of immediate cost. This impression may be one of the causes of the current trend towards standardization and/or outsourcing of systems and system capabilities.

Our view is that only a comprehensive consideration of all the elements of business and enterprise system architecture and their many complex interrelationships can reveal the true magnitude of the strategic impact of information systems and resources on an organization and its strategic goals. Such analysis must adopt a view of systems architecture that includes all of its constituent elements. Since the systems are complex and diverse, any worthwhile analysis of corporate systems architecture needs to be done at multiple levels of detail and points of focus and should provide a concrete methodology for recursive consideration of business and systems architectural elements (the framework presented later in this article adopts this approach).

The argument for looking at business and systems architecture as a part of the same system has been raised by many academic and professionals. For example, an article (Davenport & Short, 1990) argued that IT should be viewed as more than an automating or mechanizing force. This article defined a recursive relationship between IT and business process design and engineering. This relationship illustrates how advancement of IT should be assessed in terms of how it supports new or redesigned business processes instead of merely supporting organizational entities or functions. Exercising this recursive relationship helps to ensure that business process redesign is applied feasibly and that IT does not generate misguided or impractical solutions. Despite these and other similar recommendations, the corporate practice of designing, purchasing or outsourcing systems or their components often does not reflect this interdependence between the business and systems architectures. The next section will illustrate this reality.

PROCESS VS. SYSTEM DRIVEN INFORMATION SYSTEMS CHANGE

The term Enterprise Information System (EIS) refers to an information system that facilitates business processes and functionalities on an enterprise level (i.e., spanning across the enterprise). The term can include collection of systems supporting specific functions such as CRM, Supply Management, Finance, Accounting, Sales, Manufacturing, and Human Resources. These systems can work either as collections of "best of breed" units or they can be modules of a larger (single vendor) fully-integrated system. The common thread is the enterprise-wide nature. For example, if the Financial Management System encompasses financial transactions throughout the enterprise (by communicating and exchanging information with other relevant systems), we consider it a part of an EIS. Similarly if a multi-function integrated system supports its functions throughout the enterprise we consider it an EIS. In the following paragraph we will look at some of the possible ways to configure an EIS.

An EIS can be implemented as an ERP System, where suites such as SAP, Oracle Applications, or M1, provide function-specific modules integrated into a larger system. For example, Oracle Financials and Oracle Human Resource are two of many modules available in the Oracle Applications ERP suite, while SAP Financials and SAP HR are two of many modules available in SAP ERP Suite, and M1 Labor Management and M1 Inventory Management are two of many modules available in M1 ERP suite. Typically, ERP modules can be used as-configured by the vendor or they can be partly-customized. An EIS can also be created as a collection of function-specific (“best of breed”) commercial off-the-shelf software (COTS) systems, such as C2 CRM system or i2 Supply Chain Management system. And finally, an EIS may also be custom-developed as either a collection of custom-developed units that are custom-integrated or as a single fully-integrated custom-developed multi-functional system.

A general rule should hold for each component of systems architecture, whether it is custom-designed, acquired as an ERP or other semi-customizable software module, or installed as COTS adapted to organizational use. Every component should be justifiable by demonstrating a clear improvement of the process it supports, or showing that it is an enabler of new processes that have a clearly understood purpose and primary benefit to the organization. However, a closer look at the details of organizational decisions to build, acquire or redesign systems suggests that organizations often make these decisions without formal analysis of existing systems and processes or without the clear understanding of the new system’s details. Decisions are often made by “gut feelings” or intuition, rather than quantifiable criteria (Mahmood & Mann, 1993). Even when quantifiable criteria are used, they are not always firmly tied to the actual details of how processes are to be performed and how systems will support those processes. One of the common themes revealed by the interviewees in our study, was that this disconnect often occurs in the case when only financial quantifiable criteria, such as return on investment (ROI) or net present value (NPV), are used as the decisive evaluation factors. Use of operational quantifiable criteria, such as order cycle time, error rates or customer satisfaction metrics is more likely to require clear understanding of the details of existing and new processes and systems. However, the understanding of actual details of how processes are to be performed and how systems will support those processes may still be absent even in this case. This absence of the unambiguous and comprehensive cognitive understanding of the processes and systems during the decision making stage is notable in a large variety of publicly available descriptions of corporate system adoption.

To further explore the nature of enterprise information system change in practice, we conducted, over the period of 17 months, a number of interviews with managers and IT professionals from midsize to large organizations who were involved in adoption of new enterprise systems (the list available at gsbdata.wt.luc.edu/~nenad/framework/appendix.pdf). The analysis of gathered narratives, combined with an analysis of published corporate cases and other academic and practitioner articles (referred to in this article), supports classification into two general approaches. We label the prevalent organizational view that guides the system change or adoption process as the System View. We will contrast this with the process-centric view of enterprise systems adoption/change that we will argue presents a better alternative. We label this approach the Process View. We use the term Process View as it refers to the approach to the change and adoption of information systems. This term has been used in the IS literature in other contexts. For example, in (Kruthcen 1995) the term Process View is used for a completely unrelated concept in software architecture that captures software engineering issues such as performance and fault-tolerance.

The System View often results in a change or adoption process that is based on indirect measures of system success rather than direct observations and understanding of how systems operate and support the processes. In many cases, our interview data suggest that the driving force and underlying motivation is fairly narrow and the changes in existing corporate systems are often initiated by a single event. The structural changes initiated by a single event are often reactive, and some of the observed examples include: a response to a regulatory change, external change in competitive landscape, or IT personnel attrition reaching the point where existing staff is not able to support legacy technologies.

Often the systems change is initiated by changes in corporate strategy (acquisition, international expansion, etc.), or one particular development that is the result of implementation of corporate strategy. A typical example of a system change being driven by implementation of corporate strategy is a change motivated by the strategy of growth. Our survey indicated that the resulting growth of an organization often led to a perception of inherent inadequacy of existing systems. The managers with whom we spoke often expressed this inadequacy as insufficient scalability of the systems. The scalability issue then became the central driver of the decision to redesign, change or completely upgrade a corporate system or some of its crucial elements. Yet another observed change motivator was a result of real or perceived competitive pressures. Our interviews suggested that these pressures often became apparent through perceptions that the existing software applications did not fulfill the functional needs of the processes they were supposed to serve. Managers stated that new application software was then adopted primarily because of its improved process functionalities such as “better reporting functions”, “the ability to exchange data with other applications,” “better process and cost tracking,” “user interface ease and intuitiveness of use,” and “the presence of process (industry) specific options to enter track and report relevant information.”

These examples share a common thread. At a certain point in time, organizations conclude that current systems are inadequate to support their existing processes and organizational strategies. This motivation to change, dominated by the perception of systems inadequacy, is typical of the System View. It is based on the evaluation of the current organizational systems in terms of managerially observable and quantifiable measures of success, often neglecting to sufficiently analyze the core organizational processes first (day-to-day, as well as communication, coordination, and managerial decision making processes) and the ability of these processes to support organizational strategies. The conceptualization-driven progress from strategy to process to systems is not followed. As a result, single-issue drivers often trigger decisions. Consequently, the system change initiatives driven by this view have a high probability of a post-deployment experience that does not match the envisioned organizational goals. In addition, lack of complete understanding of processes and existing systems often results in ignoring the abilities of existing systems to support process changes as demanded by new strategies. For example, one of our observed scenarios of system change involved a decision at the highest level of management to change to a system that would “provide uniform service across locations (stores)”, and “centralize customer service decisions” without consultation with internal IT staff about the ability of *existing* systems to support this strategic goal.

In contrast to the System View, the Process View is an idealized, benchmark approach that should start with the conceptualization at the business process level, accompanied by (1) the key organizational strategic goals and resulting business processes (2) the abilities of the current enterprise systems to support key processes, and (3) the potential of feasibly obtainable improvements to current enterprise systems or their possible replacements. The vision of potential changes to existing enterprise systems should be based on the improvement of existing processes or facilitation of new processes, consistent with organizational strategies. This thorough understanding of process requirements and system abilities should then lead to clear and unambiguous conceptualization of system and business architecture, and as a result, an effective specification of the components of the enterprise information system.

In essence, we argue for reinvigoration of the concept of Business Process Reengineering insofar as it envisions a formal and systematic approach that integrates all of the strategic, operational and information systems dimensions. In a recent evaluation of the relationship between IT and BPR (Attaran, 2004), the role of information technology in fostering process thinking was emphasized. We extend this idea by arguing for more direct understanding of the measures of system success in terms of the clear visualization of actual process improvements. Only after that has been achieved, can truly meaningful financial and/or operational measures be derived. Also, the Process View encourages the continued evaluation of processes and systems, resulting in ongoing decisions to upgrade, modify or replace existing processes and systems. This approach requires a higher level of involvement by the internal IT staff as well as the key process owners in making the process and systems decisions.

Table 1 compares and contrasts the two views of the information systems change: the Process View and the System View. The factor listed in the first row of the Table 1 (Current and Future Process and System Conceptualization) refers to the organizational ability to achieve a clear understanding of both existing and desired business processes and related systems. We divide the remaining observed factors into two groups; observed outcomes, that is, results of adopting the System View in contrast to the Process View; and observed indicators, that is, factors that may serve as indicators whether an organization has adopted the System View or the Process View.

As stated above, the majority of corporate situations we observed may be classified into the System View category, with low level of commitment to self-examination through deliberate and ongoing process and systems conceptualization. As a result, measures of success are often indirect: operational or financial (factor 1); and the timing of change decisions is relatively sudden (factor 2), and driven by perceived inadequacy of current systems rather than the understanding the true nature and needs of business processes (factor 3).

In contrast, the Process View approach, as a result of conceptualization efforts, uses measures of success (factor 1) that can be expressed as concrete improvements of existing processes or clear understandings of a new processes and their benefit to the organization. These improvements can then be translated into operational and financial measures that, being based on clear views of new or improved processes and systems, are justifiable and logically explainable. The ideal Process View approach should be based on ongoing routine evaluation of organizational processes and needs. These routines should result in a smoother progression towards decisions to implement changes (factor 2) based on an understanding of organizational processes as well as the current state of available system technologies (factor 3).

Our analyses of scenarios that represent the System View approach suggest that there is, at best,

Table 1. System vs. process view of information systems change

	System View	Process View
Current and Future Process and System Conceptualization	Not Likely	Necessary, at varying degrees of formality
Observed Outcome Factors:		
1. Ex ante measure of success	*Indirect*: ROI or some other explicit financial or operational metric: operating cost reduction, order cycle time, customer satisfaction metrics, sales increase, labor cost reduction.	*Direct*: Specific process improvement or process change, driven by a clear vision of the new or improved process in comparison to the existing one. Indirect measures follow, with greater degree of justification.
2. Progression of the decision to change	Single event or a sequence of events in a short span of time, sudden.	Ongoing, regular process.
3. Main decision driver	Realization that "systems are inadequate". External Event: merger, managerial fiat or "challenge" by upper-level management	Understanding of the needs of business processes and abilities of all feasibly available system technologies
4. Probability of the fit between adopted systems and organizational goals	Low to Moderate	High
5. Likelihood of problematic organizational adaptation to software	Moderate to High	Low
Observed Indicators:		
6. Level of internal IT staff involvement in the process planning stage	Low	Moderate to High
7. Internal IT excellence, strong IT leadership, and understanding of organizational structure and processes	Not Likely	Highly Likely
8. Key decision makers	*External*: Vendors, Consultants	*Internal*: Process Owners

a moderate probability that the adopted systems and the processes they support are consistent with organizational strategic goals (factor 4). We will argue and demonstrate throughout this article that a Process View approach has a higher probability of achieving such fit.

Interestingly, our analysis also suggests that the System View leads to an increased probability of packaged software adoption (such as ERP or CRM packages) in an *indiscriminate* fashion (i.e. adjusting process to fit the package vs. the other way around). As stated in Hong and Kim (2002), there are essentially two alternative approaches to implementation of packaged software: package adaptation to organizational needs or organizational adaptation to the package. Vendors often discourage package adaptation to organizational needs (Hong & Kim, 2002), and often the latter (opposite) approach is adopted. Consequently, the adoption of highly standardized systems may in turn end up constraining and commoditizing the processes of the organization. The end result might still be positive, since packaged solutions essentially represent the established processes and rules in a given industry. And indeed, many organizations are quite happy to copy other organizations' business process designs. The adoption of a packaged solution may also be the most rational choice for organizations that do not possess strong IT leadership and/or internal technological capabilities. Unfortunately, a System View often leads to the adoption of a perceived “default package”, while other options do not even get serious consideration. This causes the possibility of problematic organizational adaptation to software (factor 5), where organizations find themselves trying to change their processes to fit the chosen software even in cases when some of their processes do not benefit from the required changes.

The Process View can, depending on circumstances of each case, lead into a number of different adoption outcomes (such as standard ERP package adoption, adoption of an ERP package with some customization of certain modules, or design and implementation of a customized system) but in each case the probability of the fit between the adopted systems and organizational goals (factor 4) is high and, subsequently, the likelihood of problematic organizational adaptation to software (factor 5) is low. The Process View can require organizational adaptation to software, but such adaptation is much more likely to be of a smooth nature resulting in actual improvements to the processes. Note that, like a System View, a Process View can indeed lead to the adoption of the “default standard package”, but Process View is much more likely to lead to this outcome in cases when such outcome is the right fit for the organization.

The process that is commoditized by the implementation of the packaged software may be an outcome that is completely acceptable to an organization, and is already a de-facto requirement in some commodity industries (Davenport, 1998). Nevertheless, each organization should go through a formal evaluation process and study the implications for its own competitive position. Therefore, we conclude that even in the cases where packaged software adoption initially appears to be the most rational decision, a formal planning and decision making process should be undertaken that involves all decision levels of an organization.

In addition to outcomes, our exploratory study identified several factors that can serve as clear indicators of organizational adoption of the System View versus the Process View. For example, in the System View, the observed level of internal IT staff involvement in the planning stages of business process modification or new process creation (factor 6) is low, as is the overall level of internal IT excellence and the strength of IT leadership (factor 7). In contrast, the Process View demands a significant level of IT staff involvement, even in the early process planning stages, and depends on a high level of IT excellence and leadership. These resources demand technical competency and detailed understanding of organizational processes and structure. Finally, organizations using the System View for the change and adoption of information systems often explicitly or implicitly relinquish the key decision making authority regarding customized design or the choice of system packages (and in many cases the decisions regarding their business process themselves) to external decision makers: consultants and/or package vendors (factor 8).

In summary, our investigation of the very diverse set of corporate motivators and mechanisms that initiate change in corporate information systems has revealed that organizations in our sample primarily used the System View. As a consequence, organizations typically do not undertake the formal conceptualization of processes and systems on multiple levels, either prior to the decision process or during the change to or adoption of the new system. This observation underlines the importance of a common framework for conceptualization of current corporate processes and systems across different architectural dimensions. The remaining sections of this article will introduce a methodology for conceptualizing organizational strategy and antecedent goals in terms of concrete outcomes and measures of success. This framework ties the managerial vision that is centered on strategic goals and specific business outcomes (such as cost reduction, market share increase, or improved customer satisfaction) with precise consideration of concrete business process goals that finally enables the framework to transform transforms itself into specifications for changes of the system and system components.

Number of authors have written about the need for conceptualization at the business process level as the essential part of developing information systems for the enterprises, which is at the core of the approach that we labeled in this article as Process View. This approach is reflected in comprehensive frameworks such as TOGAF (TOGAF, 2003) and Zachman (1987; 1997; 2000) that cover a broad spectrum of issues related to the architecture and development of information systems. The topics included in these frameworks range from the development of data and applications architectures and the development of technology architecture (including network and hardware configurations) to the guidelines about the roles, skills and experience of the staff involved. The methodology framework that we will introduce in this article is more focused in its scope, as it targets the *change* in the corporate information systems. We are motivated by the results of our own surveys and analysis of previously published corporate cases and academic articles, which include observations such as in (Zachman, 2000) where the author calls for the academic community to expose the correlation between the inability to deal with complexity and high rates of change and the lack of proper approach to the process of planning and design of information systems.

STRATEGIC FIT: STRATEGY, PROCESSES, AND SYSTEMS

Process and systems conceptualization can provide significant value to the achievement of organizational strategic goals. How? By reducing poor choices that lead to improper fit between the organization's strategic goals, business processes and supporting systems. In this section, we briefly discuss, using a competitive strategy example, the notion of strategic fit between an organization's business processes and its strategy. We use a two-dimensional matrix where one dimension is a generic dimension of process "quality," which may correspond to either a dominant quality dimension of process enabled by information systems (such as process completion time or consistency of process outcome) or a compound measure of process quality consisting of multiple dimensions (such as overall process quality score taken as a subjective measure of process perception by process stakeholders, or a weighted score encompassing individual process metrics.)

The second dimension of the two-dimensional matrix is labeled as process cost. For externally visible processes, especially those that are directly related to products or services consumed by customers, the process costs may be directly related to the price of the product/service, a more direct dimension that influences competitive position. For internal processes, the cost may be related to price less directly.

In Table 2, we divide the competitive space in four quadrants, corresponding to four possible combinations of process cost and quality. The perceptions of high/low quality and cost are subjective (especially for externally visible processes) and relative to the quality and cost of

Table 2. Process cost and quality matrix

		PROCESS COST	
		High	**Low**
PROCESS QUALITY	**High**	**High Quality/ High Cost**	**High Quality/ Low Cost**
	Low	**Low Quality/ High Cost**	**Low Quality/ Low Cost**

processes of other competitors. This position will change over time, meaning that a company may lose its preferred position in the matrix if it does not change the quality and/or cost of its processes. In particular, new technological generations of systems will change the definition of high and low process quality and cost. As a result, if managers fail to change processes and systems, their firms may lose their favorable positions in the competitive space. During periods of technological and architectural stability, most organizations should be able to eventually move to the upper left quadrant of high quality process at a low cost. In the short run though, while companies strive to occupy the upper right quadrant of high quality and low cost, the feasible rational choices are different high/low tradeoff combinations of quality and cost: low quality/low cost and high quality/high cost. In this period, organizations can choose their position in the two general tradeoff quadrants.

We argue that in order to provide the correct assessment of the position of their processes as well as the direction of the movement in this or any other strategic continuum, organizations need to adopt formal policies and methods of analyzing their processes and systems. An essential part of this practice should be process-and-system conceptualization through abstract modeling or other approaches. The importance of modeling was traditionally argued to have system implementation value, making sure that systems work in a manner consistent with specifications that are coming from an external source. However, we argue that modeling and abstraction create even greater value in providing a vision of the exact process that a system is supposed to support, as well as of the system itself, with a clear understanding of how the process impacts the organization's position along the relevant strategic dimensions.

Requirements engineering should be a tool to achieve an informed commitment to a certain system rather than detached consent from the management (Jerva, 2001). Our interviews suggested that managerial commitment is often based strictly on the promised outcomes without real insight as to how those outcomes are to be achieved. We postulate that four key questions should be raised during system and process planning and development. These questions signify key points in the planning and development process at which a conscious conceptualization effort should be undertaken. The questions should address the fit among strategy, processes, and systems. The questions are sequential, whereby posing of each subsequent question implies that the previous one is answered in the affirmative:

Question 1: Are current business processes consistent with organizational strategy? (Consider external factors and developments, including new technological trends in systems, applications, and technical infrastructure.)

Question 2: Given that current business processes are consistent with organizational strategy; can the business processes be improved with the existing enterprise systems? (Consider how the cost/quality mix of business processes can be moved further to the upper right quadrant of the matrix.)

Question 3: Are business processes supported properly by current systems? (Consider if the enterprise systems architecture is consistent with the organization's business architecture.

Question 4: Given that the enterprise systems in general provide proper support for organization's business processes; can the enterprise systems be further improved? (Consider if the cost/quality mix of business processes can be moved further to the upper right quadrant of the matrix by additional improvement in system components.)

In the next section we propose a conceptualization framework as an activity workflow model that is based on the constant recursive flow of conceptualization activities on different levels. We put the emphasis on differentiating between "As-Is" conceptualization with "To-Be" conceptualization (Aerts, Goossenaerts, Hammer

& Wortmann, 2004; Ceronsek & Naiburg, 2004; Okrent & Vokurka, 2004). "As–Is" conceptualization facilitates the development of clear process vision and the understanding of existing processes and systems. "To-Be" conceptualization enables proper design and implementation of new processes and systems.

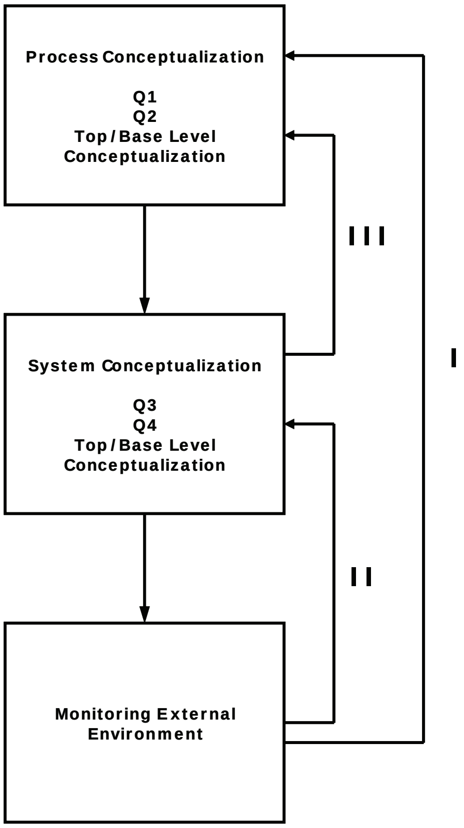
A CONCEPTUALIZATION FRAMEWORK: FROM STRATEGY TO APPLICATIONS

The conceptualization framework we propose is a series of multi-level diagrams depicting organizational efforts to achieve a clear vision of business strategy, processes and systems, as captured by four questions listed in the previous section. Each level contains the set of activities centered on sequences of "As-Is" and "To-Be" abstractions, with inclusion of additional means of conceptualization in the stages focusing on the systems. The main purpose of the "As-Is" abstraction at each level is to reveal improvement opportunities, by determining whether the current processes and/or systems are aligned with corporate goals, and if not, revealing the reasons why those processes are not performing according to the corporate goals. The goal of "To-Be" conceptualization is to create an alternative vision of processes and/or systems in response to this realization.

This framework will be described at three levels of detail. Figures 1 and 2 correspond to the high and medium level of detail, while the remaining figures (Figure 3, 4, 5 and 6) represent a more detailed view of individual set of activities as envisioned by our framework. Each figure contains solid rectangles that represent a set of activities that is centered on one or more conceptualization activity. The unidirectional lines represent the progression from one set of activities to another. They include the feedback lines representing recursion from the subsequent activity to its predecessor.

Figure 1 captures the high-level view of our conceptualization framework, where squares are used to depict three major sets of activities. The first set of activities is based on Process Conceptualization (PC), which is motivated by Question 1 (fit between processes and strategy) and Question 2 (having established general fit between business strategy and processes, how can processes be further improved). It is followed by the second set of activities that is based on System Conceptualization (SC) and motivated by Question 3 (fit between processes and systems) and Question 4 (further improvement of systems). The second set of activities is followed by the third set of activities representing the monitoring of the competitive and regulatory environment as well as the monitoring of technological developments that may influence the current and future abilities of the enterprise's information systems.

Figure 1. High level model



There is a feedback loop from the monitoring activities into the PC driven activities (recursion I) and SC driven activities (recursion II), as well as between the SC and PC driven activities (recursion III). Recursions I and II are driven by a reconsideration of processes and systems due to observed changes in the external environment. Recursion III represents process reconsiderations as driven by changes in underlying systems. The existence of feedback between the activities depicted in Figure 1 *does not* imply continuous (never-ending) *changes* of processes and systems, but rather ensures that no external (I and II) or internal (III) development of significance is neglected in its possible impact on organizational processes and underlying information systems.

Figure 2 displays a more detailed division of conceptualization activities. The first four stages (rectangles) correspond to one of the four questions listed above. Each of the four rectangles represents a set of activities motivated by the conceptualization of business processes and/or systems. The level of conceptualization changes from high (Top Level) to low (Base Level), both in the Process Conceptualization and System Conceptualization stages.

The internal feedback lines for each activity set (labeled as IV) have specific meaning as well. Our framework allows for each of four main sets of activities to have more than one level of conceptualization complexity at each stage, if needed. In that case the terms Top Level and Base Level can represent several grades of complexity, ranging, for example, from high to medium (for Top Level) and from medium to very detailed (for Base Level). The recursive efforts at each level ensure that no external (I and II) or internal (III) development of significance that might affect the organizational processes or information systems is neglected. The intensity and number of conceptualization activities at each of the four main levels will differ from one case to another, depending on the size and complexity of an organization and its processes and systems. The general rule should hold that the next set of activities should not start until the question that motivates each stage is answered affirmatively and with a level of certainty that is acceptable by the organization.

Our framework allows for various levels of change to be dealt with in a different way and at the appropriate level. First, any significant change observed through monitoring activities should be followed by high level reconsideration of key business processes, as represented by the feedback line (Ia) between the monitoring activities and the top level process conceptualization (TLPC) driven activities. Second, any significant technological change in the abilities of elements of enterprise systems or other external developments that are disruptive enough to affect the fit between processes and strategy can initially be analyzed at the high level, while other resulting analysis and process and system changes considered can be disseminated between the remaining activity sets. Third, less comprehensive technological changes in abilities of systems and system components as well as external developments that are deemed not to be of strategic impact may initiate the reconsideration on the lower (individual) process level or the system level itself. These are depicted in Figure 2 as feedback lines between the monitoring

Figure 2. Mid-level model

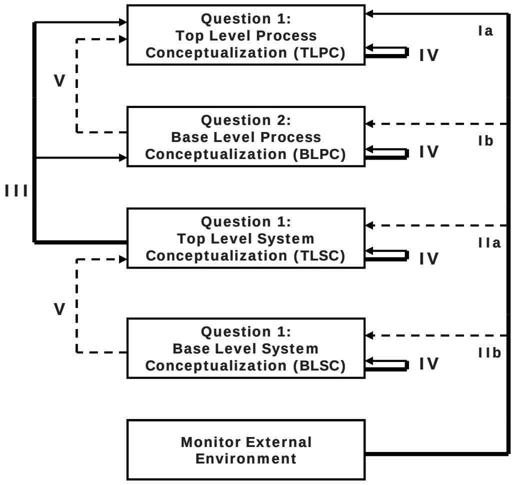
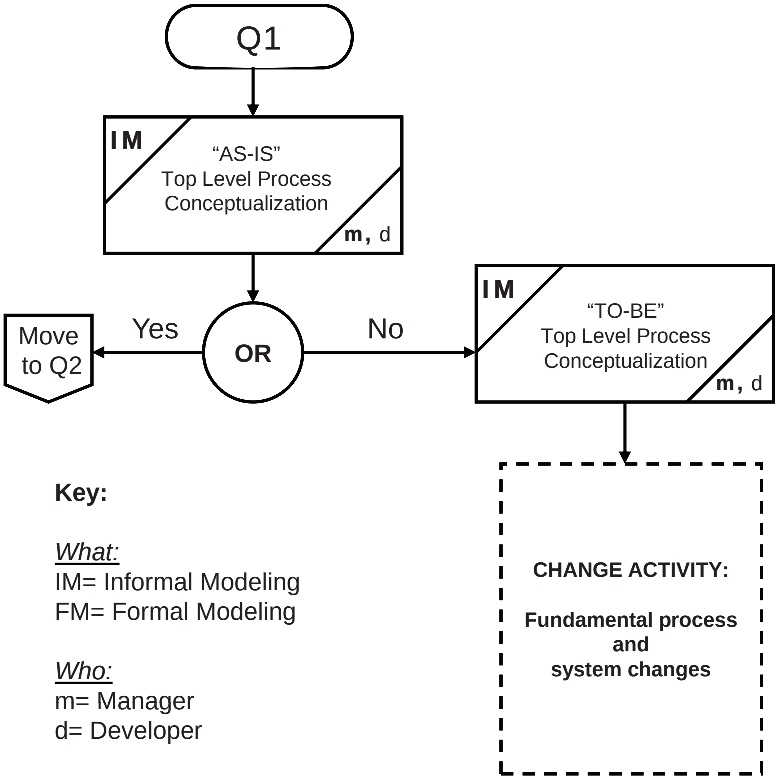


Figure 3. Top level process conceptualization (TLPC)



activity and activities motivated by Questions 2, 3, and 4, labeled as Ib, IIa and IIb respectively. These dashed lines represent alternative or non-mandatory feedback paths, since an organization may (or may not) adopt a policy to account for every external and technological development by reconsideration of processes and systems at every level. This may not be practical in every case, and each organization should choose the proper level of analysis in response to each individual external event and technological change. Less comprehensive technological changes in abilities of systems and system components as well as external developments that are deemed not to be of strategic impact may initiate the reconsideration on the lower (individual) process level or the system level itself. These are depicted in Figure 2 as feedback lines between the monitoring activity and activities motivated by Questions 2, 3 and 4, labeled as Ib, IIa and IIb respectively. These dashed lines represent alternative or non-mandatory feedback paths, since an organization may (or may not) adopt a policy to account for every external and technological development by reconsideration of processes and systems at every level. This may not be practical in every case, and each organization should choose the proper level of analysis in response to each individual external event and technological change.

Figure 2 also contains optional dashed feedback lines, labeled as V between Base Level and Top Level activities if there is an indication that a change in the process or supporting system may have implications that need to be reconsidered at the preceding level. These optional feedback lines allow for the entire process to be more complex than the single pass progression of activities motivated by Questions 1 through 4. For example, activities motivated by Question 4 may demand additional reconsideration of Question 3 and possibly other questions in return as well. If that is the case, the levels of abstraction in such an iterative process may not always follow a single descending path from the very general view of processes and systems, down to the individual organizational rules, process specifications and application elements. Again, the level of recursive reconsideration will vary greatly, depending on the size and complexity of the organization and its processes and systems.

The recursion between System Conceptualization and Process Conceptualization is captured by the feedback line III. This feedback loop ensures that the fit of the enterprise system architecture is verified by the conceptual reconsideration of the processes that the system supports.

It is important to note that the existence of multiple feedback loops in our framework does not imply that we recommend a seemingly endless cycle of analysis. Indeed, some processes and systems are so expansive that, if the impacts of every development on every feature were evaluated by multiple repetitions of conceptualization activities at each stage, the paralysis by analysis is certain to cripple the effort. Ultimately, the implementation success of this framework depends on managers and developers finding the right blend for each unique situation—one that balances analysis/conceptualization depth and its utility. On balance, however, our observations indicate that the prevailing problem is in organizations not doing enough (rather than doing too much) to understand organizational processes and systems, and in many cases a critical process or system feature may only become apparent after repeated reconsideration.

The remaining figures (Figures 3-6) represent a more detailed depiction of each conceptualization activity. In addition to the rectangles and progression and feedback lines, additional notation is used at this level of detail. We adopted a notation from EPML introduced by Dalal, Kamath, Kolarik, and Sivaraman (2004) for the purpose of Enterprise Modeling. Its versatility and ability to capture necessary detail were the main reason for our choice of this notation, even though the context and level of analysis are somewhat different from the one in which it was originally introduced. In our notation, each rectangle contains the description of the activities it contains, with the symbols representing the conceptualization method included in the upper right corner, and the symbols representing the constituents that are most likely to be involved in the effort in the lower right corner (with expected level of involvement indicated by the symbol size). The decision symbol used is a non-exclusive "OR" operator, signifying that a parallel progression of activities may occur, if the answer to the current question is part "Yes" and part "No". In the following discussion, as it relates to Figures 3-6, questions 1-4 will be repeated, for readability.

Figure 3 captures the activities motivated by Question 1, starting with the "As - Is" top level conceptualization of business processes.

In many cases, the most likely conceptualization method at this stage would involve use of informal modeling tools. The resulting vision may often be in the form of high-level visual depictions of main features of key organizational processes extracted from narratives and conceptualization sessions. This information is more likely to be drawn from the management rather than from the potential internal and external systems developers. The role of system experts, while not dominant, is still crucial at this stage, since they ensure that all participants have clear understanding of the current state of the relevant technologies and the potential impact of those technologies. The conceptualization at this stage, paired with the knowledge of existing technological trends and other external factors, should provide the direction of the remaining conceptualization activities.

One reason for a negative answer to the question of fit between the processes and business strategy may be a result of new technological developments that are of a revolutionary, disruptive nature, and render existing processes obsolete simply through opening opportunities for processes to be conducted in a fashion that is clearly superior to the existing practice. The simple existence of potentially better processes in this case may render the existing processes out of alignment with organizational strategy. Other reasons for a negative answer to the question of fit between the organizational strategy and its processes may include major changes in corporate strategy or some other disruptive external development.

If this approach is adopted and it is conducted in an ongoing fashion, the state should eventually be reached where the process and subsequent systems reconsideration cycle is only initiated by external events, rather than internal systemic weaknesses (which will be eliminated). The key is to build the ongoing reconsideration of processes and systems into organizational policies and implement them so that they do not become just another meaningless part of bureaucratic tedium. Thus, this framework can become an expression of organizational culture of seeking a clear mental picture of current processes and systems as well as the readiness to envision how any significant change should affect them. If adopted in this way, it can, in turn, gradually eliminate internal sources of imbalance among organizational strategy, processes and systems. In essence, the goal of this approach is the elimination of the System View, where the emergence of single-event issues often finds organizations unprepared for change and result in systems and process redesign efforts that never seem to be adequate, solving one set of problems while causing another.

As stated above, the answer to the question of fit between processes and systems may not be a definite “Yes” or a definite “No”, if the analysis reveals that the consistency between processes and organizational strategy is partial. If the answer is not categorical, in some cases progression to next activity set may be halted until all the aspects of all processes are brought into agreement with organizational strategy. More likely though, an organization may be able to proceed on both “tracks” simultaneously, addressing some processes at a high, strategic level (where the answer to Question 1 was a “No”) while moving on the next level of analysis for others (where the answer to Question 1 was a “Yes”).

As shown in Figure 3, this framework anticipates that top management will be responsible for the issue of the fit between key organizational processes and organizational strategy. In most cases, participation by the system development community, even at this very high level, should be welcomed, especially if emerging technologies are showing potential to affect the strategic fit. In other cases however (where the strategic fit is affected by external competitive developments of regulatory changes, for example), the process redesign at this high level will be motivated by non-technological issues.

In the early conceptualization stage level, the participants will most likely be inclined to uses informal ways of creating a conceptual vision of those processes, both as they are (“As-Is” conceptualization), and as they ought to be (“To-Be” conceptualization). More formal methods, with explicit rules and strictly defined semantics are more appropriate later in the process, when process and system details are being considered. A variety of informal techniques exist for eliciting requirements in early planning stages, such as flow charts and decision maps. These are in addition to formal and semi-formal modeling techniques such as E-R models and data flow diagrams (Giaglis, 2001).

A change activity in response to the findings of the high-level “To-Be” conceptualization effort is captured by a dashed rectangle in Figure 3. It may include significant reorganization efforts throughout the organization, such as:

- An overhaul of existing organizational processes and/or creation of new ones
- A change in governance structure through reorganization of corporate hierarchy and/or reporting practices/paths.

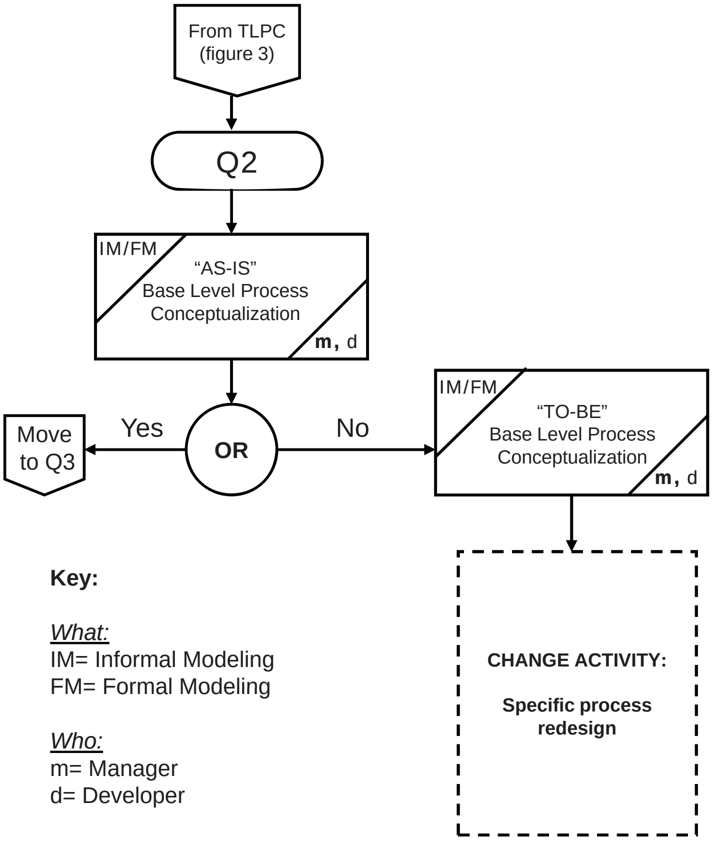
In the process of this structural reorganization, the conceptualization efforts should again be present at each stage of process and systems redesign. "As-Is" process and system conceptualization will facilitate the identification of the aspects of processes and systems that can be retained and those that require change. The sequence of conceptualization activities will create a complete list of reasons *why* the current processes and systems are inadequate and need to be overhauled. The focus of the "To-Be" conceptualization activities in this case will be on creating a clear vision of desired processes and following it with system conceptualization designed to fit the process vision. In essence, a whole new sequence of activities will be spawned, following the same progression as that shown in Figures 1 and 2.

Figure 4 depicts the activities motivated by Question 2, assuming that the question of the fit between organizational key processes and its corporate strategy has been resolved.

In this phase, the main goal is to examine processes at a greater level of detail, and look for the improvement opportunities. At this stage, either informal or formal modeling techniques, or some combination of both, may be appropriate, depending on the complexity of the process being considered, the desired level of precision, and the accepted level of modeling skill and understanding within the group involved in this stage.

Often, key contributions will be needed from management and the systems development community. Here, it is important that everyone has the same unambiguous picture of the processes being considered. A more detailed and consequently,

Figure 4. Base level process conceptualization (BLPC)



more accurate picture of processes may lead to a negative answer to Question 2, revealing potential areas of process improvement, without the need for a change in supporting systems. When the satisfactory answer to Question 2 is achieved, possibly after several iterations of process conceptualization and improvement activities, the next phase is entered, where the focus is shifted towards the analysis of current organizational systems, first at the higher level (motivated by Question 3) and then in more detail (motivated by Question 4)

The dashed rectangle in Figure 4 represents the set of activities that are undertaken in response to the “As-Is” conceptualization at the base level model of processes. These activities reveal that processes as currently in place do not optimally support the objectives of an organization, and drive the subsequent creation of the vision of the improved processes through “To-Be” Base Level Process Conceptualization. The actions in this activity set should be centered on a specific process redesign that represents an improvement in its support of the organizational goals. In short, the actions taken in response to a negative answer to the Question 2 ensure that the organization does not waste time and resources by hastily moving on towards the design and improvement of underlying information systems that will automate and otherwise support processes that were not fully suitable in terms of optimal support for the organizational goals.

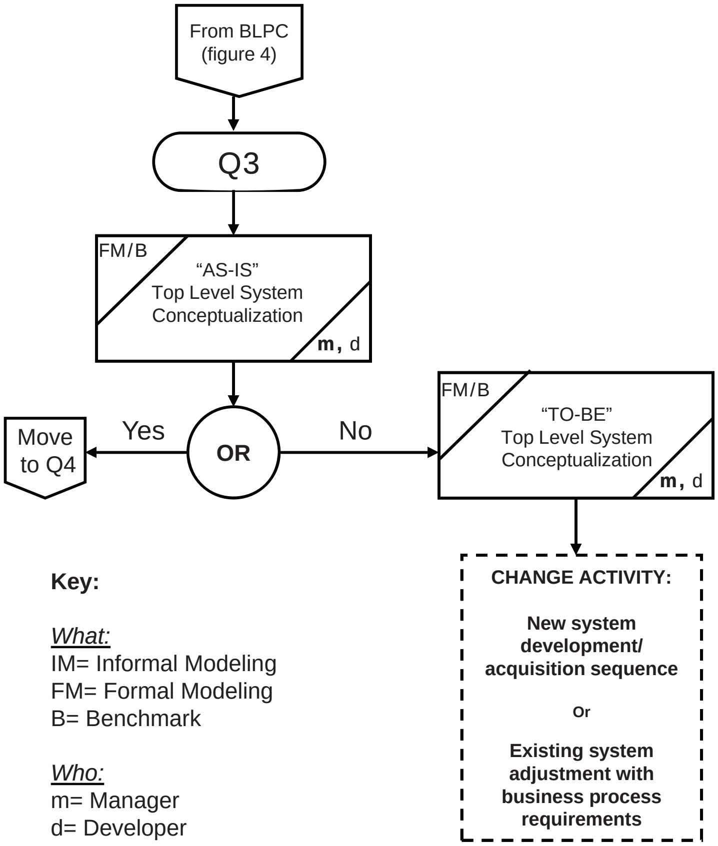
After the processes have been fully examined and redesigned in accordance with the “To-Be” vision, Question 2 should be raised again, accompanied by the examination of the new “As-Is” model of (now improved) processes. This should eventually result in a satisfactory answer and progression to the analysis of information systems in the next stage of the framework. Again, as discussed above, the number of iterations of current process consideration, conceptualization of process improvement and process redesign will vary. The goal of those involved in the effort should be to strike a proper balance. At one extreme, the goal should be to avoid an endless cycle of analysis, resulting in recommendations for concrete implementation action being generated too slowly. Another, potentially more likely extreme is an inclination to simply go through the motions, rubberstamping the current situation as satisfactory and starting the system analysis prematurely.

Figure 5 represents the view of activities motivated by the top-level system conceptualization. The main purpose of this stage is to provide an answer to the question of fit between the processes and systems, as stated in Question 3:

In this phase, the more formal modeling methods may be more appropriate conceptualization tools, with intensive participation by both the IT development staff and management. Another potential conceptualization method that may be used (in addition to, or as an alternative) is benchmarking through the analysis of existing systems as applied in comparable organizations. This is possible if access to main system features and designs is available. The top level abstract model (or other way of achieving a clear vision) of existing systems is used to provide an answer to Question 3 about the adequacy of the existing system in supporting business processes that, at this stage, are aligned with organizational goals. The answer, as in previous stages, can be a full or a partial one. In the case of a fully or partially negative assessment of existing systems at the top level conceptualization, the next step is again to craft a “To-Be” vision of systems that fulfill the goal of properly supporting business processes, based on a formal model and possibly also on a benchmark of systems already in place at other organizations.

The predominantly negative evaluation of this fit may have many causes; some rooted in the way the existing system was adopted in the first place. The realization of the inadequacy of the existing system may actually start to appear during the base level conceptualization of busi-

Figure 5. Top level system conceptualization



ness processes, as conducted in response to Q2, especially if the processes are very dependent on the features and abilities of the current system. For this reason, systems evaluation is followed by the process reconsideration, as shown by the feedback line III in Figures 1 and 2. The process analysis motivated by questions 1 and 2 will be repeated, this time assuming that systems in place are the redesigned systems, based on the "To-Be" top-level systems conceptualization. This approach ensures that processes and systems will not be considered in isolation from each other, but rather through a series of interrelated conceptualization efforts.

The dashed rectangle in Figure 5 represents change activities in response to the predominantly negative evaluation of existing systems as result of "As-Is" high-level system conceptualization. Causes of negative evaluation will vary widely from one case to another, and so will the actions that organizations will undertake in order to address them. In some cases systems may be found to be fundamentally inadequate, with the "To-Be" vision very different from the "As-Is" concept of the existing information systems. In such cases, a probable course of action at this level is the initiation of formal new systems development and design processes, including the evaluation of systems alternatives that exist in the appropriate packaged solutions market.

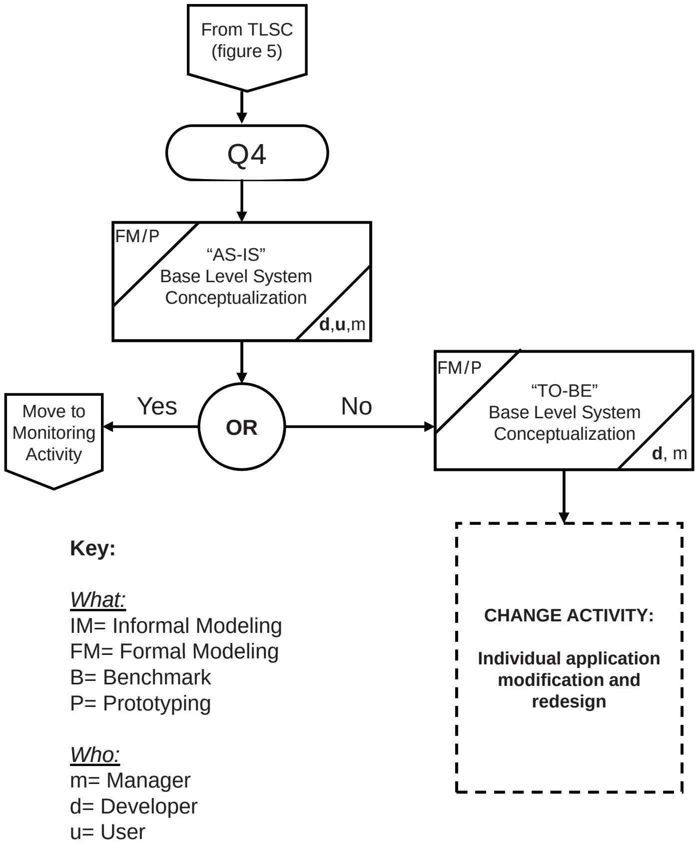
Alternatively, the detected flaws may not be related to the key functional features of existing systems, but rather to the ability to facilitate processes that are enterprise-wide and bridge single systems boundaries. In this case, a possible course of action may include the development of enterprise–wide mechanisms for the successful alignment of different components of the organizational business architecture with existing systems architecture. For example, this may start with the creation of enterprise and supply chain-wide data dictionaries and process semantics. Regardless of scope and complexity, all activities undertaken at this point need to be consistent with the established "To-Be" vision of systems that is again based on the current detailed concept of business processes created in the previous stage.

Figure 6 contains the Base Level System Conceptualization and its resultant activities in response to the Question 4:

The goal here is to achieve further alignment between individual processes and system components through incremental changes at an individual application or application component level. The methods of achieving a clear mental picture at this level may include both formal modeling and prototyping for the purpose of both "As-Is" and especially "To-Be" conceptualizations. In our context, the term "prototyping" means the repeated interaction with each incrementally improved version of the system for the purpose of evaluating its functionalities and support for business processes at the low level of detail. At this stage, the development personnel (or IT evaluation staff if a packaged solution is being considered) will have the highest level of involvement, with active participation by the end user community that may also include management, especially if the system under consideration has a prominent decision support role.

The dashed rectangle in Figure 6 contains the activities that follow low-level base conceptualization of the systems involve modifications and redesign on an individual application level or even lower, constituent object level. This process is most likely to be recursive, with several itera-

Figure 6. Base level system conceptualization



tions between the conceptualization activities and actual development and implementation activities. It is important to keep in mind the complementary roles of abstract modeling and prototyping at this stage. The prototyping approach, at a stage that is close to implementation, provides a very concrete vision of the system component under consideration and facilitates instant user feedback that reveals potential problems and improvement opportunities. The abstract model, on the other hand, is more capable of conveying how an individual application or other system component fits the overall system vision as well as the underlying process vision.

In summary, the diagrams above display a number of conceptualization and conceptualization-driven activities, distributed between high and low level of analysis. The flow of activities is driven by the four fundamental questions posed in the previous section. The emphasis is on considering processes first, in a way that takes into account organizational IT capabilities, as well as other available technologies. The process consideration starts with addressing the fit with organizational goals and then considering possible redesign, followed by understanding the implications for the redesign of underlying systems. In this, our flow model is consistent with the notion voiced by Attaran (2004). While agreeing with Michael Hammer's recommendation to redefine processes first and automate second, Attaran stated that IT capabilities can and should influence all stages of process design. Our framework is consistent with the proactive approach to process and systems planning.

The main purpose of our conceptualization workflow framework is to formalize when and why conceptualization efforts should be undertaken in process and systems planning and design. Its parts are applicable within the standard framework for development of information systems: systems development life cycle, or business process redesign and change sequence, such as those proposed by Davenport (1993), or Champy and Hammer (1993). Our intention was to go a step further beyond general strategy and IT implementation recommendations, especially for the process and system design and configuration stages, encompassing all the planning and decision making stages and pointing out situations where conceptualization is a crucial activity.

Our framework recognizes unique roles of management, developers and users in ensuring the proper alignment of strategy, processes and systems. Its intention is to provide a mechanism that facilitates enterprise wide participation in conceptualization on multiple levels of complexity. This proposed framework envisions that results of conceptualization activities at each level are shared, facilitating the communication between the management, systems analysts and developers. If this is achieved, the result should be the common vision of business goals, processes and applications.

COMPARISON WITH EXISTING APPROACHES

This section will present a comparison of the introduced framework with the existing frameworks that directly or indirectly deal with the issue of change and adoption of corporate information systems. The Open Group Architectural Framework (TOGAF, 2003) is a broad and detailed method and set of supporting tools for developing an enterprise-architecture. It includes a section on architecture change management, which, similarly to our work, recognizes both the technology and business drivers for change and advocates many of the factors (such as the understanding of key organizational strategic goals and the resulting business processes) that we summarized into the concept that we labeled as the Process View. TOGAF even list the steps, such as ongoing monitoring of technology changes and ongoing monitoring of business changes, as the key factors in the architecture-change-management process.

However, TOGAF offers no actual structured and prescriptive method that outlines how to achieve the goals of the Process View during the change process or how and when to undertake the steps during the change process. Instead, the following general advice is given:

There are many valid approaches to change management, and various management techniques and methodologies that can be used to manage change: for example, project management methods, service management methods, management consultancy methods, and many others. An enterprise that already has a change management process in place in a field other than Architecture may well be able to adapt it for use in relation to architecture.

Therefore, organizations must still choose (and then adapt) a method on how to deal with the architecture-change management, which can potentially add to the length and complexity of the change process. On the other hand, the framework based on the four questions that we introduce in this article, presents the users a ready-to-use method specifically designed for the architecture-change process. Our framework not only takes into account alignment between business strategy and business and information system architecture, but it makes it the recurring foundation of all changes in the architecture.

Similarly to TOGAF, Zachman presents in his papers (1987; 2000) a detailed framework for development of enterprise architecture which advocates business process modeling and conceptualization as the integral part of enterprise architecture development, which is also one of the main motivators for Process View. As in TOGAF, there is no specific methodology that details and structures steps for architecture change that would be equivalent or comparable to the detailed framework for architecture-change introduced in this article.

In other words, our framework serves to complement the general frameworks (such as TOGAF or Zachman) with the detailed and structured architecture-change-management component. Constituent parts of the Process View that we describe earlier in this article are not new. In addition to TOGAF and Zachman frameworks, we can find elements of Process View described in detail in other approaches dealing with the process of design and development of managerial information systems, such as OPEN Process Framework (Firesmith 2005). Here, we gathered these elements together under a label of Process View (taking into account our own surveys, as well as sources from various publications referred to in this article) to contrast it with the often inadequate, but quite widespread, practice of System View. What is new in this article is the introduction of the detailed and structured architecture-change framework, whose goal is to facilitate the Process View during the process of change, adaptation and adoption of corporate information systems.

SUMMARY AND CONCLUSION

In this article, we have argued for the importance of proper planning and decision-making during the process of information system change and adoption. We have described two different approaches to information system change; the System View and the Process View, and we argued for, and demonstrated the benefits of, the Process View. We have also shown that a number of other authors have advocated the concepts that we joined in this article under the label Process View. The central part of this article is presentation of a framework that is rooted in the active and conscious usage of various methods of process and system conceptualizations at multiple levels. The framework is designed as a sequential set of activities centered on the questions of fit among organizational goals, processes, and systems. We have motivated this discussion by our classification of motivating factors and outcomes of the change and adoption of new enterprise information systems and/or their components. We have asserted the importance of conceptualization as a means of achieving proper fit between strategic goals and the resultant business processes and systems that support them.

The following question may be posed: is the framework described in this article practical and to what extent would managers and IS professionals be willing to put in the time and effort required to follow the steps of this process approach? As we outlined in this article and illustrated by Figures 1-6, our approach is highly structured and prescriptive, which in itself is practical in the sense that, if this framework is adopted, organizations do not have to spend additional effort and resources on creating their road-maps for the enterprise information system change and adoption. Our framework relies on recursive and continuous "As–Is", and "To-Be" conceptualizations at both high and low levels of process and systems detail. The recursion encourages continuous monitoring of technological and other external (market, regulatory, etc) developments, without which it would be very difficult to make the right decisions during the change and adoption process.

The framework is flexible and adjustable so it can fit a variety of situations and scenarios within enterprises. As show in by Figure 2, many of the recursive steps are optional and, as we discussed earlier in the article, are to be applied only if required by a particular scenario or company policy. Also, a closer look at Figures 3-6 reveals the straightforward and simple nature of each individual step in the framework. For each of the four questions, an "As-Is" conceptualization is recommended as the way to answer the question properly, together with recommendations on which methods (such as informal modeling or prototyping) and people (such as managers, developers or users) to involve. Organizations that adopt the framework essentially commit themselves to considering the four questions and then choosing from the recommendations given in the framework on how to do so. Therefore, any organization that recognizes the need and benefit of conceptualization and is willing to examine its organizational strategy, business processes, and its existing information systems before the actual change and adoption process takes place (i.e., consideration of questions 1 – 4) is, by default, willing to put the time and effort required to follow the steps of the proposed framework.)

Our view is that there is no single conceptualization method uniquely suited for each level, but we do envision the progression from less to more formal techniques as the level of detail and complexity increases. We believe that the first important step is for organizations to be aware of the need for process and system conceptualization at multiple levels. Subsequently, each organization needs to seek a combination of methods that fulfills its specific needs in the most feasible fashion.

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Chapter 5.21

Supply Network Planning Models Using Enterprise Resource Planning Systems

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ABSTRACT

The advent of the Web as a major means of conducting business transactions and business-to-business communications, coupled with evolving Web-based *supply chain management* (SCM) technology, has resulted in a transition period from “linear” supply chain models to “networked” supply chain models. Various software industry studies indicate that over the next five to seven years, interenterprise business relationships, information structures, and processes will evolve dramatically. Enterprises will blend internal production and supply chain processes with those of their external trading partners. Currently, organizations are finding creative ways to mitigate supply chain costs while maintaining operational efficiency. New approaches, technologies, and methodologies are aiding with these cost-cutting measures to drastically reduce supply chain costs and increase customer satisfaction. This chapter discusses the background of supply chain planning and execution systems, their role in an organization, and how they are aiding in collaboration. The chapter concludes with a case study on how a supply chain management system could help an organization be more effective.

INTRODUCTION TO ERP SYSTEMS

Enterprise resource planning (ERP) systems aim to integrate all business functions and data of an organization into a single integrated system. The main component of an ERP system is the use of a common database. A typical ERP system landscape consists of a variety of hardware and software to help integrate the business functions and data. The goal of an ERP system is to provide a unified scheme to perform and record all the business activities of an organization and ensure organization, classification, and structure of the business processes and data.

An ERP system can be viewed as a group of processes, applications, and technology and consists of the following:

- Databases
- Applications to support business processes
- Network and systems infrastructure
- Middleware (group of software that aid integration of the various components)

This chapter discusses the evolution of ERP systems, provides brief information on the various ERP vendors and details the role and the impact of the integrated business software in manufacturing intelligence.

Evolution of ERP Systems

The concept of ERP has been around since the 1960s, and has its beginning in materials requirements planning (MRP). It was meant to provide an integrated approach to reduce inventory and process times and better manage procurement and production. In the 1970s, ERP systems evolved into manufacturing resource planning (MRP II) to involve financial and human resource planning in a limited capability. MRP and MRP II had their own limitations in terms of handling multiple locations, product aggregations, capacity constraints, and so forth. These limitations resulted in the development of ERP systems.

ERP systems, in the simplest sense, can be considered as a single, integrated database that gathers, stores, and helps analyze the data of an organization. Until the early 1990s ERP products were running on mainframes; however, with the advent of the client-server architecture in the mid-1990s, a majority of the ERP systems run on client-server architectures. The emergence of ERP systems went hand in hand with the idea of concentrating on single enterprises. The primary goal of these systems was to integrate the business processes of a single company. The business process integration capabilities were also very limited even if multiple companies of a conglomerate used the same information system. Among the biggest hurdles for this integration was the cost of technology. However, with significant development in technology over the last 5-7 years, the idea of cross-enterprise integration has become achievable and affordable. This led to the next generation of integrated business software products, commonly referred to as ERP II.

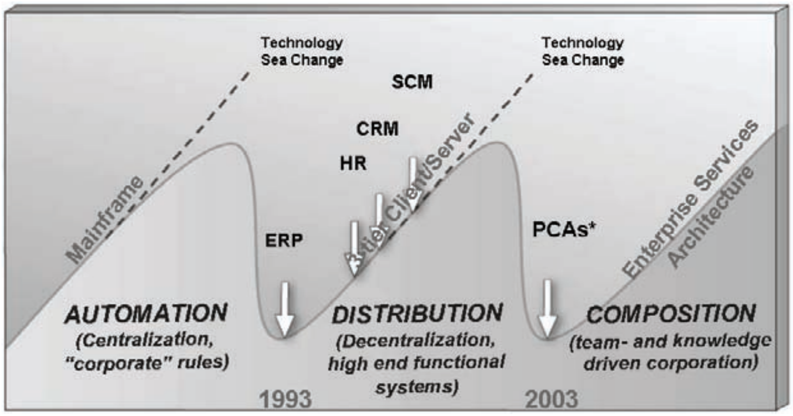
ERP II is the latest evolution that adapts ERP to the e-commerce environment through changes in functionality, technology, and architecture. The most evident change from ERP to ERP II is a change in focus of a business process from enterprise-centric to a collaborative environment. ERP II extends the scope of the business processes from an individual organization to all the stake holders in the supply chain. According to the Gartner Group, ERP II is “a business strategy and set of industry-domain-specific applications that build customer and shareholder community’s value network system by enabling and optimizing enterprise and inter-enterprise collaborative operational and financial processes” (Gartner Group, May 2001).

Table 1 represents the timeframe, industry needs, and the progress of technology of these systems.

Table 1. History of ERP systems

Year	Industry Need	Technology Progress
1970 - 1990	Real-time Automated systems	Automation systems, Transactional systems (OLTP)
Early 1990s	Scalable Integrated business processes	Analytical systems (OLAP), ERP
Late 1990s	Heterogeneous business processes	Integration, Web-services, "e-commerce"
2000s	Packaged composite business processes	ERP II

Figure 1. Paradigm shift in technology (Source: Gartner Group, 2003)



The 1970s through the 1990s saw a significant need for real-time automated systems to enable faster transaction entry. In the early 1990s this expanded by requiring analytical systems to process the transaction data in order to better understand the business. During the late 1990s, the industry requirement further expanded to requiring integration of Web-enabled heterogeneous systems. Organizations used proprietary interfaces to communicate between systems. This approach treats the Web application tier as just another silo, rather than as the integration hub through which all transactions flow, resulting in the need for the development of a technology that could reuse the applications developed. This technology is referred to as packaged composite application software, and the concept is very similar to objects in software development, where applications are built by reusing logic from two or more existing applications to form a new application without having to start from scratch. A composite application consists of functionality drawn from several different sources integrated by a technology platform. The components may be individual Web services, selected functions from within other applications, or entire systems whose outputs have been packaged as Web services.

Figure 1 represents the paradigm shift in technology and the products developed in the respective time frames.

Until the early 1990s, the ERP solutions were hosted on mainframes. With mainframe software architectures all intelligence is within the central host computer, and users interact with the host through a terminal that captures keystrokes and sends that information to the host. A limitation of mainframe software architectures is that they do not easily support graphical user interfaces or access to multiple databases from geographically dispersed sites. As a result of the limitations of file sharing architectures, the client/server architecture emerged in the mid-1990s. This approach introduced a database server to replace the file server. Using a relational database management system, user queries were answered directly. The client/server architecture reduced network traffic by providing a query response rather than total file transfer, improving multiuser updating through a GUI front end to a shared database. This technology evolution resulted in the IT landscape of most organizations being heterogeneous with a variety of enterprise suites, best-of-breed systems, and legacy systems. Also, they have a mixture of hardware platforms, operating systems, and databases.

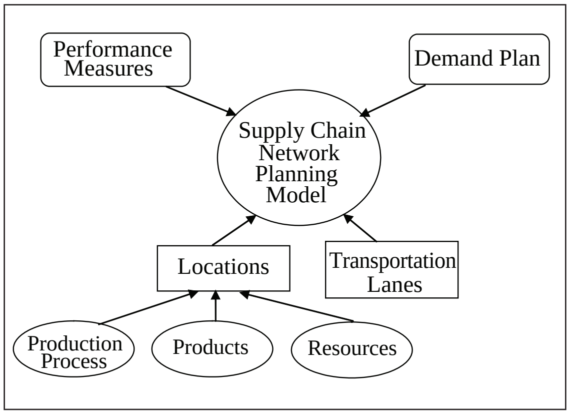
Further complications occur when organizations go through mergers, acquisitions, and divestitures. The traditional applications are designed for efficiency, not reuse, since there is no clear distinction between user interface, logic, and data, and they usually have a high cost of modification. In 2003, the concept of service-oriented architecture (SOA) was developed, which is the underlying structure supporting communications between services. An SOA solution consists of a composite set of business services that realize an end-to-end business process. SOA architecture is an application architecture that is designed to map directly to business requirements and is key to achieving the agility required. SOA, together with the emergence of service-oriented business applications (SOBAs) and service-oriented development of applications (SODA) are among the most significant shifts in IT.

Software is often completely inflexible once deployed, thus changing the nature of software can improve agility. For this to work, packaged business applications need to be broken down into smaller pieces that are easier to change. SOA makes it possible to look at software in pieces. As technology and standards evolve SOA will allow enterprises to mix applications services with others, regardless of the original supplier and the hardware and software platforms they use. We can think of it as separating business functions into subroutines/methods with the subroutines existing in any machine. SOA for an enterprise is usually referred to as the enterprise service architecture (ESA), and is the technology format currently being adopted by all the major ERP vendors in their product development. The evolution of SOA architectures and systems affects all levels, from business-IT alignment to hardware and devices. It will help software developers develop business applications faster and will help users to realize the full potential of integration.

It is important to understand that ERP systems were originally developed as transaction-based systems. With increased competition and shorter product life cycle, there was a significant demand for robust planning systems. It has also become very important for an organization to have near real-time collaboration and integration with all the stakeholders in the supply chain. Organizations have better understood the need for a higher level of information exchange with the vendors to ensure optimized cost and quality (Turban, McLean, & Wetherbe, 2004). Similarly, the impact of increased levels of collaboration with the distributors and the customers has also been recognized (Hitt, Wu, & Zhou, 2002).

The demand for faster and increased levels of information exchange saw the development of functionality-specific planning systems (e.g., supply chain management systems, product life cycle management systems, customer relationship management systems, and supplier relationship management systems, etc.). In addition, the roles

Figure 2. SAP Corporation Product Suite



of planning and execution in a business process are starting to converge. The future integrated business software products will be adaptive in nature, and groups of systems will continuously interact, exchange information, and iteratively plan and execute. For example, Figure 2 represents the product suite from SAP Corporation.

ERP Systems

mySAP ERP serves as the primary transaction processing system, while the rest of the systems are primarily designed for analytical purposes. Netweaver is the technology platform that integrates all these products. mySAP ERP is SAP's latest version of the core ERP software. It is primarily used as an online transaction processing system. Some of the capabilities of mySAP ERP include:

- Streamlining operations and optimizing the use of corporate resources and assets,
- Accelerating time to market and time to value,
- Delivering higher levels of service and more individualized products and services, and
- Enhancing customer satisfaction.

mySAP ERP includes financials (financial and management accounting and financial supply chain management), human capital management (talent management, core HR processes, and workforce deployment), corporate services (managing real estate; enterprise assets; project portfolios; corporate travel, environment, health, and safety [EH&S], quality, and global trade services), and operations (end-to-end procurement and logistics business processes, including discrete and process manufacturing).

ERP systems are the core of an organization's ERP landscape. They have become the primary transaction processing system. The historical transactions are stored in a data warehouse and are diced and sliced by the analytical systems – supply chain, customer relation, supplier relation, and product lifecycle – to help make better business decisions.

Customer Relationship Management Systems

Customer relationship management (CRM) is an information industry term for methodologies, software, and usually Internet capabilities that help an enterprise manage customer relationships in an organized way. For example, an enterprise might build a database about its customers that described relationships in sufficient detail so that management, salespeople, service providers, and perhaps the customer could directly access information, match customer needs with product plans and offerings, remind customers of service requirements, know what other products a customer had purchased, and so forth.

CRM consists of helping an enterprise enable its marketing departments to identify and target their best customers, manage marketing campaigns with clear goals and objectives, and generate quality leads for the sales team. CRM also involves assisting the organization to improve telesales, account, and sales management by optimizing information shared by multiple employees, and streamlining existing processes (e.g., taking orders using mobile devices). Enabling CRM allows the formation of individualized relationships with customers, with the aim of improving customer satisfaction and maximizing profits, and identifying the most valuable customers and providing them the highest level of service. CRM also provides employees with the information and processes necessary to know their customers, understand their needs, and effectively build relationships between the company, its customer base, and distribution partners.

According to the Gartner Group, there are three aspects of CRM, each of which can each be implemented in isolation:

1. **Operational CRM:** Automation or support of customer processes that include a company's sales or service representatives
2. **Collaborative CRM:** Direct communication with customers that does not include a company's sales or service representatives ("self service")
3. **Analytical CRM:** Analysis of customer data for a broad range of purposes

For example, mySAP customer relationship management provides solutions so that organizations can act immediately to improve sales, service, and marketing effectiveness. mySAP CRM provides the functionality to:

- Analyze, plan, develop, and execute all marketing activities.
- Help acquire, grow, and retain profitable.
- Drive service revenue and profitability with support for service sales and marketing.
- Enable e-commerce to increase sales and reduce transaction costs.

CRM systems have gained importance in the last three to four years. For CRM to work, companies must bring together a number of disparate processes, systems, and types of data, regardless of where they reside, to deliver an integrated, unified view of the customer that drives a consistent approach to interactions that is proactive as well as reactive. Adapting an integration technology, like ESA, will help organizations realize system.

Supply Chain Management Systems

Supply chain management (SCM) is the oversight of materials, information, and finances as they move in a process from supplier to manufacturer to wholesaler to retailer to consumer. Supply chain management involves coordinating and integrating these flows both within and among companies. The ultimate goal of any effective supply chain management system is to reduce inventory (with the assumption that products are available when needed). As a solution for successful supply chain management, sophisticated Web-enabled software systems are available.

Supply chain management flows can be divided into three main flows:

- Product flow.
- Information flow.
- Financial flow.

The product flow includes the movement of goods from a supplier to a customer, as well as any customer returns or service needs. The information flow involves transmitting orders and updating the status of delivery, as well as other inventory related data. The financial flow consists of credit terms, payment schedules, and consignment and title ownership arrangements.

There are two main types of SCM software: planning applications and execution applications. Planning applications use advanced algorithms to determine the best way to fill an order. Execution applications track the physical status of goods, the management of materials, and financial information involving all parties. Some SCM applications are based on open data models that support the sharing of data both inside and outside the enterprise (this is called the extended enterprise, and includes key suppliers, manufacturers, and end customers of a specific company). This shared data may reside in diverse database systems, or data warehouses, at several different sites and companies.

By sharing this data "upstream" (with a company's suppliers) and "downstream" (with a company's clients), SCM applications have the potential to improve the time-to-market of products, reduce costs, and allow all parties in the supply chain to better manage current resources and plan for future needs. For example, mySAP supply chain management enables adaptive supply chain networks by providing planning and execution capabilities to manage enterprise operations. mySAP SCM supports supply chain functionality to:

- Model existing supply chain and ensure a profitable match of supply and demand.
- Enable supply chain planning and with distribution, transportation, and logistics integrated into real-time planning processes.
- Provide network-wide visibility across your extended supply chain to perform strategic as well as day-to-day planning.

Supply chain management systems will yield improvements in the areas of cost, time, and quality. A very effectively implemented supply chain management system will help an organization with making processes more transparent and improve flexibility. SCM systems will not only concentrate on the order fulfillment cycle, but also incorporate product design, process recovery, and customer relationship.

Supplier Relationship Management Systems

Supplier relationship management is a comprehensive approach to managing an enterprise's interactions with the organizations that supply the goods and services it uses. The goal of supplier relationship management (SRM) is to streamline and make the processes between an enterprise and its suppliers more effective, just as customer relationship management (CRM) is intended to streamline and make more effective the processes between an enterprise and its customers.

SRM includes both business practices and software and is part of the information flow component of supply chain management (SCM). SRM practices create a common frame of reference to enable effective communication between an enterprise and suppliers who may use quite different business practices and terminology. As a result, SRM increases the efficiency of processes associated with acquiring goods and services, managing inventory, and processing materials.

For example, mySAP supplier relationship management helps simplify and automate procurement, and integrate strategic practices for supplier qualification, negotiation, and contract management more tightly and cost-effectively with other enterprise functions and their suppliers' processes. mySAP SRM supports:

- Supplier qualification, more efficient supplier negotiation, and better contract management.
- Requisitions, orders, goods receipt, and invoice settlement.
- Linking suppliers to purchasing processes and collaborate more effectively.

If correctly put into practice, SRM systems in a firm can enhance supplier selection, improve business interactions, and accelerate purchasing cycle time. SRM systems can definitely be an asset to companies, especially those who are trying to cut down costs.

Product Lifecycle Management Systems

Product lifecycle management (PLM) is a strategic business approach that applies a consistent set of business solutions that support the collaborative creation, management, dissemination, and use of product definition information. PLM supports the extended enterprise (customers, design and supply partners, etc.). PLM spans from concept to end of life of a product or plant and integrates people, processes, business systems, and information.

It is important to note that PLM is not a definition of a piece, or pieces, of technology. It is a definition of a business approach to solving the problem of managing the complete set of product definition information by creating that information, managing it through its life, and disseminating and using it throughout the lifecycle of the product. Three core or fundamental concepts of PLM include universal, secure, managed access, and use of product definition information. PLM helps maintain the integrity of that product definition and related information throughout the life of the product or plant. PLM also helps manage and maintain business processes used to create, manage, disseminate, share, and use the information.

PLM includes management of all product-related information from requirements, through design, manufacturing, and deployment. This information ranges from marketing requirements, product specifications, and test instructions and data to the as-maintained configuration data from the field. The PLM solution links information from many different authoring tools and other systems to the evolving product configuration. At the same time, the lifecycle began to include production-focused attributes and information. Manufacturing and operational process plans are also now viewed as an inherent part of PLM. Processes, and the workflow engines that control them, ensure complete digital feedback to both users and other business systems throughout each lifecycle stage.

The mySAP product lifecycle management application provides an integrated, single source of all product-related information needed for collaborating with business partners and supporting processes including product innovation, design and engineering, quality and maintenance management, and control of environmental issues. mySAP PLM had the functionality to:

- Manage specifications, bills of materials, routing and resource data, project structures, and related technical documentation throughout the product life cycle.
- Helps plan, manage, and control the complete product development process.
- Support collaborative engineering and project management.
- Provide integrated quality management for all industries.
- Coordinate enterprise asset management.
- Monitor, environment, health, and safety.

Enterprises are adopting PLM solutions to meet a variety of challenges. They are increasingly discovering that PLM helps them deal with daunting growth, global operations, and highly competitive market demands. PLM solutions connect people to work collaboratively, and centralize and improve the management of the product data. It streamlines the process steps to create, manufacture, and support products throughout their lifecycle from concept to retirement.

ERP VENDORS

ERP vendors are those organizations that develop, sell, and support ERP systems. The biggest ERP vendors include SAP AG, Oracle Corporation, and Microsoft Corporation. AMR Research expects the enterprise applications market to grow from

$47.8 billion in 2004 to $64.8 billion by 2009 (AMR Research, 2005). Table 2 lists the various enterprise applications, their current market size, and market forecasts until 2009.

Manugistics (recently acquired by JDA) and i2 were among the pioneers in developing supply chain management software. However, the traditional ERP software manufacturers like SAP and Oracle have also been developing supply chain management solutions.

Organizations implementing the entire suite of integrated software solutions have the option of selecting a single integrated system approach or the best-of-breed approach. The single integrated system provides efficient and reliable interfaces between the analytical and transactional systems. Examples of vendors providing a single integrated system include SAP and Oracle. The best-of-breed approach is adopted by organizations that use different "brands" of products for transactional and analytical systems. The best-of-breed approach may provide organizations with better functionality, but lacks the tight integration between the transactional and analytical systems. Historically, the best-of-breed approach has not provided good overall solutions (*Optimize*, September 2006).

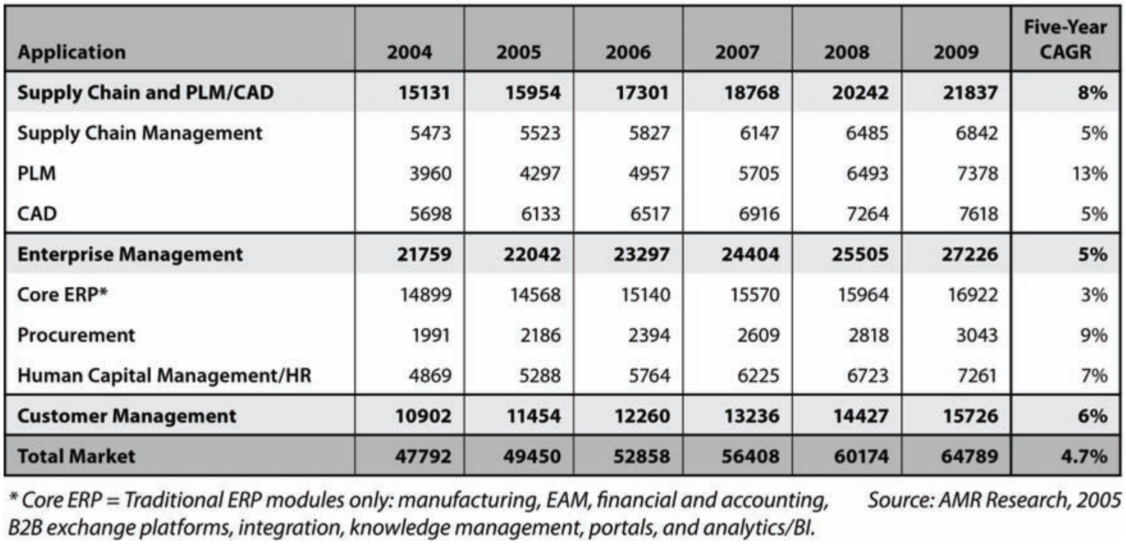
The developments in technology have revolutionized manufacturing processes. The rest of this chapter discusses the impact of the technology and the latest software, and how they have enabled firms to be more profitable.

MANUFACTURING PROCESSES

Traditionally, manufacturing processes included planning and execution. However, with the understanding of the importance of the supply chain and the advances in technology, collaboration has also become an important process in manufacturing.

Until now, most ERP systems performed both strategic and operational level activities, with primary goal being operational activities. The systems performed online transaction processing and online analytical processing. As the planning criteria became complex, the traditional ERP systems were unable to provide accurate planning results. The primary reason is that the data structure of a transaction processing system is very inefficient for analytics purposes. However, with increasing demand for better planning capabilities,

Table 2. Enterprise applications market size and forecasts, 2004-2009



Application	2004	2005	2006	2007	2008	2009	Five-Year CAGR
Supply Chain and PLM/CAD	**15131**	**15954**	**17301**	**18768**	**20242**	**21837**	**8%**
Supply Chain Management	5473	5523	5827	6147	6485	6842	5%
PLM	3960	4297	4957	5705	6493	7378	13%
CAD	5698	6133	6517	6916	7264	7618	5%
Enterprise Management	**21759**	**22042**	**23297**	**24404**	**25505**	**27226**	**5%**
Core ERP*	14899	14568	15140	15570	15964	16922	3%
Procurement	1991	2186	2394	2609	2818	3043	9%
Human Capital Management/HR	4869	5288	5764	6225	6723	7261	7%
Customer Management	**10902**	**11454**	**12260**	**13236**	**14427**	**15726**	**6%**
Total Market	**47792**	**49450**	**52858**	**56408**	**60174**	**64789**	**4.7%**

** Core ERP = Traditional ERP modules only: manufacturing, EAM, financial and accounting, B2B exchange platforms, integration, knowledge management, portals, and analytics/BI.*

Source: AMR Research, 2005

ERP vendors have developed products specific for these requirements. These products are referred to as supply chain management systems. The ERP systems have to be tightly integrated with the supply chain management systems to take advantage of its planning capabilities.

Planning

Manufacturing planning requires determining the location, type of product, and the magnitude of the customer demand. The planning results will differ depending on the time frame under analysis. For example, a strategic plan (long-term) may involve determining the product group requirement for a particular region. Tactical (medium-term) and operational (short-term) planning may involve more details about the product, a specific location in the region, and so forth. The first step in manufacturing planning involves calculating the independent requirements based on the forecast values and requirements from the sales information system and costing/profitability analysis. The next step involves the planning of only those items that are critical to the overall process. The final step involves creating the materials requirement planning. The output of MRP is a planned production order, purchase requisition, or a planned purchase order.

Execution

Manufacturing execution involves procurement and supply of goods and services among all the stakeholders in the supply chain. The first step in manufacturing execution is the release of the production order. The next step in this process involves the issues of the materials from the storage location to the work center. After the manufacturing process is complete, goods are received into stock.

Collaboration

Manufacturing companies have increased their productivity and efficiency over time by implementing new strategies like total quality management, lean manufacturing, and Six Sigma. Although these have significantly improved the efficiency, there is an increasing recognition that companies are competing as supply chains, not individual entities. To maintain a competitive advantage, manufacturers must make a significant change in strategy to effectively synchronize activities among functionally and geographically dispersed organizations. All the stakeholders of the supply chain need to collaborate. A collaborative manufacturing strategy would help a company maximize the effectiveness of its value chain and, hence, be more profitable. Collaborative manufacturing strategies will play a crucial role in helping world-class companies increase business value in the emerging global economy. To successfully meet marketplace requirements, manufacturers must create business processes that leverage shared information. ERP solutions provide the perfect platform to aid this collaboration.

A well integrated ERP solution provides all the stakeholders in the supply chain with relevant, real-time information and analysis to be efficient not only as an individual organization, but also as an entire supply chain.

ERP SYSTEMS AND MANUFACTURING PROCESSES

Supply Chain Management Systems

Planning is one of the most important tasks in a supply chain. The software systems that help perform planning are called as supply chain management systems. Advanced planning systems is the generic name for this breed of software.

Advanced planning systems are by no means a replacement to the ERP systems. The aim of an advanced planning system is to address the deficiencies of an ERP system for planning. The two main characteristics of an advanced planning system are:

- **Integral planning:** Plan for the entire supply chain
- **True optimization:** Defining objectives and constraints for every part of the supply chain and solving it

However, it must be acknowledged that it is impossible to plan for the entire supply chain and at the same time perform optimization for every piece of the puzzle. Hence, a new architecture called the hierarchical planning system was developed. Hierarchical planning systems decompose the planning tasks into partial plans based on aggregation and disaggregating capabilities of time, products, resources, and so forth. Hierarchical planning systems provide the feasibility required for addressing integral planning and true optimization at the same time. Advanced planning systems are based on the hierarchical planning architecture, and address the planning requirements for all the four stages of the supply chain (i.e., procurement, production, distribution and sales). They also address planning for all time horizons (i.e., long-term, medium-term and short-term).

Product Lifecycle Management Systems

Product lifecycle management (PLM) systems describes a framework of technology and services that permit manufacturing companies and their partners and customers to collaboratively conceptualize, design, build, and manage products throughout their entire lifecycle. PLM systems enable organizations to create digital product information, and facilitate collaboration during the product development phase. PLM systems also control and automate critical processes such as release to manufacturing, change, and configuration management, throughout the product's lifecycle.

PLM systems have emerged as the primary means by which manufacturing companies can achieve significant improvements in their product development process. PLM systems are unique from other enterprise applications because they manage digital product information and optimize the digital product value chain. PLM systems also act as a document management system throughout the life cycle of a product. PLM systems have to integrate with other enterprise systems including traditional enterprise resource planning (transactional) and supply chain management systems (analytical).

CASE STUDY

Supply chain models give an overview of all elements in the supply chain and their relationship to each other, and are used to describe the strategic view of a supply chain from a planning perspective. There are a lot of models that break down the total supply chain into simpler subsystems and optimize each of them individually; however, optimized subsystems do not necessarily mean the total supply chain is optimized.

Supply network planning models integrates purchasing, production, distribution (of demands), and transportation so that comprehensive mid-term to long-term tactical planning and sourcing decisions can be simulated and performed on the basis of a single, global consistent model.

The case below discusses the methodology to define a supply chain model and suggests techniques for implementation of a supply chain network planning model in an ERP environment. The model, if implemented, would serve as a very valuable tool to enhance learning experience.

Task 1: Defining the Supply Network Planning Model Agents

Supply network planning includes all the processes from the demand plan to the delivery of goods/services to the customer. Definition of the supply network planning process consists of three main subtasks and is represented in Figure 3.

Task 1a: Defining the Supply Chain Model

The supply chain model is a combination of the following agents: production process, locations, products, resources, and transportation lanes. Production process defines the detailed information required for manufacturing a product, and contains the recipe and the routing for the goods/services to be manufactured/rendered. A location is a logical or physical place at which products or resources are managed on a quantity basis. Location includes production plant, distribution centers, customers, and vendors. Resources enable the definition of capacities of equipment, machines, personnel, means of transport, and warehouses. Transportation lanes represent a direct route between two locations that can be used to source and transport products.

A new agent-based supply chain model, as shown in Figure 4, with production process, locations, products, and resources will be created in this research effort.

The location is assigned to the model and the production process, products, and resources are assigned to the location. The supply chain model will be used to synchronize activities and plan the flow of material along the supply chain, thus, creating feasible plans for purchasing, manufacturing, inventory, and transportation, as well as service enterprises.

Task 1b: Analysis of Supply Network Model

For analysis of the supply network model, optimization-based, heuristics-based, and supply/demand propagation-based planning techniques could be investigated to determine their feasibility and appropriateness. Optimization-based planning techniques are typically based on quantitative models aimed at minimizing costs (or maximizing profits) subject to constraints. Heuristics-based

Figure 3. Supply network planning process (Source: SAP AG, 2004.)

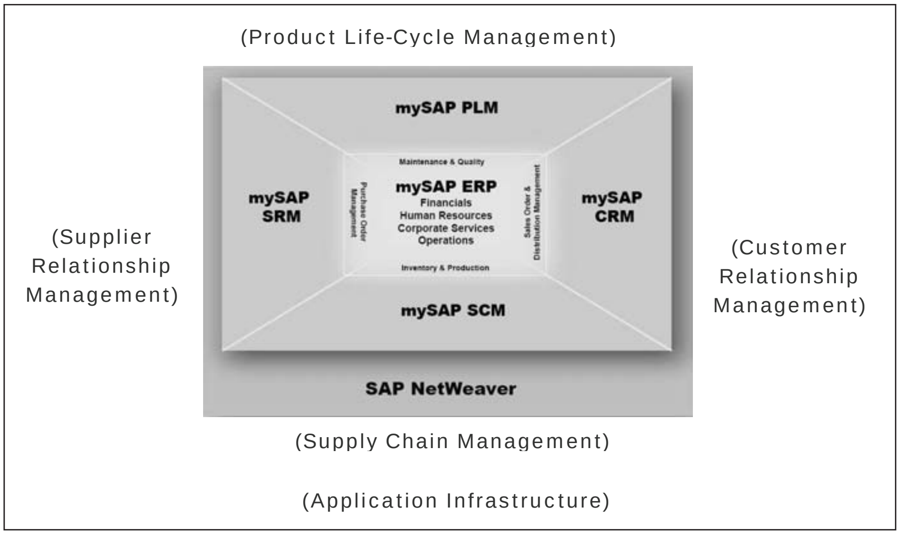
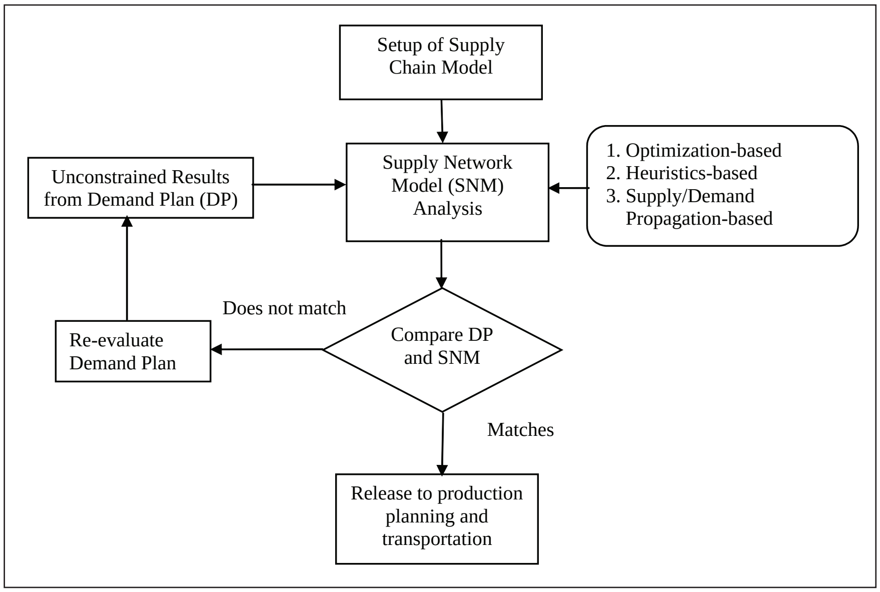


Figure 4. Agent-based supply chain network planning model



planning techniques work to create feasible (often nonoptimal) plans, and supply/demand-based planning techniques are based on statistical analysis of time series data. Quantitative and qualitative forecasting techniques can be used to develop a demand plan for comparison prior to release of the plan. The results from the demand plan (either real or simulated) are released to the supply network model and they form the basis for the analysis. The results from the demand plan do not include any constraints (e.g., production and distribution).

Task 1c: Validation and Implementation of Supply Network Planning Process

Validation of the model will be based on comparing the results from the constrained supply network model and the unconstrained demand plan. Since the initial model is formulated using an unconstrained demand plan, results may not be feasible when constraints are added, and the model must be modified. For example, available capacity may be less than the planned demand, hence, pricing parameters or resource constraints must be reevaluated.

The agents of the supply chain model represent the enterprise-wide integration, and the analytical agent-based model will be used to determine rules for agent behavior. Once the initial model and rules are developed, they would be evaluated and improved.

Task 2: Model Evaluation and Improvement

Measuring the effectiveness of the supply chain is very important. Successful evaluation and improvement of the agent-based supply chain integration model depends on concentrating on specific key business processes and developing an appropriate set of key performance indicators (KPIs) applicable at the enterprise level to measure the effectiveness of the supply chain. KPIs are quantifiable measurements that reflect the critical success factors of an organization, and depend on the product/service offered by an organization.

Task 2a: Definition of Performance Measures

Five main performance measures could be used for the evaluation of the supply chain models. The performance measures listed below are based on the guidelines from the SCOR model:

- **Supply Chain Delivery Reliability:** The performance of the supply chain in delivering the correct product, to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct customer.
- **Supply Chain Responsiveness:** The speed at which at which a supply chain provides products to the customer.
- **Supply Chain Flexibility:** The agility of a supply chain in responding to marketplace changes to gain or maintain competitive advantage.
- **Supply Chain Costs:** The costs associated with operating the supply chain.
- **Supply Chain Asset Management Efficiency:** The effectiveness of an organization in managing assets to support demand satisfaction. This includes the management of all assets, fixed and working capital.

Task 2b: Evaluation and Improvement of Performance Measures

The performance measures should be then evaluated for appropriateness for an enterprise-wide model in an ERP environment. Additional performance measures could be developed based on results of the definition and analysis/evaluation of the model. Comparison of the performance of the developed supply chain model with historic data and theoretical results provides an opportunity for benchmarking the performance of the model, as well as continuous improvement. The performance measures defined by SCOR will be studied for their validity and application on an enterprise-wide basis and additional measures will be developed, if necessary.

Task 3: Implementation of Supply Chain Network Planning Model in ERP Environment

Enterprise resource planning (ERP) is a software-driven business management system that integrates all facets of the business, including planning, manufacturing, sales, and marketing. The integrative capability of the ERP software makes it attractive for implementation of the agent-based supply chain integration model presented in this business case.

SAP advanced planner and optimizer (APO) is a component of the mySAP supply chain management solution that is used for planning and optimizing supply chain processes at a strategic, tactical, and operational planning level. APO is used for creating the model agents defined earlier, and assigning agents such as locations, products, resources, and production process models. After the initial assignments are made, agents for transportation lanes are added to link supply to demand locations, allocate products to the transportation lanes, and maintain quota arrangements. The developed model will be capable of tracking and evaluating supply chain agents including products, production process models and material handling, production, storage, and transportation. APO acts as the interface that acts as a top enterprise planning layer covering other planning areas such as manufacturing, demand, distribution, and transportation.

APO supply network planning (SNP) integrates purchasing, manufacturing, distribution, and transportation so that comprehensive tactical planning and sourcing decisions can be simulated and implemented on the basis of a single, globally consistent model. Supply network planning uses advanced optimization techniques based on constraints and penalties to plan product flow along the supply chain. The result is improved purchasing, production, and distribution decisions, reduced order fulfillment times and inventory levels, and improved customer service.

Starting from a demand plan, supply network planning determines a permissible short- to medium-term plan for fulfilling the estimated sales volumes. This plan covers both the quantities that must be transported between two locations (e.g., distribution center to customer or production plant to distribution center), and the quantities to be produced and procured. When making a recommendation, supply network planning compares all logistical activities to the available capacity.

The deployment function determines how and when inventory should be deployed to distribution centers, customers, and vendor-managed inventory accounts. It produces optimized distribution plans based on constraints (i.e., transportation capacities) and business rules (i.e., minimum cost approach, or replenishment strategies). The transport load builder (TLB) function maximizes transport capacities by optimizing load building.

For the implemented scenario, interactive demand planning will be used to create a demand plan, which is released to supply network planning to determine production planning. The process is simulated in APO utilizing planning techniques (cost-optimization, heuristics, and supply/demand propagation). Implementation of the supply chain model in an ERP environment will provide a test bed for validation, benchmarking studies, as well as further research on development and evaluation of analytical supply chain models. As an additional bonus, the implementation provides an infrastructure for creating case studies and exercises utilizing real-world data.

FUTURE RESEARCH DIRECTIONS

Further research in the field of supply chain management should consider analysis to determine the level of implementation of collaborative planning (such as CPFR) and collaborative replenishment (such as CRP) systems in different industries and the effects of this knowledge sharing on the performance of the supply chain. Collaborative planning includes the forecasting aspect of the demand management process, while collaborative replenishment covers the synchronization part of this supply chain process. Research and development of multidecision models which consider the objectives of the different companies will play an important role in these decision and planning systems.

Further research in the field of customer relationship management should try to analyze how different business units can use the same customer data: What specific type of integration alternatives are available for organizations working with rapidly changing CRM and SCM support technologies? Future studies should also develop decision and operations research tools to analyze the large amount of data gathered through the Internet. Further progress in research should be made in order to analyze intraorganizational and interorganizational effects simultaneously.

Further research in the field of order fulfillment needs to address the better use of information and creation of knowledge by using actual and new analytical and decision tools. The access to more data and information will put more emphasis in global optimization along the entire supply chain, instead of the usual models that focus on local optimization. More work considering the global supply chain will appear in this area. Also, more models using multicriteria decision making that reflect the integration and collaboration aspects of the e-fulfillment process will be the subject of future work.

Researchers should develop more decision models that take into account the global aspects of the supply chain to help to improve the manufacturing planning. Significant research is also required to help develop real-time tools, modeling, and decision systems that use real-time data available through the Internet.

CONCLUSION

With the continuous improvement in technology with software and computational capabilities organizations are able to better plan and execute their vision. The role of ERP software in this success cannot be undermined. However, there have also been instances where ERP implementations have resulted in large financial losses, even bankruptcy. It is important for organizations to recognize their core mission and capabilities and understand how ERP software can help achieve better efficiencies at their capabilities. If implemented the right way, ERP software unequivocally can help in the success of an organization.

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Chapter 5.22

The Strategic Implications of E-Network Integration and Transformation Paths for Synchronizing Supply Chains

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ABSTRACT

Streamlining information flows across the physical supply chain is crucial for successful supply chain management. This study examines different structures of e-networks (i.e., virtual supply chains linked via electronic information and communication technologies) and their maximum capabilities to gain e-network benefits. Further, this research explores four levels of e-network integration based on a 2x2 e-network technology and transaction integration matrix. Of the four levels, an e-network with high e-technology/high e-transaction integration appears to be most desirable for the companies that aspire to achieve the maximum benefits from their IT investments. Finally, this study identifies three alternative transformation paths toward a powerful high e-technology/high e-transaction integration network and discusses strategic implications of selecting those paths, in terms of e-network structures, availability of financial and technical resources, supply chain members' collaborative planning, e-security mechanisms, and supply chain size.

INTRODUCTION

As competition in the marketplace has increasingly intensified during the past decade, the strategic significance of close collaboration among supply chain members has dramatically increased. This advanced importance of collaborative chain activities is primarily attributable to the change of competitive scenes from a firm vs. a firm to a supply chain vs. a supply chain (Li, Rao, Ragu-Nathan, & Ragu-Nathan, 2005). A supply chain can be defined as encompassing all activities associated with the flow and transformation of goods from the raw material stage through to the end user, as well as the associated information flows (Handfield & Nicholas, 1999).

As this definition implies, a high level of information sharing and collaboration among chain members is an important prerequisite to achieving high performance of the entire supply chain (Li, Ragu-Nathan, Ragu-Nathan, & Rao, 2006; Monczka, Peterson, & Handfield, 1998; Sahin & Robinson, 2005). Many researchers have emphasized this crucial role of inter-organizational information transactions in supply chain management (SCM). They consistently argue that streamlining information flows across the entire chain is one of the critical success factors for gaining maximum SCM benefits, such as lowering product costs, reducing product development cycle time, and increasing responsiveness to customers' changing preferences (e.g., Christiaanse & Kumar, 2000; Cooper & Tracey, 2005; van Hoek, 2001).

However, in reality, lack of information sharing due to inadequate information systems and lack of trust among chain members appear to be serious obstacles to obtaining such SCM benefits (Cooper & Tracey, 2005; Wisner & Tan, 2000). Therefore, to survive in today's fierce competition between supply chains in global markets, the effective use of newly emerged information technologies has already become an important concern for managers who aspire to use an SCM approach as a strategic competitive weapon (Chopra, 2003; Elmuti, 2002). Those information technologies include the Internet, intranet, extranet, wireless technologies like radio frequency identification (RFID), and information integration systems such as enterprise resource planning (ERP), product lifecycle management (PLM), supply chain planning (SCP), supply chain execution (SCE), customer relationship management (CRM), supplier relationship management (SRM), and business process management (BPM).

However, despite the prominent importance of information systems and their integration across the supply chain, most of the previous studies have addressed this issue in the context of a dyadic relationship (e.g., a buyer and a supplier), rather than from the vantage point of an entire supply chain with multiple layers (e.g., a buyer, a buyer's buyer, and a supplier, a supplier's supplier) (Christiaanse & Kumar, 2000). More specifically, relatively little research has addressed such an important issue as "what types of, and in what way, electronic chains (e-networks) should be adopted and implemented to support all the intra- and inter-organizational activities across the supply chain, where the e-network refers to a non-physical, virtual supply chain linked by electronic information and communication technologies?"

Therefore, this study aims at expanding the body of knowledge on e-networks established in the physical supply chain by addressing the following five questions:

1. What types of e-networks exist in practice and what are their key characteristics?
2. What potential benefits can be obtained by an effective e-network management?
3. What measurement schemes can be employed to assess and categorize the various levels of e-network integration?
4. What are the strategic implications of various e-network integration levels and e-network types in gaining e-network benefits?
5. What transformation strategies and their related factors need to be considered in transforming an existing e-network into the most desirable one, which enables chain members to effectively achieve their common SCM goals?

The present study contributes to the literature in three ways. First, this study develops a classification scheme to better represent and understand the diverse and complex nature of e-network structures and their maximum capabilities to gain e-network benefits. Second, this article proposes a 2x2 e-network technology and transaction integration matrix to categorize various levels of e-network integration, and to identify the most desirable level of integration for achieving the maximum benefits from IT investments. Finally, this study introduces three alternative e-network transformation paths toward a powerful high e-technology/high e-transaction integration network and discusses the managerial implications related to those paths.

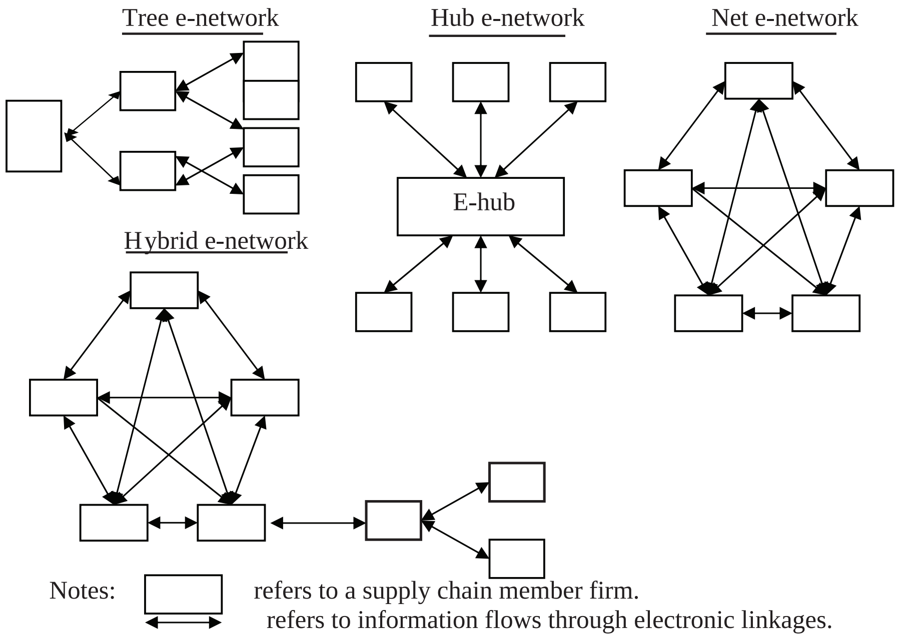
E-NETWORK TYPES AND POTENTIAL BENEFITS

Kumar and van Dissel (1996), from an interdependence view of organizations, have classified electronic data interchange (EDI)-based inter-organizational information systems (IOSs) into three categories: value/supply-chain IOS (enabling sequential transactions among chain members), pooled information resource IOS (sharing common IS/IT resources), and networked IOS (sharing data and supporting collaborative work among members). Building on Kumar and van Dissel's (1996) work, the present study developed a four-type e-network classification scheme to better represent current IOS environments, where Web-based technologies are widely utilized for data sharing and information transmissions. These four types are tree, hub, net, and hybrid e-networks (see Figure 1).

Tree E-Network

The "tree" e-network, similar to Kumar and van Dissel's (1996) value/supply chain IOS, is very close to a typical, physical supply chain in its shape, which has one or more suppliers or buyers in each of its multi-tier stages. This e-network structure usually takes a linear form of electronic linkages, reflecting sequential supplier-buyer relationships

Figure 1. Classification of e-network structures



Notes: refers to a supply chain member firm.
refers to information flows through electronic linkages.

from end suppliers to end customers. Currently, it is commonly found in most industries, including basic apparel, book publishing, computer, and food and beverage.

Hub E-Network

Similar to the pooled information resource IOS, the "hub" e-network, often called "e-hub" or "e-marketplace," is centered on a platform through which both suppliers and buyers are linked to make transactions and/or simultaneously exchange necessary data and information such as order status, shipment schedules, inventory levels, and CAD/CAM data with one another (Kaplan & Sawhney, 2000; Sharifi, Kehoe, & Hopkins, 2006; Zeng & Pathak, 2003). This nonlinear intermediary, often called infomediary, is further classified into vertical and horizontal exchanges, aggregation, and auction and reverse auction hubs (Kaplan & Sawhney, 2000; Zeng & Pathak, 2003). Vertical exchange hubs (e.g., eSteel.com, PaperExchange.com, FloraFlex.com) provide deep domain-specific content and relationships, typically by automating and hosting procurement process for an industry-specific vertical market, while horizontal exchange hubs (e.g., SupplyCore.com, Employease.com, Citadon.com) focus on providing the same functions, such as procurement, benefit administration, and project management, or automating the same business process scalable across multiple vertical markets (Jennings, 1999; Kaplan & Sawhney, 2000).

Next, aggregators serve as hubs in one-way B2C networks (e.g., AOL, Yahoo!, Tavelocity.com, Buy.com) to function as one-stop shopping places for smaller purchasers or operate as hubs in two-way B2B networks (e.g., PlasticsNet.com) that mediate between buyers and sellers and create benefits for both sides with domain expertise. Finally, auction (e.g., eBay, FreeMarkets) or reverse auction (e.g., uBid, Priceline.com) hubs create value by spatial matching of buyers and sellers for a specific bid event for unique non-standard or perishable products. Recently, more companies act as reverse auction hubs, but not as intermediaries, by increasingly sharing material specifications with suppliers, selecting and pre-qualifying them, and running bidding events (e.g., GE's Source-Bid Events). Furthermore, some hubs in the automotive, consumer packaged goods (CPG), logistics service, and business solution system industries (e.g., Transora.com, Transplace.com, mySAP.com) are providing some or all of the aforementioned services.

Net E-Network

The "net" e-network, similar to the networked IOS, refers to the structure in which chain members have direct electronic linkages with one another in a networked supply chain (or a supply network) (Kehoe & Boughton, 2001). For example, in the construction industry, each firm involved in a specific construction project needs to have a direct access to other participants, even though they may not have an explicit or a direct contracting relationship (Cheng, Li, Love, & Irani, 2001). Although these virtual nonlinear net e-networks are rarely found in practice, this type of e-network is increasingly emerging in some industries as evidenced by the interviews of managers in electronic, mechanics, and paper industries (Kemppainen & Vepsalainen, 2003).

Hybrid E-Network

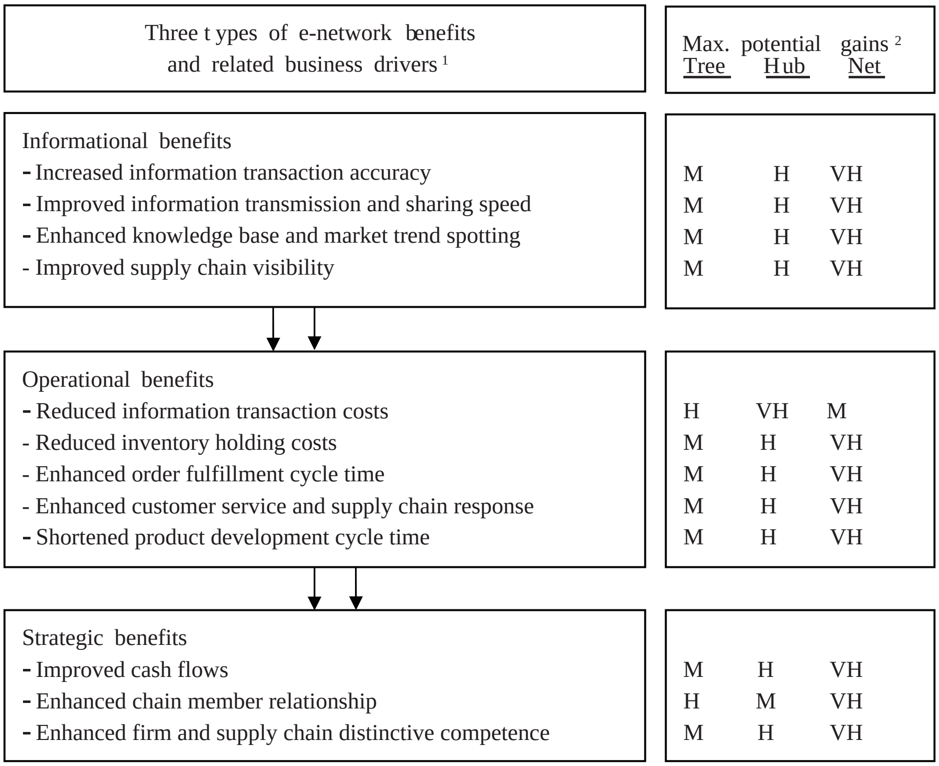
The "hybrid" e-network takes a combined form of the previously mentioned e-network structures, for example, a tree-hub e-network or a tree-net e-network. In practice, many large-sized firms, such as Ford, GM, GE, and Cisco, often employ this complex type of e-networks for managing their supply chains.

Potential E-Network Benefits and E-Network Type

A review of the relevant literature (e.g., Bauer, Poirier, Lapide, & Bermudez, 2001; Edwards, Peters, & Sharman, 2001; Heinrich, 2003; Hendon, Nath, & Hendon, 1998; Iacovou, Benbasat, & Dexter, 1995; Jennings, 1999; Kaplan & Sawhney, 2000; Ovalle & Marquez, 2003; Phan & Stata, 2002; Poirier & Bauer, 2001; Sharifi et al., 2006; Turban, Lee, King, & Turban, 2000) has revealed a variety of potential e-network benefits and varying degrees of the benefits that can be realized by each e-network type. Figure 2 summarizes the key points of benefits and capabilities.

There are three categories of potential e-network benefits: informational, operational, and strategic. First, informational benefits pertain to the effects of e-networks on intra- and inter-organizational information transactions: increased information transaction accuracy, improved information transmission and sharing speed, enhanced market knowledge base and trend spotting, and improved supply chain visibility (Iacovou et al., 1995; Ovalle & Marquez, 2003; Sharifi et al., 2006; Turban et al., 2000). Second, operational benefits refer to the impacts of e-networks on the efficiency of the intra- and inter-organizational business processes: reduced information transaction costs and inventory holding costs, enhanced order fulfillment cycle time, customer service

Figure 2. E-network benefits and maximum potential gains by e-network type



Three types of e-network benefits and related business drivers [1]	Max. potential gains [2] Tree	Hub	Net
Informational benefits			
- Increased information transaction accuracy	M	H	VH
- Improved information transmission and sharing speed	M	H	VH
- Enhanced knowledge base and market trend spotting	M	H	VH
- Improved supply chain visibility	M	H	VH
Operational benefits			
- Reduced information transaction costs	H	VH	M
- Reduced inventory holding costs	M	H	VH
- Enhanced order fulfillment cycle time	M	H	VH
- Enhanced customer service and supply chain response	M	H	VH
- Shortened product development cycle time	M	H	VH
Strategic benefits			
- Improved cash flows	M	H	VH
- Enhanced chain member relationship	H	M	VH
- Enhanced firm and supply chain distinctive competence	M	H	VH

Notes:

1. *Three types of e-network benefits and their related business drivers are partly adapted and compiled from Bauer et al. (2001), Edward et al. (2001), Heinrich (2003), Hendon et al. (1998), Iacovou et al. (1995), Jennings (Jennings, 1999), Kaplan and Sawhney (2000), Phan and Stata (Li et al., 2006; Monczka et al., 1998; , 2002), Ovalle and Marquez (2003), Poirier and Bauer (2001), Sharifi(2006), and Turban et al. (2000).*
2. *Maximum potential gains by e-network type: M = Moderate, H = High, VH = Very High.*

and supply chain response time, and shortened product development cycle time (Hendon et al., 1998; Iacovou et al., 1995; Sharifi et al., 2006). Finally, strategic benefits relate to the effects of e-networks on the competitive position of the entire supply chain in the marketplace: improved cash flows, enhanced chain member relationships, and enhanced distinctive competence of member firms and the entire supply chain (Edwards et al., 2001; Iacovou et al., 1995; Phan & Stata, 2002).

It should be noted that the informational benefits achieved by a highly effective e-network can help chain members obtain a wide range of operational and, in turn, strategic benefits. For example, accurate real-time information transactions across the e-network can enable members to reduce their inventory holding costs and improve their customer service, which in turn could improve their cash flows and enhance distinctive competence of the supply chain as a whole. Moreover, in principle, the net and hub e-networks have a greater potential in gaining maximum e-network benefits than the tree e-network, because the net and hub e-networks enable their members to communicate simultaneously with one another through direct connections (net type) or indirect connections via a platform (hub type), rather than transferring necessary information in a sequential fashion (tree type).

The overall magnitude of informational, operational, and strategic benefits that can be obtained tends to increase as the e-network structure changes from tree to hub to net. However, compared to tree e-networks, hub and net e-networks might have some constraints in gaining substantial cost savings on information transactions as one of the key informational benefits and improving chain partner long-term relationships as one of the key strategic benefits, because of the inherent nature of the hub and net e-networks—that is, multilateral and simultaneous communications among chain members and low switching costs to reconfigure the e-network after changing some of its partner firms. Furthermore, the actual realization of e-network benefits across the supply chain, in reality, is still highly dependent upon the chain members' planning and execution of their e-network efforts. It should also be noted that the aforementioned operational and strategic benefits could also be achieved by other initiatives, such as eliminating non-value-added activities across the supply chain and carefully selecting and retaining competent chain members.

E-NETWORK INTEGRATION MEASUREMENT FRAMEWORK

Successful e-network implementation—seamlessly automating the information transaction processes across organizational boundaries via information and communication technologies—helps all of the chain members achieve maximum e-network benefits and in turn can enhance their competitiveness. Specifically, the types and magnitude of e-network benefits that a supply chain obtains can be primarily determined by how well an e-network is integrated among members. In addition, different e-network structures and supply chain sizes may moderate the effects of e-network integration levels on the e-network benefits that are actually realized.

Measurements of E-Network Integration

Prior studies have proposed various measurements to assess the integration level of inter- and intra-organizational electronic communication. In the context of EDI, Premkumar and Ramamurthy (1995) suggest three key dimensions of EDI utilization: extent of adaptation (the extent of using EDI for generating purchasing order and sales invoice for trading partners), internal diffusion (extent to which EDI is integrated to systems such as shipping/distribution and inventory control), and external connectivity (the extent to which customers are linked by EDI, and the amount of transactions conducted through EDI). Similarly, Massetti and Zmud (1996) propose a four-facet measurement of EDI usage. They are: (1) volume, which represents the extent to which an organization's document exchanges are handled through EDI connections; (2) diversity, which refers to the number of distinct document types that an organization handles via EDI; (3) depth, which refers to the degree of electronic consolidation that has been established between the business processes of two or more trading partners; and (4) breadth, which represents the extent to which an organization has established EDI connections with external organizations such as suppliers, customers, government agencies, and financial institutions.

Later, Shore and Venkatachalam (2003) attempted to measure supply chain information sharing capability in terms of information technology infrastructure (infrastructure capability) and capability of communication collaboration activities (collaboration capability). Recently, in the context of Internet communication, Cai, Jun, and Yang (2006) measured inter-organizational Internet communication in terms of frequency, diversity, and formality dimensions.

It should be noted that all the dimensions identified by the aforementioned studies could be broadly categorized into two groups: e-technology integration (the extent to which electronic linkages are established among chain members) and e-transaction integration (the extent to which electronic linkages are utilized to share information by chain members). Considering the characteristics of the two groups of integration, the following two dimensions of e-network integration are proposed in this study: *e-network information technology (e-technology) integration* and *e-network information transaction (e-transaction) integration*.

The *e-technology* integration dimension, similar to Shore and Venkatachalam's (2003) concept of infrastructure capability, measures the extent to which business processes are electronically consolidated via ICT within and between members in a supply chain. The degree of e-technology integration is heavily influenced by the chain members' willingness to participate in the e-network integration efforts, as well as the connectivity and compatibility of their IS infrastructure (Byrd & Turner, 2001). Connectivity (or breadth) refers to the ability of chain members' IS infrastructure to link to any other IS within and between organizations (adapted from Duncan, 1995; Massetti & Zmud, 1996). On the other hand, compatibility (or depth) means the ability of chain members' IS infrastructure to automatically exchange and handle any type of information (e.g., text, video, image, and audio) across any technology components (regardless of manufacturer, make, or type) in the chain (adapted from Duncan, 1995; Massetti & Zmud, 1996). Thus, high e-technology integration refers to the ideal situation where all chain members' information systems are not only linked internally and externally across the chain (high connectivity), but also able to automatically share information among themselves (high compatibility). Conversely, low e-technology integration pertains to situations where most chain members' ISs are not linked either internally or externally across the chain (low connectivity) and/or are unable to automatically share information among themselves (low compatibility).

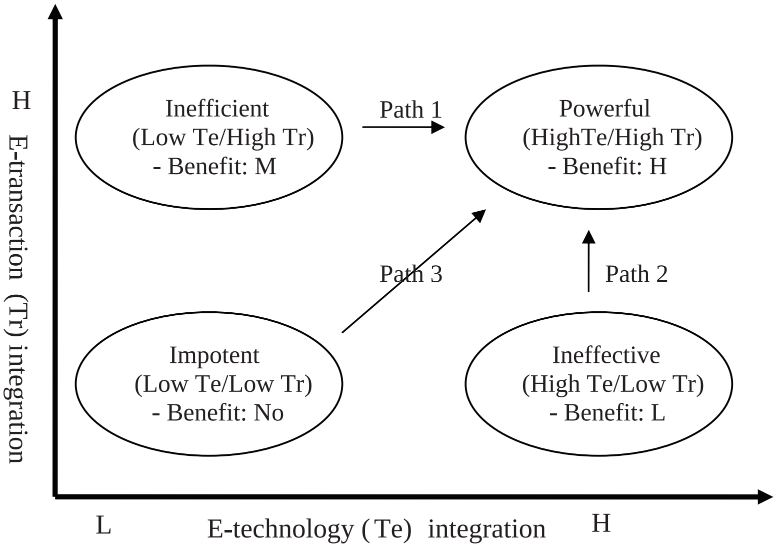
The *e-transaction* integration dimension, similar to Shore and Venkatachalam's (2003) concept of collaboration capability, represents the extent to how much (volume) and what types of documents (diversity) are transmitted via electronic linkages among members within a supply chain (adapted from Massetti & Zmud, 1996). The chain-wide electronic transaction volume can be determined by dividing the total number of documents transmitted through *electronic linkages* in a given time period within a supply chain by the total number of documents transmitted through electronic linkages or other communication means such as mail in the same time period within the supply chain. The chain-wide electronic transaction diversity can be measured by the total number of different document types transmitted through electronic linkages in a given time period within a supply chain. Consequently, the e-transaction integration should reach a certain level for individual members to benefit from their IT investments. This constraint often makes some chain members reluctant to participate in the chain-wide efforts of tightening e-technology integration. Many firms in the consumer packaged goods industry often face this economic feasibility constraint in adopting collaborative planning, forecasting, and replenishment (CPFR) practices.

However, it should be noted that there are some differences between the present study's two measurements and Shore and Venkatachalam's (2003) counterparts. First, while Shore and Venkatachalam's (2003) information technology infrastructure dimension focuses on assessing downstream *individual* suppliers' integration capabilities, the present study's e-technology integration dimension concentrates on measuring both upstream buyers' and downstream suppliers' IS integration (i.e., dual-direction communication). Next, while Shore and Venkatachalam's (2003) collaboration capability dimension focuses on assessing suppliers' ability and willingness to share a variety of information with buyers, the present study's e-transaction integration dimension concentrates on measuring the extent of actual information sharing between upstream buyers and downstream suppliers throughout the supply chain.

E-Network Technology-Transaction Integration Matrix

Based on the two dimensions of e-network integration discussed earlier, the authors developed a 2x2 matrix with vertical and horizontal axes representing the high–low levels of e-technology integration and e-transaction integration, respectively. Figure 3 presents four groups of e-networks classified by the two e-network integration dimensions. The four groups are: powerful e-networks (high e-technology/high e-transaction integration), inefficient e-networks (low e-technology/high e-transaction integration), ineffective e-networks (high e-technology/low e-transaction integration), and impotent e-networks (low e-technology/low e-transaction integration).

Figure 3. E-network technology-transaction integration matrix and transformation paths



Powerful E-Network: High E-Technology/High E-Transaction Integration

In the high e-technology and high e-transaction e-network, a variety and large volume of information is transmitted between members through highly automated (or high-depth) electronic linkages like computer system-to-computer system connections. For example, the members of this powerful e-network can communicate real-time information with one another through SCM solution systems or other inter-organizational systems that are integrated with their respective internal ERP systems, thereby ensuring the visibility or transparency of supply chain business processes. A typical example would be the Cisco Systems' virtual manufacturing system. The system included 37 factories, which are linked to Cisco via the Internet. Approximately 80% of Cisco's purchase orders were automatically released via the Internet to its members. By using this virtual system, Cisco's partners manufactured all the components, performed 90% of the subassembly work, and conducted 55% of the final assembly. Furthermore, the system allowed Cisco to speed time-to-market of its products through collaboration with its suppliers and customers (Ansley, 2000). In other words, through the virtual manufacturing system, Cisco was able to create the right design in a shorter time frame by sharing information seamlessly with its partners in the process of new product development, including prototyping, design change, and quality testing.

The potential benefits that can be realized by this powerful e-network are not greatly affected by e-network type. In the case of advanced hub and net e-networks, the highly automated and integrated electronic linkages enable their members to perform simultaneous, real-time communications with one another directly (net e-networks) or indirectly through a platform (hub e-networks). Even in the less advanced tree e-network, the information and data sent by one member can be rapidly transmitted throughout the e-network without any interruption, because the fully integrated electronic linkages within and between members can automatically handle and deliver electronic documents in a sequential order across the e-network. Therefore, this powerful e-network can eliminate or significantly reduce labors needed for intra- and inter-organizational information exchanges, resulting in eliminating keyed-in errors, lowering information transaction costs, increasing information sharing, and making timely information available to all participants.

In addition, the powerful e-network can help members to eliminate or substantially mitigate so-called "bullwhip effects" in a supply chain. The bullwhip effects can occur when the members make ordering decisions based on the orders only from the next downstream member rather than all the chain members (Lee, Padmanabhan, & Whang, 1997). In this case, each member tends to overestimate the demand of its products to ensure on-time delivery, and order raw materials and components based on the inflated forecasting. The overestimated order variability is then amplified across the supply chain, resulting in high inventory, poor customer service, lost revenues, misguided capacity plans, ineffective transportation, and missed production schedules (Lee et al., 1997). Therefore, in order to reduce the bullwhip effects and improve the total supply chain performance, the extent of information sharing needs to increase in a supply chain (Yu, Yan, & Cheng, 2001). All firms within such a powerful e-network are most likely to achieve a wide range of informational, operational, and strategic e-network benefits to the maximum. Further, the high level of information transactions across the chain can warrant its partners' IT investments.

Inefficient E-Network: Low E-Technology/High E-Transaction Integration

In the low e-technology and high e-transaction integration e-network, active information transactions occur between members, mostly through inefficient low-depth electronic linkages, such as file-to-file connections (e.g., e-mail exchanges between trading partners), since many members have not yet integrated their own internal IS with an IOS, such as Web-EDI, extranets, and SCM solution systems. Some chain partners may not even have any electronic connections with other members, and may rely on traditional communication media like fax and phone for their inter-firm communication needs.

Therefore, this type of e-network usually employs numerous employees to manually handle a large volume and variety of information transmission; such human intervention may result in slow and inaccurate information transactions and/or less information sharing between members. Consequently, those firms are likely to incur "opportunity costs" and fail to gain the maximum potential of IT benefits by additional investment on their IS infrastructure.

One typical example of such inefficient network could be found in the case of one of the Komatsu America Corp.-Peoria Manufacturing Operations (KAC-PMO). The company is a world-leading producer of special, heavy mining equipment, which has approximately 350 direct materials suppliers. Although KAC-PMO had its own ERP system in place and made various types of data, such as sales forecasts and an e-catalog electronically available to its key suppliers through the system, both the company and its suppliers had to utilize mostly traditional communication channels to exchange information, because there was a lack of fully integrated IOSs between them (Versendaal & Brinkkemper, 2003). According to Versendaal and Brinkkemper (2003):

> *[KAC-PMO's] forecast reports and purchase orders were printed and faxed to suppliers. Suppliers keyed-in order data when receiving a purchase order fax. Suppliers provided [order] fulfillment dates to KAC-PMO on paper or by phone. KAC-PMO entered promise dates of supplier fulfillment manually. Purchase order change proposals needed to be approved manually.* (p. 44)

Later, under the heavy pressure of the needs to share a large amount of information with its key suppliers more frequently, KAC-PMO decided to implement an electronic trading exchange system, which enables the company to connect with most of its suppliers electronically.

It is worth noting that when some members form a hub or net e-network in a small segment of this inefficient e-network, the negative impacts of the overall low e-technology integration on the speed, accuracy, and timeliness of information transmission may be restricted only to the remainder of the members linked by low-depth electronic connections. On the other hand, if this inefficient e-network takes the form of a tree e-network and thus all information transmission across the e-network should be performed in a sequential fashion, most of the supply chain members will gain very limited informational benefits because of some "bottleneck" members, which inadvertently make delays or errors in transferring information through their low-depth electronic connections, requiring frequent human interventions.

Ineffective E-Network: High E-Technology/Low E-Transaction Integration

Even though most members in the high e-technology and low e-transaction integration e-network adopt modern IT, they use their highly integrated electronic linkages just to transmit a small volume and few types of documents. Thus, such underutilization of the e-network causes those firms to incur "out-of-pocket costs" and achieve only minimal benefits from their IT investments.

The high e-technology/low e-transaction integration e-network can often be found in a small supply chain or a partial segment of a large supply chain, where a focal company has a dominant position and coerces other members to adopt intra- and inter-organizational IS. In this case, the coerced members tend to be reluctant to share their critical information with the focal company because they fear that the dominant firm would exploit the information to its own advantage, resulting in an ineffective e-network. Mostly, this phenomenon is due to the lack of trust, collaboration, and win-win thinking. The failure of Covisint, a hub e-network in the automotive industry, represents a good example of the gloomy future of the ineffective e-network that fails to transform itself into the powerful e-network and justify its huge IT investment. As a joint venture of Ford, General Motors, and DaimlerChrysler, Covisint promised to bring more suppliers to the table of the OEM giants, lower the cost of transactions, open up the market for suppliers, and create visibility in the chain (Campbell, 2004).

However, while the suppliers of the big three were pushed to adopt Covisint, mistrust between the vehicle manufacturers and their suppliers resulted in the resistance from the suppliers (Koch, 2002). Particularly, the major first tier suppliers were reluctant to utilize Covisint since they wanted to maintain their own data and subcontractors separately from the system (Rosenberg, 2003). Furthermore, many suppliers viewed such a network as a ‘competitive-edge equalizer’. That is, if all parties are using the same technology and process, it is impossible for an individual supplier to build competitive advantage (Campbell, 2004). Thus, although 11,000 auto parts suppliers utilized the Covisint in some fashion, they only occupied 10-15% of the exchange’s revenue, and the big three automotive makers accounted for the majority of the revenue. This fact implies that the Covisint (high e-technology integration) was severely underutilized (low e-transaction integration) by the downstream chain members. Eventually, the Covisint was sold to other firms in early 2004.

Impotent E-Network: Low E-Technology/Low E-Transaction Integration

In the low e-technology and low e-transaction integration e-network, most of the information exchanges between members are handled through low-depth electronic linkages and/or traditional communication media. This rather disintegrated e-network with a low volume and few types of document exchange usually slows down the pace of manufacturing processes across the supply chain, resulting in losses of its competitive edge against competitors.

Such a low e-technology/low e-transaction integration e-network can be observed in a large supply chain, where little or no chain-wide effort has been exerted to build highly integrated communication networks between members. For example, before Hewlett-Packard adopted the SCM software for its supply chain, its chain members had been using various applications with different sophistication levels, ranging from complex ERP programs to simple spreadsheets. Thus, sharing information among the chain members had been limited to passing data only to their adjacent members, and the speed of communication across the supply chain had been very slow. Consequently, this impotent e-network had slowed down the pace of the chain-wide manufacturing process and negatively affected the cash flows of all the chain members (eCompany Now Staff, 2000). In addition, the impotent e-network can often exist in a traditional EDI environment, where a dominant firm in an asymmetric relationship forces its weak trading partner to adopt EDI systems and the reluctant EDI adopters are inclined to use non-integrated, PC-based standalone EDI systems due to the lack of financial and technical resources.

STRATEGIC IMPLICATIONS OF E-NETWORK TRANSFORMATION PATHS

Of the aforementioned four groups of e-network integration, the high e-technology/high e-transaction e-network ideally provides maximum IT benefits to its members and can contribute to the sustainable competitiveness of the entire supply chain. Hence, it can be recommended that firms with e-networks falling into the other three groups (low e-technology/high e-transaction, high e-technology/low e-transaction, and low e-technology/low e-transaction) should consider transforming their e-networks into a powerful e-network (high e-technology/high e-transaction). The following section discusses three alternative transformation paths toward the powerful e-network and strategic considerations involving the transformation process.

Path 1: From Low E-Technology/High E-Transaction to High E-Technology/High E-Transaction

According to the case reported by Kok et al. (2005), Philip Semiconductors (PS) followed Path 1 in its transformation from an inefficient e-network (low e-technology/high e-transaction integration) to a powerful e-network (high e-technology/high e-transaction integration). Before 1999, Philip Semiconductors had a decentralized short-term planning process, which was disconnected from its medium-term planning. All the members of PS's supply chain, including contract manufacturers and customers, had independent weekly planning cycles based on orders from the immediate downstream member (i.e., tree e-network, low e-technology/high e-transaction). These independent processes caused long information latency and strong information distortion by poor visibility of material availability and local optimization, resulting in high bullwhip effects across the supply chain.

Later, PS implemented the collaborative planning process, which calculates the synchronized plan that determines and transmits all orders to be released at all links in the supply chain via a tightly integrated e-network system with a central (or shared) database (i.e., hub e-network; high e-transaction/high e-technology). The e-hub has enabled PS's chain members to virtually guarantee quantities and delivery time, thereby mitigating dramatically the influence of bullwhip effects and saving around US$5 million each year.

When members in an inefficient low e-technology/high e-transaction e-network attempt to fully integrate their ISs across the chain, it is recommended that they pay particular attention to the following three important issues: acquiring needed financial and technical resources, planning collectively for seeking the best software solutions, and adopting Internet-related technologies as communication channels.

First, some members in an inefficient low e-technology/high e-transaction e-network, mostly small firms, may not have sufficient financial and technical resources for integrating ISs internal and external to them. It is thus essential for a focal company to assist its partners in solving diverse and complex problems associated with IS integration.

Second, all members should take a collective planning approach to seeking optimal software solutions for the entire chain, which can avoid or significantly mitigate the adverse impacts by the lack of IS connectivity and compatibility on chain-wide information flows and ultimately reduce total e-network costs. For example, in today's chemical industry, many firms with ERP systems have been experiencing difficulties in connecting their ISs with those of other members, since they purchased the systems from various ERP vendors (e.g., SAP, Oracle) which have set their own standards (Roberts, 2000). Under such circumstances, only collective planning processes can yield a unified software solution to the various connectivity and compatibility problems. Of the three e-network structures, the net e-network is more likely to experience such problems than the tree or hub e-networks, since each member of the net e-network should establish its direct electronic linkages with the rest.

Finally, as argued by Horvath (2001), it is important for the e-network with a low e-technology integration to have the capability of open and low-cost connectivity through broadband Internet connections or virtual private networks. This capability enables small chain members to access a collaborative e-network infrastructure without a major investment in proprietary technology, thereby leading to a high level of e-network integration. In addition, third-party software and systems support for supply chain applications may play a key role in integrating small chain partners into a powerful e-network (Green, 2001; Horvath, 2001).

Path 2: From High E-Technology/Low E-Transaction to High E-Technology/High E-Transaction

Westerman and Cotteleer (1999) report the case of Tektronix Inc., a manufacturer of electronic tools and devices, which has migrated from an ineffective EDI-based net e-network (high e-technology/low e-transaction) to a powerful Internet-based hub e-network (high e-technology/low e-transaction) by following Path 2. In 1992, the company operated seven separate data centers, which were decentralized and segregated by divisions. It had over 460 legacy systems just in the United States, none of which was standardized for global operation. Moreover, each of the company's manufacturers had its own communication protocol. In order to coordinate among these manufacturers, the company had to install multiple lines and protocol converters around its global network. As a result, although the connection between these divisions and manufacturers could be regarded as a high level of integration, the performance of the overall network was still suffering. Due to the sub-optimization of the network by the different divisions, the company could not obtain real-time information of inventory and performance, and could not effectively manage customer account and credit on a global basis. Therefore, the volume and diversity of documents transmitted electronically across the entire supply chain was limited.

To overcome the ineffective use of the information systems, the company initiated a project of network restructure. By 1994, all the members in the network switched from EDI- to Internet-based systems. The company also consolidated its multiple data centers into a single one. A global ERP system was also implemented to integrate all of its business divisions together. With such an Internet-based, fully integrated hub network and improved information flow, the company was able to achieve good inventory visibility, reduce credit approval cycle time, and make better decisions.

The ineffective high e-technology/low e-transaction e-network has technologically the greatest potential to be transformed into a powerful high e-technology/high e-transaction e-network by rapidly increasing the variety and volume of information that transmitted through its already established electronic networks. One major reason for the low information transmission is that the e-network has been optimized only for its certain segment(s), rather than for the entire e-network. This sub-optimized information network discourages members from increasing document variety and volume transmitted throughout the e-network, resulting in an ineffective e-network. Hence, to optimize and standardize IS infrastructure, members should not only adopt advanced electronic linkages, but also exert collective e-network planning efforts.

Another key reason for the e-network underutilization is related to potential security risks and trust issues. There exist various types of potential security threats to the e-network: destruction or unauthorized use of information/resources; corruption or modification of information/resources;

theft, removal, or loss of information/resources; and deception via presentation of false data (Kolluru & Meredith, 2001). Because of such potential security risks and lack of mutual trust, many members might have intentionally restricted the use of their electronic linkages to exchanging just a few routine documents, and avoided adopting advanced applications that enable them to share confidential information, such as CAD/CAM, capacity, and demand data, which are essential for gaining operational and strategic e-network benefits.

Therefore, to utilize their integrated ISs to the full extent, various security technologies, such as authentication, access control, and auditing processes, are needed to ensure the confidentiality of members' critical information. In addition, it is necessary to establish legal and contractual mechanisms that regulate member behaviors and specify policies regarding the deviations from the contract terms. In an effort to establish effective security measures, all members should participate in the process of designing and implementing both technical mechanisms and legal agreements, thereby enhancing mutual trust among them. Over time, however, trust and cooperation need to be generated as a result of a series of interactions between chain members (Chopra & Meindl, 2004).

Path 3: From Low E-Technology/Low E-Transaction to High E-Technology/High E-Transaction

Liu, Zhang, and Hu (2005) report a case of one large Chinese motorcycle corporation, Nanjing Jin Chen Motorcycle, and its suppliers, which have implemented an inter-enterprise supply chain management system to move from an impotent e-network (low e-technology/low e-transaction) to a powerful e-network (high e-technology/low e-transaction), following Path 3. Before the implementation of the e-network, the company and its suppliers generally did not have efficient internally integrated information systems in place, not to mention IOSs (i.e., low e-technology/low e-transaction).

To enhance the work flows between the supply chain members, the motorcycle company initiated a project to integrate its business processes with those of its suppliers through an Internet-based IOS, which allows them to share and exchange information smoothly and quickly. Each of the supply chain members is provided with a workflow support supply chain management system, which comes with an integrated interface that enables seamless information exchange between the supply chain members. The implementation of the systems enables the company and its suppliers to share a variety of real-time information, such as statistical data, manufacturing plan, and inventory information (i.e., high e-technology/low e-transaction).

The impotent low e-technology/low e-transaction e-network is most likely to face the obstacles that both high e-technology/low e-transaction and low e-technology/high e-transaction e-networks often encounter during their transformation process towards a high e-technology/high e-transaction e-network. Thus, members of the impotent e-network should pay attention to the suggestions offered in the two previous sub-sections to increase the levels of both e-technology and e-transaction integration. Further, they may also need to address the following two issues involving the issue of supply chain size.

First, it is conceivable that members of certain segments within a large-scale supply chain have engaged in a so-called "market exchange" relationship. This type of business relationship can be easily observed in the e-marketplace, where firms neither exchange much information with one another nor develop specialized assets to work together (Bensaou, 1999). Since firms in such a relationship, if necessary, want to switch their trading partners at a low cost with minimal damage, they are not strongly motivated to invest substantial funds on the projects for inter-organizational IT integration, thereby resulting in a low e-technology/low e-transaction e-network.

To solve the e-network problems originating from the different types of business relationships among chain members, leading firms in a large-scale supply chain may need to consider a hybrid e-network that consists of multiple e-network structures and/or various levels of electronic linkages. For example, a focal company and its key chain members can establish a private e-hub that allows a large volume of information exchange and close coordination of inter-firm operations. In addition, an e-marketplace, like eSteel.com, can be offered to the firms in the "market exchange" relationship to negotiate, buy, and sell products over the Internet without heavy capital investment in their IS infrastructure.

Next, when multiple focal companies coexist in a large-scale supply chain, and each of those firms has electronic linkages with its close trading partners (e.g., first-tier suppliers or buyers), chain members will encounter various problems arising from the software incompatibility between sub-chains in their endeavor to increase e-technology and e-transaction integration simultaneously (Raupp & Schober, 2000). Thus, these focal companies are well-advised to work together to address such an issue and adopt a common standard and/or flexible technologies such as those enabled by XML (eXtensible markup language) which allow data exchange between different applications for their e-network (Meehan, 2001). Further, a recent RFID initiative by Wal-Mart with its key chain members could be considered a next-generation level of e-technology and e-transaction integration that enables all the chain members to achieve not only informational and operational benefits, but strategic benefits of their e-network.

CONCLUSION AND MANAGERIAL IMPLICATIONS

In recent years, an increasing number of companies have adopted supply chain management (SCM) as a key driver for delivering increased value to customers by focusing on their core competencies, outsourcing non-critical and/or non-competency activities to their upstream suppliers and downstream customers, and integrating all chain members to act as a single entity (Chandrashekar & Schary, 1999). Accordingly, to coordinate and synchronize various business activities at all levels across the supply chain, an effective e-network, along with its associated business process reengineering, should be adopted and implemented (Elmuti, 2002; Kehoe & Boughton, 2001).

In theory, an e-network with high e-technology/high e-transaction integration appears to be the most desirable for the companies that aspire to achieve the maximum benefits from their IT investment and in turn enhance their competitiveness in the marketplace. This fully integrated e-network makes it possible to timely exchange diverse information and data and offer real-time high visibility to all chain partners, thereby eliminating the bullwhip effect across the supply chain. At the same time, the high level of information exchange in such an e-network warrants members' IT investment. In practice, however, such an e-network is not always desirable and feasible. The varying degrees of members' IS infrastructure, competitive pressure in the marketplace, and more importantly, various types of inter-organizational relationships collectively and substantially affect the magnitude of e-network technology and transaction integration.

For example, some firms adopting a total SCM approach may seek to fully integrate chain members' IS for streamlining and synchronizing information flows across the supply chain. However, as time passes, these firms may recognize the need to disintegrate and reconfigure their entire supply chain to sustain their competitive advantages by eliminating non-value-added activities and incompetent chain members, and by utilizing distinctive competence of new members (Markus, 2000). In this case, those firms would have improved their performance by pursuing a "quick integration/

quick disintegration" IS strategy to quickly adapt themselves to changing business environments (Christiaanse & Kumar, 2000; Markus, 2000). Fortunately, the enhanced modularity (which is defined as the ability of the IS infrastructure to add, modify, and remove any software or data components with ease and with no major overall effect; see Duncan, 1995) of current ERP systems (which are mainly used as a means to integrate a firm's internal functions) and the increasing availability of the Internet (which is increasingly used as a major communication channel between firms) enable companies to adopt such a flexible and dynamic e-network strategy.

Next, managers should clearly understand key characteristics of three types of e-networks in terms of information flows control. While the information transmitted across a tree e-network could be easily intercepted or manipulated by any chain members because of its sequential nature of information flows, such a security problem can be eliminated or substantially mitigated in a net e-network, since all members can directly communicate with one another simultaneously. However, in the net e-network, conflicts concerning the ownership of information and accountability of its transactions may arise frequently, since a focal company has almost no control over the information exchange between other chain members (Kumar & van Dissel, 1996). In the case of a hub e-network, a focal company can use the e-hub to monitor all the information transmitted through a central platform. This may pose a threat to other members in that the focal company may exploit the collected information through the platform to seek its own interests rather than those of all chain participants. Another point that should be considered by managers in the adoption of high e-technology/high e-transaction e-networks is that establishing new electronic networks often entails redesigning physical supply networks and restructuring business processes internal and external to all chain members (Barratt, 2004).

Finally, it is often more difficult to manage highly automated electronic linkages in a large supply chain than a small counterpart. As argued by Raupp and Schober (2000), members in a small supply chain are likely to share common norms and attitudes, thereby enhancing their supply chain cohesion and ensuring efficient collaboration. Therefore, to establish a high e-technology/high e-transaction e-network in a small supply chain, the chain members can rely on implicit contractual arrangements to coordinate and regulate their interactions and information sharing through the e-network. In contrast, a large supply chain has such a complex e-network that there is always a probability that some members will have their direct or indirect competitors in the same chain. Consequently, these firms are often reluctant to release their sensitive information to others in the chain. Thus, to maintain a high e-technology/high e-transaction e-network, members should establish tight security mechanisms, mutual trust among members, and right alignment of roles and responsibilities toward common SCM goals, thereby preventing opportunistic behaviors of any member.

Future research, as an extension of the current study, should empirically examine the five research questions mentioned in the introduction section based on the proposed 2x2 e-network technology and transaction integration matrix, and the topology of e-networks. Since the study will explore a relatively new research area, the study of cases is deemed appropriate (Yin, 1994). For this study, multiple data collection methods, such as interviews and on-site observations, should be employed to triangulate the information collected. Interviewees are composed of top managers including IT and SCM directors from focal companies as well as their chain members, who are in charge of the design and/or implementation of e-networks. Several rounds of interviews need to be conducted with each of the interviewees through site visits or telephone calls. The collected data need to be coded and analyzed by following the procedure suggested by Miles and Huberman (1994): conducting within-case analysis (e.g., identifying each participant company's e-network transformation path) and then cross-case analysis (e.g., comparing and contrasting the e-network transformation paths adopted by different participant companies).

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Chapter 5.23

The Factors Influence Suppliers Satisfaction of Green Supply Chain Management Systems in Taiwan

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ABSTRACT

This study investigated user satisfaction when a new interorganizational information system (green supply chain management system; GSCMS) was introduced to a supplier by a leader in the Taiwan electronic industry. GSCMS providers, according to the requirements of the supplier network leader, trained the representatives of suppliers. All suppliers of two sample vendors (manufacturers of electronic products) were surveyed. Five putative influencing factors were considered: perceived usefulness, perceived ease of use, training, computer anxiety, and computer self-efficacy. We find four factors significantly affect user satisfaction. The results show that the training provided by focal vendors will influence the satisfaction of users. Next, the anxiety and uncertainty experienced by users decreases when they acquire more knowledge about the operation of the new GSCMS. Finally, user satisfaction can be increased by designing the functions and interfaces of a GSCMS in accordance with the user perceptions of usefulness and ease of use,

moreover, implications and suggestions are also discussed.

INTRODUCTION

European Union (EU) RoHS Directive relates to restrictions of the use of certain hazardous substances in electrical and electronic equipment, and states that from July 1, 2006, all electrical and electronic products imported into the EU must be proved not to contain six certain hazardous substances. The Ministry of Economic Affairs of Taiwan assesses that around 44 types of Taiwanese electrical and electronic products (which are exported to the EU) will be impacted by these restrictions. The directive will directly influence over 30,000 companies and annual trade of around NT$ 250 billion in Taiwan (i.e., 2.45% of the GDP), and indirectly influence over NT$ 400 billion annually (Epoch Times International, 2005). In order to facilitate the export of products to Europe, Taiwanese companies that export electrical and electronic products have embarked on implementing green supply chain management systems (GSCMSs) in order to conform to the new requirements.

Park and Krishnan (2005) point out that effective supply chain management can lower development and procurement costs, spur innovation, increase flexibility, and speed up product development. The function of a GSCMS is to ensure that all electrical and electronic products will conform to the relevant environmental controls before they are exported. The implementation of GSCMS by Taiwanese companies that export electrical and electronic products is therefore expected to be an important and necessary weapon to maintain their global competitiveness.

Generally, an electronic product was composed of a large number of raw materials that provided by many different suppliers, the formats of substances examination reports of each raw material may also be different. In the past, to obtain a substances report of an electronic product, manufactures (dominant network vendors) have to contact each raw material supplier individually and ask them to deliver their substance examination reports. Then, the focal vendors integrate all substance examination report of each raw material into a substance report of an electronic product manually. The whole process is complex, time-consuming, and easy to make mistakes to endanger the results. Besides, if there were any tiny changes on substance examination reports, the whole process will be run again.

GSCMS is a Web-based interface, which integrates with the bill of material (BOM) of dominant network vendor. This means that the GSCMS could easy obtain all the raw materials of an electronic product from the BOM. The vendors will set up an account and a password for each supplier that enables them to access the GSCMS. Once the supplier login the GSCMS, they will see a list of all raw material and requirements that they have to provide the substance examination reports and relevant information. The suppliers can upload or manage their substance examination reports online immediately. Besides, they can also search and trace all the substance examination reports status confirmed by the vendor. As long as the substance examination reports are in the valid period, they can be repeatedly used. Furthermore, GSCMS also save every substances examination reports, suppliers can download their former reports, and modify the formats to fit with other dominant network vendors' requirements. After all the substance examination reports of each raw material are entered by their supplier, the vendors can calculate the substance of their electronic products easily and accurately.

Dominant network leaders can use their superior bargaining power in an interorganizational information system to increase their competitive advantage as well as to secure supplier benefits by streamlining interorganizational processes. In Taiwan, a GSCMS is mainly constructed by focal vendors in the electrical and electronic industry, with suppliers generally not being invited to participate in its design and development. Thus, introducing a GSCMS into the supplier network will inevitably cause changes in organizational culture and in the behaviors of managers and data processing users at both the dominant network leaders and supplier sites (Soumi, 1994).

There is literature on supply chain management suggesting that a collaborative relationship is beneficial to achieving long-term competitive advantages (Faisal, Banwet, & Shankar, 2006; Hsu, 2005; Olorunniwo & Hartfield, 2001). Thus, implementing an effective win-win GSCMS requires both dominant network vendors and suppliers to accept and be satisfied with the system. The purpose of this study was to elucidate the satisfaction of suppliers who employ an interorganizational GSCMS under pressure from focal vendors. The influencing factors examined were perceived usefulness, perceived ease of use, training, computer anxiety, and computer self-efficacy. We chose two dominant network vendors (manufacturers of electronic products) and their suppliers' representatives as our research samples. The survey approach and statistical analyses were applied in this study.

The remainder of this article is structured as follows. Section 2 discusses the key factors that may affect user satisfaction with a supplier, and then describes the research model. Section 3 delineates the processes used for data collection, selection, and analysis. Section 4 presents and discusses the results from the study, and finally conclusions are drawn and suggestions for further research are presented in Section 5.

MODEL FACTORS

User satisfaction is an important indicator of the success of an information system. DeLone and McLean (1992) evaluate this through six indicators: the quality of the system, the quality of the information, the system usage, user satisfaction, individual influences, and organizational influences. In 2003 DeLone and McLean reviewed the successful information system models that were implemented during the intervening decade, and reasserted that successful information systems are those that promote user working performance and efficiency.

The parameters used to directly evaluate the success of information systems include the promotion of cost-effectiveness, productivity, accuracy of decision-making, and competitive advantage. However, at the time of the present study, the application of GSCMSs was still in its infancy, and data related to these parameters were difficult to acquire; thus, user satisfaction was chosen as an index to evaluate the success of a GSCMS. Indeed, this is consistent with many studies assessing the success of information systems based on user satisfaction (Igbaria, 1992; Ives, Olson, & Baroudi, 1983; Lee, 1995; Palvia, 1996; Whitten, 2004).

Acceptance behavior is considered to be influenced by a variety of factors, including individual differences, social influences, beliefs and attitudes, situational influences, and managerial interventions (Agarwal, 2000). The subjects in the present study were GSCMS representatives of suppliers, with the focus on the individual user level. Individual user's differences may influence user evaluations of a GSCMS in this environment. Moreover, because the GSCMS was in the introductory stage, system characteristics such as functions and interfaces had significant effects on user satisfaction. Training performances was another possible influencing factor due to the users having been trained by the GSCMS software provider. This study therefore investigated the factors influencing user satisfaction in three dimensions: system, individual differences, and training. The system dimension includes the perceived ease of use and perceived usefulness, and the factors of individual differences include computer self-efficacy and computer anxiety.

Perceived Usefulness and Perceived Ease of Use

At the time of this study, the application of GSCMSs was still in its infancy in Taiwan. At such an early stage, the most important question is what will affect user acceptance of the new type of system. The technology acceptance model (TAM) is frequently applied to predict user acceptance of new systems, where the perceived usefulness is defined as the beliefs of individuals that using a particular technology will enhance their working performance and efficiency (Davis, 1989). Hsu and Chiu (2004) believe that perceived usefulness is a critical factor to determining user satisfaction, because users can evaluate a new system directly after they have applied it. Hsu and Chiu also show that there is a positive relationship between the perceived usefulness and satisfaction of users with electronic information services. Zviran, Pliskin, and Levin (2005) demonstrates the presence of a strong positive correlation between perceived usefulness and user satisfaction, implying that perceived usefulness is one of the critical factors affecting user satisfaction with an electronic data processing system. Moreover, Bhattacherjee (2001) uses expectation confirmation theory to explore the relationship between user perceptions and satisfaction with online bank services, and declares that user satisfaction is influenced by user expectation and perceived usefulness after applying a new system.

GSCMSs represent new integrated systems for examining products that are being employed by suppliers. Before applying such a system, suppliers may assess its usefulness based on the existing processes used to examine products, with this being evaluated after the suppliers have actually used the new system. We believe the evaluation of the usefulness of a new GSCMS will affect user satisfaction. Thus, the first hypothesis is proposed as follows:

H1: *Perceived usefulness is positively related to user satisfaction with a GSCMS.*

In the TAM theory of Davis, perceived ease of use is defined as how little effort it required to use a particular system. Igbaria, Guimaraes, and Davis (1995) believe that the ease of use of an information system determines the user acceptance. Moreover, Mahmood, Burn, Gemoets, and Jacquez (2000) assert from a meta-analysis that the user perception of the value of an information system is positively correlated with its ability to support decision-making. Furthermore, Adamson and Shine (2003) point out that in a mandatory environment, perceived ease of use is the most important factor affecting user satisfaction.

The bargaining power is asymmetric when implementing a GSCMS, in that it is higher for focal vendors than for suppliers. Moreover, a GSCMS is only constructed by focal vendors; that is, without the participation of suppliers. The suppliers can only participate in transactions with focal vendors by adopting a GSCMS, and thus face a mandatory environment in such trading. From the research results mentioned above we can infer that in a mandatory environment, perceived ease of use will be one of the key factors influencing user satisfaction of suppliers who use a GSCMS. This leads to the following second hypothesis:

H2: *Perceived ease of use is positively related to user satisfaction with a GSCMS.*

Training

Amoako-Gyampha and Salam (2004) describe training as the transfer of knowledge about the basic framework and the skills needed to operate the information system to users. The aim of training is to facilitate the correct and smooth operation of an information system by its users. Training has been validated as an essential factor influencing the successful implementation of an information system (Saga & Zmud, 1994; Webster, 1998). The user satisfaction index of Bailey and Pearson (1983) evaluates user satisfaction with an electronic data processing information system, and Palvia (1996) asserts that in small companies training is a significant factor affecting user satisfaction.

Training helps users to familiarize themselves with the system (Saga & Zmud, 1994). In this study, the GSCMS was a new system for those suppliers who did not have the opportunity to participate in its development. Hence, the provision of sufficient training programs by focal vendors to users before implementing a GSCMS might reduce user resistance and increase user satisfaction. The third hypothesis is therefore stated as follows:

H3: *Training is positively related to user satisfaction with a GSCMS.*

Computer Anxiety

Individuals experience anxiety when one or more of their values are threatened, since such values form the foundation of their existence (May, 1996). When faced with a new information system, uncertainty regarding the cost, individual performance, and/or organizational effectiveness may induce anxiety in individuals. Fagan, Neill, and Wooldridge (2003-04) argue that anxiety is an unpleasant emotional reaction experienced by individuals in threatening situations, and the use of a computer appears to provide a fertile environment for such reactions. Heinssen, Glass, and Knight (1987) indicate that computer anxiety is an affective state where an individual feels fear and apprehension about interacting with the computer, and also anticipates negative outcomes from the interaction. Thus, there is a negative relationship between computer anxiety and utilization (Harrison & Rainer, 1996). The fourth hypothesis is thus as follows:

H4: *Computer anxiety is negatively related to user satisfaction with a GSCMS.*

Computer Self-Efficacy

The notion of self-efficacy comes from cognitive psychology, and refers to the perceived ability of an individual to perform a given task, which further affects behaviors and decisions (Bandura, 1986, 1997). When individuals believe that they are able to successfully perform a task, they tend to be satisfied with the outcome of their behavior (Bandura, 1986, 1997; Hsu & Chiu, 2004). Compeau and Higgins (1995) extend the concept of self-efficacy to the field of information technology, and propose the concept of computer self-efficacy that refers to individuals believing they are able to use computers effectively in any situation (Compeau & Higgins, 1995; Marakas, Yi, & Johnson, 1998; Venkatesh, Morris, Davis, & Davis, 2003).

Several studies have revealed that the confidence of individuals in using computers to perform specific tasks influences their acceptance of an information system. For example, Wu (1999) found that the computer self-efficacy and satisfaction with their computer ability were related in students after they had learnt about operating computers. Henry and Stone (1994) assert that computer self-efficacy affects user satisfaction in the use of medical information systems, and Henry and Stone (1995) demonstrate that computer self-efficacy is positively related to performance satisfaction. Hsu, Chiu, and Fu (2004) described how satisfaction with the utilization of the Web, Web self-efficacy, and user expectations determine the continuation of Web usage. Accordingly, computer self-efficacy is also regarded as an important factor for the evaluation of user satisfaction with a GSCMS. Therefore, the fifth hypothesis is as follows:

H5: *Computer self-efficacy is positively related to user satisfaction with a GSCMS.*

RESEARCH METHODOLOGY

Research Model

Drawing on the related concepts of user satisfaction discussed above, we proposed the research model shown in Figure 1 to identify the factors that affect user satisfaction with a GSCMS. The definitions and sources of the six constructs contained in the model are summarized in Table 1.

Instrument

The survey questionnaire contained three parts: (1) general demographic questions, (2) perceptual scales of each construct in the research model, and (3) one open-ended question. The demographic questions were used to collect information about the respondent's sex, age, level of education, working experience, previous experiences of using computers and the Internet, and similar experiences of applying other information systems. In the final part of survey, the respondent was free to write down any ideas about the GSCMS.

To investigate the factors that may affect supplier satisfaction with a GSCMS, the respondents were asked to indicate their degree of agreement with 42 statements, and the user satisfaction was measured by 4 items (see Table 3). The six constructs other than computer self-efficacy were scored on a 7-point Likert scale ranging from strongly disagree (=1) to strongly agree (=7). Computer self-efficacy was measured on a percentage scale comprising 10 increments, ranging from 0% (not at all confident) to 100% (totally confident). The different measurement scale of computer self-efficacy was due to follow its original development format.

Data Collection and Sample Analysis

The sample vendors of this study were two manufacturers of electronic products. The survey was conducted after two GSCMS training programs were run in 2005. The GSCMS adopted by both vendors were the same systems that implemented by a software Corporation. This Corporation is the market leader of GSCMS and holds 55% market share in Taiwan. Thus, it could be a case in point for this investigation. The paper-based questionnaires were distributed to 229 representatives of the suppliers, with the 164 returned questionnaires being examined by 4 researchers. Fourteen questionnaires were discarded due to the presence of many missing values, and hence 150 completed questionnaires were used in statistical analyses, representing a response rate of 65.5%.

Table 2 lists the demographic statistics of the sample. Among the 150 respondents, most of them (*n* = 104, 71.3%) were between 21 and 35 years

Figure 1. Factors affecting user satisfaction with a green supply chain management system, with the associated hypothesis numbers

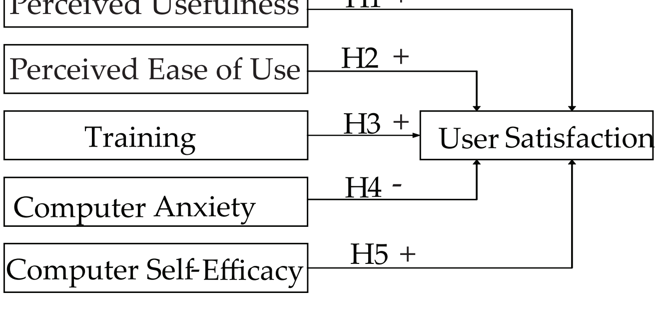

Table 1. Constructs, definitions, and sources

Construct	Definition	Sources
User Satisfaction	Users believe that an information system is able to fulfill their requirements.	Ives et al., 1983; DeLone and McLean, 1992
Perceived Usefulness	Users believe that using the system would enhance their working performance.	Davis, 1989
Perceived Ease of Use	Users believe that using the system would be free of effort.	Davis, 1989
Training	Instructing users to operate the information system correctly and smoothly.	Nelson and Cheney, 1987
Computer Anxiety	Users fear negative outcomes from using computers.	Heinssen et al., 1987; Fagan et al., 2003-04
Computer Self- Efficacy	Users believe that they are able to handle a computer well in any situation.	Compeau and Higgins, 1995; Marakas et al., 1998; Venkatesh et al., 2003

Table 2. Demographic characteristics of the samples (some frequencies do not sum to 150 due to missing data)

Characteristic	Category	Frequency	Percentage (%)
Age (years)	21–30	62	42.5
	31–35	42	28.8
	36–40	19	13.0
	41–45	16	11.0
	>45	7	4.8
Level of education	High school diploma	20	13.7
	Associate’s degree	71	48.6
	Baccalaureate degree	53	36.3
	Master’s degree	3	2.1
Working experience (years)	1	28	19.0
	2	43	29.3
	3	31	21.1
	4	17	11.6
	5	8	5.4
	6	20	13.6
Experience of computer use (years)	<3	8	5.4
	3, 4	11	7.5
	5–7	27	18.4
	8–10	42	28.6
	>10	59	40.1

continued on following page

Table 2. continued

Characteristic	Category	Frequency	Percentage (%)
Experience of Internet use (years)	<1	2	1.4
	1, 2	7	4.8
	3, 4	25	17.0
	5–7	44	29.9
	8–10	43	29.3
	>10	25	17.0
Experience of using a similar system (years)	Never	68	46.3
	<1	29	19.7
	1, 2	28	19.0
	3, 4	9	6.1
	5–7	3	2.0
	>8	1	0.7
Position	Manager	18	14.17
	Auxiliary Manager	7	5.51
	Chief of Section	17	13.39
	Sales	37	29.13
	Engineer	8	6.30
	Quality Assurance Staff	7	5.51
	Employee	33	25.98

old. The majority (*n* = 124, 84.9%) were educated to the associate's or baccalaureate degree level, and had worked for 1–3 years (*n* = 118, 69.4%). Most of them (*n* = 131, 87.1%) had used computers for at least 5 years, and had at least 5 years of experience using the Internet (*n* = 116, 76.8%). About half of the users had never used a similar information system previously (*n* = 68, 46.3%). In spite of our samples are representatives of suppliers, it is notable that among our samples, about 33% (managers, auxiliary managers and chief of section) were staffs of management level, and 1/3 (quality assurance staffs and employee) were the potential system users. The combination of our research samples was suitable for representing the suppliers' attitude toward the system usage.

DATA ANALYSIS AND DISCUSSION

Construct Validity and Reliability

First, an exploratory factor analysis was used to examine the construct validity. Principal components analysis with varimax rotation revealed that all items loaded on their expected constructs greater than the threshold loading of 0.45 for more than 150 samples (Hair, Anderson, Tatham, & Black, 1998). Cronbach's alpha coefficient was assessed to examine the internal consistency of the items in each construct, and exceeded the threshold of 0.6 recommended by Nunnally and Bernstein (1994) for all six constructs. As indicated in Table 3, all constructs in the model exhibited adequate construct validity and reliability.

Table 3. Reliability, descriptive statistics, and factor loadings

Construct (Sources) (Cronbach's alpha)	Measure	Mean	SD	Factor loading
Perceived Usefulness (Davis, 1989) (0.970)	Using the GSCMS in my job will help me to perform tasks quickly.	4.787	1.207	0.813
	Using the GSCMS will improve my working performance.	4.737	1.173	0.846
	Using the GSCMS in my job will increase productivity.	4.660	1.169	0.880
	Using the GSCMS will enhance my effectiveness in the job.	4.691	1.170	0.894
	Using the GSCMS will assist me to handle my job easily.	4.740	1.184	0.865
	The GSCMS is useful to my job.	4.927	1.136	0.810
Perceived Ease of Use (Davis, 1989) (0.956)	I believe learning how to operate the GSCMS will be easy for me.	4.739	1.028	0.846
	I can operate the GSCMS easily to complete my job.	4.620	1.054	0.879
	Interfaces of the GSCMS are clear and understandable.	4.704	1.067	0.825
	I can use the GSCMS skillfully.	4.507	1.035	0.859
	It is easy for me to become a skillful GSCMS user.	4.844	2.622	0.42
	I consider the GSCMS to be easy to operate.	4.676	1.020	0.812
Training (Amoako-Gyampah & Salam, 2004) (0.931)	The GSCMS training is comprehensive.	4.777	1.073	0.829
	My understanding of the GSCMS improved after receiving training.	4.765	1.083	0.821
	Training assists me to adopt the GSCMS with confidence.	4.698	1.041	0.753
	The length of training is adequate, and includes a detailed introduction to the GSCMS.	4.537	1.162	0.817
	Program instructors have sufficient knowledge to help me to understand the GSCMS.	4.805	1.109	0.816
Computer Anxiety (Heinssen et al., 1987) (0.950)	I am anxious about using computers.	2.704	1.432	0.909
	I am afraid that the computer will destroy my data if I press the wrong key.	2.822	1.409	0.897
	My fear of making irrecoverable mistakes makes me hesitant to use a computer.	2.510	1.423	0.945
	Computers scare me.	2.308	1.415	0.916
Computer Self-Efficacy (Venkatesh et al., 2003) (0.879)	I believe I can use the GSCMS to complete my job even without any instructions.	5.514	1.806	0.701
	With help, I can use the GSCMS to complete my job even when I encounter difficulties.	7.141	1.845	0.869
	I believe I can complete my job by using the GSCMS if I have sufficient time.	7.490	1.686	0.881
	I can complete my job by using the GSCMS if it contained a help systems.	7.280	1.755	0.875

continued on following page

Table 3. continued

Construct (Sources) (Cronbach's alpha)	Measure	Mean	SD	Factor loading
User Satisfaction (Wixom & Todd, 2005; Palvia, 1996) (0.879)	I am satisfied with the information that I receive from the GSCMS.	4.587	0.936	0.672
	I consider the GSCMS a success.	4.615	0.948	0.660
	I am satisfied with the GSCMS.	4.608	0.997	0.651
	I consider that the GSCMS fulfills my expectations.	4.538	0.988	0.633

We also examine the discriminant validity by comparing the square root of the AVEs (Average Variance Extracted) and the interconstruct correlations which indicates that more variance is shared between the construct and its indicators than with other constructs (Fornell & Larcker, 1981). Table 4 shows that the square roots of all the AVEs (i.e., the numbers on the diagonal) are greater than the correlations among constructs (i.e., the off-diagonal numbers), indicating satisfactory discriminant validity of all the constructs.

Hypothesis Testing

Multivariate regression analysis with the stepwise method was used to validate the hypothesized relationships among the research constructs. User satisfaction was set as the dependent variable, and the independent variables were perceived usefulness, perceived ease of use, training, computer self-efficacy, and computer anxiety. Multicollinearity was examined in the regression analysis using the variance inflation factor, which was below the common cutoff threshold of 10 (Hair et al., 1998) for all constructs, indicating the absence of significant multicollinearity.

Four factors, perceived usefulness (H1), perceived ease of use (H2), training (H3), and computer anxiety (H4) were significant ($P < 0.05$), indicating that they affected user satisfaction with the GSCMS. Training explained most variance (53.03%) of user satisfaction, next perceived usefulness explained 9.75% variance, and computer anxiety was negative effect that accounted 1.51%

Table 4. The square root of AVE values

Construct	Training	PU	PEOU	CA	CSE	SA
Training	**0.8857**					
PU	0.6032	**0.9333**				
PEOU	0.4989	0.5307	**0.8496**			
CA	-0.1334	-0.1357	-0.1472	**0.8373**		
CSE	0.1428	0.2218	0.2353	-0.3258	**0.8550**	
SA	0.7304	0.6920	0.5312	0.0109	0.1795	**0.9615**

Note:
1. PU=Perceived Usefulness, PEOU=Perceived Ease of Use, CA=Computer Anxiety, SA=User Satisfaction
2. The diagonal elements (in bold) represent the square root of AVE.

variance, finally perceived ease of use accounted 0.85% variance. However, computer self-efficacy (H5) was not significantly related to user satisfaction. A total of 65.14% of the variance (adjusted R^2) was accounted for user satisfaction. The hypothesis testing results were summarized in Table 5. The analysis results will be discussed in next section.

CONCLUSION AND DISCUSSIONS

This study reveals that perceived usefulness, perceived ease of use, training, and computer anxiety significantly affect user satisfaction with a GSCMS, with training being the most significant factor. GSCMSs are a new type of system for suppliers and not participating in their development. Thus, appropriate training programs can familiarize users with the functions and interface of a GSCMS so as to facilitate their operation of the system. This would also decrease the user perceptions of uncertainty when they encounter a new GSCMS, and lead to positive evaluations of the new system. The investigation by Yasin and Quigley (1994) into the viewpoints of chief executive officers on the effectiveness of information systems revealed that training decreases their anxiety about using information technology and helps them to understand the restrictions and potentiality of information technology. Moreover, William and David (1995) asserted that the training is strongly positively correlated with user satisfaction.

The EU RoHS Directive forces suppliers to search for a suitable new system that helps them to immediately conform to the regulations. The functions and interfaces of such a supply chain management system are expected to operate effectively and efficiently so as to meet the requirements of focal vendors. The results in perceived usefulness and perceived ease of use significantly influences user performance and satisfaction. As discussed earlier, the TAM has been widely and successfully adopted to predict the acceptance and usage of information systems. For example, Lin and Wu (2004) apply the TAM to the influence of end-user computing on small and medium enterprises in Taiwan. Haines and Andrew (1997) employ perceived usefulness and perceived ease of use in an exploration of the factors underpinning successful human resource management systems. Our research results similarly demonstrate the importance of user perceptions of usefulness and ease of use.

Table 5. Results from regression testing

Independent Variable	Dependent Variable (Satisfaction)			
	Standardized Coefficient (Beta)	Significance	Variance Inflation Factor	Correlation
H1: Perceived Usefulness	0.326	0.000 *	1.770	Yes
H2: Perceived Ease of Use	0.127	0.035 *	1.505	Yes
H3: Training	0.468	0.000 *	1.693	Yes
H4: Computer Anxiety	–0.141	0.005 *	1.029	Yes
H5: Computer Self-Efficacy	0.057	0.277	1.180	No
R^2	0.661			
Adjusted R^2	0.651			

*Note: *P < 0.05*, ***indicating correlated factors***

The results also show that computer anxiety is one of the significant factors affecting user satisfaction that employ a GSCMS. When adopting a new system, users will encounter both managerial and procedural changes. People instinctively tend to resist changes due to the associated anxiety. However, in our study we found that the level of suppliers had an average under 2.822 on the 7-point scale. The association between computer anxiety and user satisfaction shows that a lower computer anxiety brings higher supplier satisfaction.

Previous studies have found that computer self-efficacy is positively related to user satisfaction (e.g., Fagan et al., 2003-04), whereas in the present study we found no such relationship. According to Bandura (1997), self-efficacy improves after a new technology has actually been used, even when the users initially doubt their own ability to do this. Guskey and Tschannen-Moran (1988) also suggest that the introduction of a new technology can initially have a negative impact on users, but that their self-efficacy will improve gradually as they become accustomed to the new technology. Although computer self-efficacy did not have a significant effect on user satisfaction in our study, it is thought to affect user satisfaction after sufficient training and practical operation.

The EU is one of the most powerful economic entities in the world, and is also the main export area for Taiwan. Ever-increasing eco-awareness will mean that strict restrictions such as the RoHS Directive will increase the importance of GSCMSs in assisting suppliers. The results from this study also show that training is the most significant factor influencing supplier satisfaction with a GSCMS. Therefore, both the focal vendors and the system designers should provide training that is sufficient to increase user satisfaction of suppliers. Moreover, the results indicate that usefulness and ease of use are fundamental to the success of a system, and hence system designers must understand user requirements and the practical problems that they will encounter. With regard to computer anxiety, previous studies have indicated that people who are familiar with computers show more confidence and feel less anxiety when using computers (Coffin & MacIntyre, 1999; Loyd & Gressard, 1984;). Hence, this study argues that training is essential in order to decrease computer anxiety and promote satisfaction with a GSCMS amongst representatives of suppliers.

Finally, the use of GSCMSs is still in its infancy in Taiwan. The problems or the implications that may occur after their adoption for suppliers are not addressed in present research. Future studies should aim to develop managerial and practical solutions to all the related problems. Besides, the condition and structure of industry in Taiwan may be specific to our study, and it should be careful to generalize the research results to other countries.

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Chapter 5.24

SHRM Portals in the 21st Century Organisation

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INTRODUCTION

The importance of people to organisational success has been recognised; the implications of this for human resource departments forms the basis for the content of this article. The ways in which information technology has been used to support changes in the human resource function are discussed, leading to an exploration of the role of strategic human resource management portals. The content of strategic human resource management portals is then outlined, and covers the range of information they currently provide and their future role. Finally, issues relating to implementation are addressed. The need for human resource practitioners to develop a greater understanding of technology and its potential benefits is discussed. This article concludes by reiterating the uses made of strategic human resource portals and by acknowledging the need to continue to strive for improvements in the implementation of IT systems.

PEOPLE IN THE 21ST CENTURY ORGANISATION

The resources and capabilities that have the potential to provide an organisation with competitive advantage include financial, physical, and human assets. In this context, human resources include the people and their experience, knowledge, judgement, and wisdom (Barney, 1995). The move to a knowledge and service economy has created a range of changes in organisations; these changes have impacted all areas of the organisation, including the human resource (HR) function. Knowledge work and service provision are highly people-dependent, and hence the importance of people to the success of the organisation has increased with this change. Today's managers rely heavily on people for achievement of their goals; they recognise that people have become their greatest competitive weapon.

Whereas the primary focus of the past has been on managing financial and physical assets, the recognition that staff, and their collective knowledge, have become important assets will require executives to pay more attention to managing people in the coming years (The Boston Consulting Group, 2005). Those entrusted with responsibility for people management within organisations—the HR department which sets the HR strategy and line managers who play a major role in implementing the strategy—now recognise the contribution of HR to organisational performance (Barney & Wright, 1998; Brockbank, 1999; Ramlall, 2003). To add strategic value, HR departments have been asked to develop strategic partnerships (Lawler & Mohrman, 2003), and to become strategically proactive (Brockbank, 1999). This is now happening (Brockbank & Ulrich, 2005).

TECHNOLOGY'S ROLE IN HR MANAGEMENT

Information technology (IT) has an important role to play in strategy formulation and implementation (Powell & Dent-Micallef, 1997), in supporting improved knowledge management processes, in customer relationship management through customer knowledge management (Bueren, Schierholz, Kolbe, & Brenner, 2005), and in organisation-wide financial performance reporting capability. Considerable effort and expense has gone into developing technology-supported financial management systems, client data bases, and data warehouses, with access to a broad range of information provided through purpose-specific portals. The HR function has also been quick to integrate technology into its operations, with the payroll process being one of the first to be automated (Lengnick-Hall & Moritz, 2003).

The HR professional's role is changing in response to changes in the workplace. In the past, the personnel department's role centred on recruiting, selecting, inducting, and paying employees. With the increased importance of people to organisational success, skills shortages as a result of the aging workforce, especially in developed countries, and reduced numbers of young people entering the workforce, HR professionals' services are required for a different range of tasks (Brockbank & Ulrich, 2005). Today's HR staff are involved in organisation-wide strategic planning. Their strategic HR plans no longer merely support achievement of organisational goals set by others; HR practitioners are developing plans to drive organisational success. This strategically proactive approach to HR (Brockbank, 1999) acknowledges that transactional HR activities must still be performed. Staff must be paid, records kept, policies and procedures developed, and HR departments must ensure legal compliance and reporting in relation to income tax, superannuation, and health and safety. But many of these operational tasks are now performed using human resource information systems (HRISs).

Using HRISs to provide employees with the information they require, through an employee self service (ESS) portal, the dependence on HR administrative officers for information provision is reduced. HRISs, especially when part of an enterprise resource planning system (ERP), are being accessed by a range of people for a variety of purposes. HR managers use the information stored within the HRIS, combined with that from other management systems, for strategic planning. HR officers use the system to store records, generate reports, and ensure legal compliance. Supervisors use these systems to track employee and unit performance, to measure their employees' productivity, to compare sick leave figures with industry standards, or to compare performance with that of other units within the organisation.

HR Portals

Strategic human resource management (SHRM) portals, like ESS portals, provide access to information for a specific group of users. SHRM and ESS portals could be seen as two levels of access to HR-related information with some organisations having one HR portal with two or more levels of access. To distinguish between provision of information to employees and access to information for strategic, organisation-wide planning, we have broken HR portals into two types: those providing information to employees (ESS), and those providing a higher, strategic planning level of information to senior and executive level staff (SHRM).

SHRM PORTALS AND ORGANISATIONAL PERFORMANCE

SHRM portals usually form part of an HRIS which, in turn, may be integrated within an ERP of which HRISs have in recent years become a subset. ERPs integrate information from a diverse range of areas and applications within an organisation (Ashbaugh & Miranda, 2002).

SHRM portals support HR managers and others involved in organisation-wide planning within organisations by providing access to information stored in an HRIS, or that contained in an ERP, for strategic planning.

Since the 1990s, it was predicted that improved HR systems would result in improved organisational performance, and this link between HR management practices and organisational performance continues to be acknowledged (Bowen & Ostroff, 2004; Guest, Michie, Conway, & Sheehan, 2003; Wright, Gardner, & Moynihan, 2003), though some suggest more research is required to fully explain this link (Paauwe & Boselie, 2005; van Veldhoven, 2005). Carmeli and Tishler (2004) found that intangible organisational elements, including human capital and culture, are positively associated with organisational performance.

HR activities, or practices which support high performance HR systems, are increasingly being incorporated in SHRM portals; those which support high performance HR systems. ESSs can free HR professionals of operational activities, enabling them to introduce high performance work practices. SHRM portals provide strategic planning information for HR and other senior managers, including line managers to whom an increasingly large range of HR activities have been devolved (Kulik & Bainbridge, 2005). Devolution further frees HR specialists for their more strategic role.

WHAT SHRM PORTALS DO

Portals enable information from multiple sources to be pooled, organised, and distributed through the gateway that the portal provides. SHRM portals enable access by a range of users to information at a variety of predetermined levels. When linked to other organisational information systems, HR information may be combined, for instance, with productivity, sales, and other information to aid high level decision making.

Supporting Devolution of HR Activities to Line

Devolution of HR activities to line means supervisors now conduct many HR activities formerly carried out by HR personnel. Recent research found line managers are now responsible for a range of day-to-day people management activities, such as managing performance, disciplinary action, coaching, and promotion decisions. However, HR's desire to reduce their involvement in a range of HR activities was not matched by line management's enthusiasm for assuming responsibility for these activities (Kulik and Bainbridge, 2005).

While line managers may feel their current role is complex and demanding enough without accepting responsibility for an increasing range of HR activities, research demonstrates that when HR staff are freed from day-to-day people management activities, they are better able to contribute to strategic planning and this, in turn, has been found to lead to improved organisational performance (Lawler & Mohrman, 2003).

Freeing HR Staff for Strategic Planning

There has been a gradual shift toward a more strategic role of HR professionals in the US, and in 2005, Australian HR managers felt they were performing a more strategic role (Sheehan, Holland, & DeCieri, 2005), although as recently as 2002, HR was reported to still be playing an administrative support role in organisations (Michelson & Kramar, 2003). Attempts were being made to devolve administrative tasks to line management using technology to support this process. Many saw IT and its various applications as having the potential to free HR professionals from transactional tasks enabling them to assume the more strategic role (Shrivastava & Shaw, 2003). This automation of transactions using e-HR is seen as the second or higher-level of use of technology to support the HR function because it goes beyond providing only information. It is this level of e-HR that is predicted to transform the HR function by liberating it from its operational role so it may become more strategic. This level of use will lead to nonstrategic HR tasks being performed faster and cheaper, while involving HR staff less in the process (Lengnick-Hall & Moritz, 2003). The study which found Australian HR managers believe they are playing a more strategic role in their organisations did not consider the impact IT may have had on this change. However, when contrasted with Michelson and Kramar's (2003) findings only two years earlier, it is possible that a recent increase in the use of IT to support the HR function has helped bring about this change.

Technology to support initiatives to devolve HR activities is important if organisations are to achieve their goal of increased success through improved people management. As well as reducing HR's transactional tasks, technology can provide line managers with the information they require to perform their increasing range of HR activities through SHRM portals. It is important that line managers can access the information they require to successfully perform their new role.

Strategic Workforce Planning

Skills shortages across developing countries as a result of the aging population present challenges for organisations wishing to succeed in the global marketplace. Strategic workforce planning requires input from a range of sources, something a SHRM portal providing access to HR and other organisational information can provide by linking a diverse range of organisational plans for product changes or service quality improvements to enter new markets, or to compete in new industry sectors.

Information on university enrolments, especially in highly specialised skills areas, is required for good strategic workforce planning. SHRM portals can also be linked to research conducted outside the organisation, which is vital for good planning.

Assisting Cultural Change

A global organisation operating within the automotive, aeronautical systems, space, electronics, and information systems fields, TRW experienced challenges in 2001 as a result of a general downturn in their markets. With two thirds of their business being within the highly competitive/low profit margin automotive industry, turning around their performance was not going to be easy. Pressure to improve shareholder value combined with a change in leadership led to TRW deciding to create systems to support what could be viewed as a cultural revolution within their organisation (Neary, 2002).

TRW developed six company-wide behaviours, to be incorporated in individual performance plans, to enable them to turn around their organisation's performance. To succeed, they needed to develop one uniform method of performance development and review for their almost 100,000 employees (Neary, 2002). The new leadership of TRW put together a team of IT experts, HR staff, and representatives from all business units to develop a Web-based employee performance and development process (EP&DP) to incorporate measurement of the six identified behaviours. The diverse team established guiding principles to ensure that the new system could be in place in just four months.

TRW benefited greatly from the new system. Good design principles ensured the system met the organisation's needs, and being user friendly paid off. Organisation-wide benefits included ensuring the six new behaviours were incorporated in all employees' performance reviews. The EP&DP enabled identification of company talent from around the world, or specific needs such as location of a degree-qualified HR manager with Chinese language skills, in minutes. The system provided wide-ranging and valuable benefits for TRW. In the second year of use, TRW claimed they were more uniformly managing "the day-to-day operations and the long term vitality of the company" (Neary, 2002, p. 498).

An example of IT supported HR systems driving change and improving organisational performance, the EP&DP enabled managers to access information to support cultural change, improve organisational performance, and manage talent. SHRM portals which incorporate access to employee performance data and enable it to be combined with other performance data (e.g., production, sales, or finance) supported change and improved organisational performance.

Supporting Knowledge Sharing

A global communications company, Ericssons, implemented an IT-supported competence management system (CMS) as part of their HR management system. Competence management ensures that both the employees and the organisation have sufficient competencies to support achievement of the organisation's objectives (Nordhaug, 1993). Ericsson's CMS included a register of competence detailing employee qualifications and experience; it enabled identification and mapping of present and future target competence levels and analysis of competence gaps across the organisation. It contained records of the outcome of HR discussions, and stored and tracked competence development actions, including training. It supported Ericsson's knowledge creation efforts by both locating "experts and stimulating emerging communities of knowing" (Hustad & Munkvold, 2005, p. 78).

Ericssons found the design and development of the CMS challenging, but the potential benefits of enabling access to competence resources worldwide, combined with the ability to link experts enabling knowledge sharing to increase innovation and stimulate new learning processes, made the challenge worthwhile. Although Ericssons is a technology savvy organization, it did confront challenges in gaining commitment to the new system and in encouraging the necessary change in employee mindsets to use the system to build individual competence (Hustad & Munkwold, 2005).

HRISs can support improved organisational performance through individual employee performance improvement. The ability to access information stored in the CMS, using the SHRM portal, is a vital element in the success of such a project. The information contained in the CMS and the linking of expertise for organisational learning have the potential to provide considerable benefits if the issues of planning, design, and implementation are managed to deliver a system which will be used to its full potential.

FUTURE ROLE OF SHRM PORTALS

SHRM portals will enable the combination and manipulation of a range of information from across the organisation to support overall organisational planning. By providing direct comparison between performance ratings, career aspirations, training completed, and qualifications and experience, selection of suitable employees for vacancies will be streamlined. Much of the increased use of SHRM portals in the future will involve extending the number of activities performed, increasing the range of information available and expanding the level of integration of HR and other organisational information.

Moving beyond HR-related information to production, financial, sales, logistics and distribution, and even research and development plans, planning for people can be linked to developments across the organisation, all geographic locations, and business units.

Health and Safety

Using the SHRM portal to record and analyse near misses and minor accidents, not just those where injuries or equipment damage are sustained, information will be available to guide the redesign of work processes, to inform changes in OH&S procedures, and to highlight OH&S training needs.

Flexible Work Practices

SHRM portals can combine and analyse information from a broad range of sources. To attract and retain quality staff, SHRM can assist innovative job design. Redesign of managerial roles can design challenging senior positions which are worked part time, perhaps linked to phased retirement. A senior manager may work only four days a week by isolating a range of tasks and responsibilities to be taken over by another member of staff. This increased responsibility may form part of a formal mentoring program, tracked through the HRIS, details of which may be accessed via the SHRM portal. The SHRM portal can provide information to those taking on new roles, and support planning for the flexible work arrangements.

Linking HR and Organisation-Wide Information

Linking HR information to other organisational information will support overall firm and HR specific strategic planning. For good people management, understanding how training, development, coaching, flexible work practices, extended leave programs, and a range of innovative HR initiatives are impacting the wider organisation will be important. Analyses can be made of staff turnover numbers or retention of key staff, absenteeism can be tracked, accident rates monitored, and the impact of changes introduced in response to analysis of near misses evaluated. Changes in employee engagement levels across areas of the organisation can be tracked and productivity and profit linked to the introduction of people management programs.

This information will be made accessible to managers through the SHRM portal.

Implementation

Planning, design, and implementation of SHRMs can be complex and require considerable cooperation and discussion between IT experts, senior HR managers, and executive management to identify the range of information required, uses to be made of the information, and levels of access required. Success will only come after considerable time investment by a range of personnel, making it a costly process, but one which has the potential to bring considerable benefits to the organisation.

Technology Acceptance

HR professionals need to learn how to communicate their needs to IT professionals. In turn, IT professionals have to develop an understanding of the HR function so that they can better communicate with and address the needs of HR staff. User acceptance will present issues to be considered in the design and implementation of sophisticated HRISs and their access points, ESS and SHRM portals. The change of management strategy, including a comprehensive implementation plan, will be required to positively influence portal acceptance across user groups (Ruta, 2005).

The aim of SHRM portals is to provide management with a range of information to guide strategic planning; hence, the SHRM portal will need to support the generation of a range of reports combining data from multiple sources for planning purposes. Benefits will only be gained when users are willing to change the way they have obtained information in the past. Of importance here is the often held view that HR professionals lack technology literacy and will not be able to communicate needs effectively to technology staff to direct the design process. Additionally, the reticence of HR professionals to use IT may influence the level of acceptance by other users because technology use will not be strongly driven by the commissioning department (HR).

HR Professionals

HRM has often been characterised as a “soft” or nontechnical profession (Townsend & Bennett, 2003). Initially, managerial resistance to such initiatives as SHRM portals was based on a fear of becoming displaced by IT. The “taking over” of HR tasks by line managers was also viewed as a threat (Lepak & Snell, 1998). However, these fears have been replaced by an enthusiasm to take on the new strategic role required of HR in today’s organisation.

IT to support the transfer of operational HR processes to technology requires of HR staff a new set of capabilities in order to perform their new role and to carry out parts of their old role in different ways (Lawler & Mohrman, 2003). This change includes the need to have HR professionals who can work with IT specialists to develop appropriate solutions (Ulrich, 2000).

If any investment in IT is to deliver value, the technology must be adopted and properly used. Only some organisations gain the full potential value of their IT investments. This may be for a variety of reasons; users may not have learned how to use technology or it may be because managers have not learned how to manage its benefits. A lack of senior executive use of IT applications means they do not experience first hand the benefits IT offers, and this leads to attitudes remaining unchanged (Pijpers & van Montfort, 2006). Successful implementation of a SHRM portal will include making strategic planners in the organisation aware of the benefits the portal can provide, and conducting training on how to use the portal to advantage. If senior HR managers use the SHRM portal, it will help to create a level of acceptance throughout the organisation.

E-business is creating new roles for HR, as well as offering creative ways of changing its role to provide increased competitive advantage by freeing HR of operational tasks. Using Web-based technologies to support the HR function will require HR and IT to form alliances to develop integrated solutions to business problems. By ensuring IT has the people and processes in place to provide systems to support decision making and service delivery, HR assists IT and IT, in turn, provides HR with “the technological infrastructure to more efficiently and effectively deliver HR” (Ulrich, 2000, p. 20).

This transformation of HR into e-HR will require HR professionals to take on the challenge of developing new skills to take advantage of the opportunities it offers. HR professionals will continue to require behavioural and strategic competencies, but they will need to add to these technological competencies (Hempel, 2004).

CONCLUSION

The increasing involvement of HR managers in the strategic planning team within organisations, and the increased use of HR information by other members of the planning team, requires new and different technology to support the planning process.

By integrating HR information with that in organisation-wide ERPs, SHRM portals support devolution of HR enable transactional HR activities to be conducted via technology, freeing HR staff for strategic planning, and support report generation for strategic planning.

To ensure that the technology delivers the gains desired of it, implementation needs to address issues of technology acceptance and use. With HR departments commonly staffed by people from nontechnology backgrounds, this raises issues which need to be addressed as part of the change program.

SHRM portals will increasingly in the future drive HR strategy implementation within organisations. They will provide information for management and strategic planners. IT/HR partnerships to plan and manage the crucial implementation stage will be required if organisations are to achieve the benefits available from SHRM portals (Ruta, 2005). The benefits that organisations might gain from SHRM portals will be limited by the quality of the planning, design, and implementation stages (Shrivastava & Shaw, 2003).

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KEY TERMS

Devolution of HR to Line Management: Handing over the responsibility for the conduct of a range of HR activities to immediate supervisor.

E-HR: Using the Web to deliver HR activities in much the same way as e-business uses the Web to conduct business.

Employee Self Service: A portal which provides access to strategic information from a range of areas in the organisation, including HR, for strategic planning purposes. Using technology to enable employees to gain HR information without consulting HR staff.

Enterprise Resource Planning Systems: Systems which have the capacity to integrate information from a diverse range of areas and applications within an organisation.

Human Resource Information System: An information system designed to support the organisation's HR function. It is used to store and to distribute HR-related information, and to communicate with employees.

Human Resource Portal: A means through which HR information and HR applications can be accessed Strategic HRM portal

Strategic Planning: Devising the way in which an organisation will go about achieving its goals.

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Section VI
Managerial Impact

This section presents contemporary coverage of the managerial implications of strategic information systems. Particular contributions address firm performance as it relates to IT strategy, the nature of knowledge in the IT workforce, and the effectiveness of strategic implementation. The managerial research provided in this section allows executives, practitioners, and researchers to gain a better sense of how strategic information systems can inform their practices and behavior.

Chapter 6.1

IT-Enabled Strategy:
Implications for Firm Performance?

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ABSTRACT

The rapid evolution of IT has enabled new organizational capabilities to manage knowledge and information. Given this evolution, IT systems for enabling the acquisition, processing and dissemination of knowledge may present unique opportunities, if effectively leveraged, for firm competitive capabilities. This chapter examines some of these uses of IT; offers a framework to view firm activities as knowledge Inflow, Intraflow and Outflow processes; and explores possible performance implications of some potential IT-enabled capabilities. Such IT enablement challenges some existing views of strategic management theory and suggests that theory may need to be reexamined and extended to handle some implications arising from advances in IT systems. We explore potential implications of IT-enabled capability and argue that through adopting, integrating and effectively leveraging these capabilities, firms may have the opportunity to enhance their competitive advantages and performance.

INTRODUCTION

Information processing and knowledge management (KM) systems have seen a significant evolution over the past decade. As management research from a knowledge-base view (KBV) links the competitive advantage of an organization to individual tacit knowledge (Kogut & Zander, 1992; Grant, 1996), what impact has this rapid evolution in IT capabilities, and the resultant increase in organizational abilities to now codify and more effectively acquire, store and transfer knowledge, had on firms and their performance? These changes in management information systems (MIS) capabilities may also provide cause to reexamine some of our theories and accepted views of the bounds of organizational capabilities based upon knowledge. Specifically, if a firm's KM systems are significantly augmented in terms of their capabilities for data acquisition, codification and combinative capabilities, what are the theoretical implications of the sustainability of competitive advantages and firm performance based upon such knowledge? These are the issues and implications explored in this chapter.

In this chapter, we explore IT-enabled means of acquisition of data and information, and systems for conversion of information into actionable knowledge. This is conducted through exploration of the potential impacts of KM technology in combination with variations of IT systems infrastructure. We are specifically interested in exploring the potential implications for firm performance through mediating or moderating relationships of IT resources on firm knowledge flows. We discuss how IT systems may enable organizations to more effectively acquire, codify, aggregate and allocate competitive knowledge. Through this discussion, we review common competency-based perspectives of strategic management. From this theoretical basis, we develop propositions regarding whether IT-enabled knowledge capabilities should lead to increased performance or a corresponding decrease in the firm's ability to sustain competitive advantage on that knowledge. To facilitate this, the chapter provides a brief review of research on related IT applications and platforms in the context of organizational KM processes, and then explores theoretical implications of IT-enabled KM on firm competitive advantage and performance.

ISSUES, CONTROVERSIES, PROBLEMS

The Evolution of IT-Enabled KM Capability

IT knowledge systems have evolved significantly over the past decade. These include a wide variety of approaches, which range from simple e-mail and groupware collaboration tools to extensible markup language (XML)-based workflow management systems, knowledge repository networks and aggregated knowledge portals, to complex Online Analytical Processing (OLAP)-based customer data warehouse (CRM) and data mining/business intelligence (BI) and alerting systems. Regardless of the technical system, common threads exist across IT platforms and applications. Among current and recent generational systems, these include relational database central processes, XML- and Java-based open architectures, and fairly transparent workflow management (WFM) capabilities. These solutions are significantly advanced from previous systems of only a few years ago, and the MIS field has been actively attempting to address limitations of the models underlying these technical systems.

Current generational databases have benefited from extensive theoretical advances in the areas of database design (Dey, Sarkar & De, 1998; ; Storey, Chiang, Dey, Goldstein, & Sundaresan, 1997; Storey & Dey, 2002) and database design cost-benefit considerations (Dey et al., 1998). Further, current-generation databases are more capable of handling entity matching and semantic heterogeneity, which is a key issue facing organizations with both cross-generational legacy technology and in the management of knowledge inflows. Object-oriented database approaches (Dey, Sarkar, & De, 2002), as well as significant advances using decision theoretic (Dey et al., 1998, 2002), and algebraic and probabilistic solutions to these issues (Dey & Sarkar, 1996, 2000) have also been advanced, which may benefit current and future generation databases. Therefore, the existence of prior- or current-generation databases may significantly moderate the effectiveness of current-generation IT, such as CRM systems, on the organization's ability to acquire information and generate knowledge (customer analytics), as well as create knowledge outflows to improve sales (such as sales force automation and targeted marketing campaigns). For example, based on these database system advances, we can assume that CRM systems built upon modern CDW or relational database management systems (RDBMS) systems should be more effective for KM capability than implementations less effectively integrated to online transaction processing (OLTP), or CRM implementations on older non-RDBMS systems.

IT systems also deal with the information and business process workflows that underlie the organization's activities. Advances in this area from the MIS literature include extensive analysis and conceptual introductions of modern workflow management systems (WFMS) (Bussler, 1999; Georgakopoulos, Hornick, & Sheth, 1995), as well as significant improvements in the codification and modeling of workflows (Aalst, 1998; Basu & Blanning, 2000). Of particular interest to management scholars may be findings that inter-firm and cross-organization interactions may also rely heavily on the seamless, transparent and automated exchange of information facilitated through inter-organizational workflow systems that have been advanced in recent MIS literature (Aalst & Kumar, 2003; Klingeman, Wasch, & Aberer, 1998). Additional research indicates that knowledge flows are also dependent upon open-architecture solutions and e-service platforms to facilitate inter- and intra- workflows via the Internet as evidenced through discussions of exchange and XML-based solution propositions in recent literature (Basu & Kumar, 2002; Casati & Shan, 2001).

These IT advances in the workflow area may be quite timely. Inherent uncertainty in the exogenous, real-world environment forces business decisions to be made with uncertain data and incomplete information. IT-enabled knowledge systems, based on these improved databases and workflow systems, may be utilized to provide actionable knowledge to more effectively support managerial decision making under prevalent conditions of uncertainty. These and other advances in database and workflow technology have and will enable an organization's knowledge acquisition, codification, analysis and transfer capabilities. This, in turn, may significantly enable more effective knowledge-based competitive advantages for some organizations. Further, organizations not utilizing such current-generation KM technology may likely have redundant data collection activities, difficulty sharing information between groups within the firm, and difficulty enforcing and standardizing workflows. Therefore, current-generation KM systems may be fairly reliant on the presence of current- or recent-generation WFMS-type systems to facilitate KM capabilities. However, to make more sense of the potential implications of these KM technology advances, we need to first explore the theoretical mechanisms through which they may contribute to the firm.

IT-Enabled Capability and Strategic Management Theory

What impact have these advances in IT capability had on firms' abilities to manage knowledge, and what implications might a continuing advance of IT-enabled knowledge capabilities hold for strategic management theory? Specifically, what are the theoretical implications of a firm's ability to now more effectively acquire, process, store and transfer knowledge on the sustainability of competitive advantages and firm performance based upon such knowledge?

The management field's current theoretical treatment of knowledge may perhaps be best viewed through common competency-based theoretical perspectives, such as the RBV and KBV of the firm (Barney, 1991; Grant, 1996; Kogut & Zander, 1992; Wernerfelt, 1984). In these views, RBV deals with the potential for a firm's resources to generate sustained competitive advantage if the resource is: (1) valuable; (2) rare; (3) imperfectly imitable; and (4) non-substitutable (Barney, 1991). Whereas KBV, as an outgrowth of resource-base view (RBV), treats individual or organizational knowledge as a distinctively unique resource that is the true source of sustained competitive advantage in organizations (Grant, 1996; Kogut & Zander, 1992).

Extensions of KBV have argued that the ability to transfer knowledge within the firm is a critical component of an organization's ability to build competitive advantage and appropriate rents from internal knowledge resources (Szulanski, 1996). While such competencies and/or knowledge are ideally imperfectly imitable by a firm's competitors, they are also then by nature difficult to imitate internally, and may therefore represent a limiting factor on a firm's competitive advantage if methods of effective intra-firm knowledge transfer are not institutionalized or technically enhanced. Therefore, increased adoption of modern IT-enabled KM systems could facilitate an increase in organizational knowledge flow. Further, organizations adopting these IT-enabled knowledge systems could, therefore, potentially experience increased performance. However, where, when and how should IT systems align with an organization's knowledge processes to potentially result in such IT-enabled capabilities?

SOLUTIONS AND RECOMMENDATIONS

A wide body of literature from various academic disciplines has attempted to explore and address issues of knowledge acquisition and learning processes within organizations. Some common historical perspectives may treat knowledge as a specific static construct that must be uniquely constructed. More recent research advocates examining KM from an organizational capabilities perspective (Gold, Malhotra, & Segars, 2001). This suggests that knowledge infrastructure should consist of technology as well as a supportive organizational structure and culture to effectively facilitate acquiring, processing, applying and protecting knowledge (Gold et al., 2001).

Along these lines, we suggest that one possible solution approach to better understand how IT may enhance or enable organization capabilities may be to adopt the perspective utilized in the KBV (Grant, 1996; Kogut & Zander, 1992). This perspective views knowledge as more of a complex creation evolving from data and information. KBV perspectives of KM focus on issues of how knowledge is acquired, where knowledge is stored, how learning takes place and how knowledge is transferred. Despite extensive work on knowledge and organizational capability topics, few studies have specifically or effectively addressed knowledge acquisition and transfer processes within an organization in terms of their effects on organizational performance metrics.

Organizational KM Processes

As recent work (Argote, 2000) rationalizes that technical systems may be one of the most effective means of acquiring, storing and transferring knowledge between individuals and organizations, this chapter addresses this gap by examining firm performance implications of organizational knowledge processes supported through such systems. To facilitate this approach, we design a simplified taxonomy to group organizational knowledge processes and their related IT systems into three categories based on the type of knowledge process. This simple typology is applicable to either information or knowledge flows through the organization. It consists of knowledge flows into the organization (*Inflows*), knowledge flows within the organization (*Intraflow*) and knowledge flowing out of the organization (*Outflows*). The knowledge flow typology is depicted in Table 1.

Organizational Knowledge Inflows

Organizational knowledge inflows consist of data and information entering the organization from multiple external sources and channels, which the organization can convert to actionable knowledge.

Table 1. Knowledge flow typology

	Inflows	**Intraflows**	**Outflows**
Knowledge Management Process	Knowledge search and acquisition	Knowledge codification, aggregation, recombination and intra-firm transfer	Knowledge allocation, deployment, inter-firm transfers and leakage
Information Source and Flow	External information and new hires	Internal existing data and employees	Organization
Technical System Support Applications	External databases, CRM, OLTP, open and proprietary Internet, extranets and CI systems	Internal databases, OLAP, WFMS, ERP, ELS, BI tools, Intranets, collaboration tools, e-mail/exchange systems	INET, B2B and business-to-consumer (B2C) exchanges, hubs, information security, cross-organizational WFMS and extranets

Inflows can also consist of external knowledge entering the organization through the acquisition of new individuals or interactions with individuals external to the organization.

IT systems supporting knowledge and information search and acquisition activities include external open and proprietary Internet resources and databases, online transaction processing systems for the collection of customer data, CRM systems for the analysis and handling of customer information flows to the organization, and competitive intelligence (CI) tools for acquiring and analyzing competitive information. While these systems tend to be more current, the presence of previous-generation workflow management systems as well as legacy databases and related OLTP systems in the organization may complement the effectiveness of these systems.

Therefore, leveraging a KBV perspective of treating acquired information or knowledge as a resource, and utilizing such enabling technologies to enhance the knowledge acquisition (*inflow*) processes, we make the following proposition:

Proposition #1: *Firms utilizing IT-enabled information and knowledge acquisition capabilities, in conjunction with complementary supporting technology and processes, will experience increased knowledge inflows and the benefits corresponding to these knowledge flows, compared to firms not utilizing IT-enabled information and knowledge acquisition capabilities.*

Organizational Knowledge Intraflows

Internal information flows deal with the processes of codifying, aggregating and recombining internalized information and knowledge for transfer within the organization. Complex knowledge may require IT systems for its effective codification and deployment. Knowledge requiring high internal transferability should greatly enhance organizational performance when flows are facilitated through technical systems. However, much of the valuable knowledge is usually tacit by nature, and historically has been difficult or impossible to codify until the recent advances of modern KM technologies. Further, once codified, if the knowledge is proprietary or strategic to the firm, it must also be protected and secured to avoid its potential loss and possible resulting harm to the firm. Therefore, trade-offs must be evaluated if the organization also depends on the internal transferability of strategic and proprietary knowledge.

IT systems that support internal knowledge processes include current RDBMS and prior-generation internal databases, as well as RDBMS-based customer-centric data warehouses, OLAP systems and analytical CRM/data mining/BI analysis tools. Further, intranets, knowledge repositories, collaboration tools and e-mail systems may also facilitate the intraorganizational exchange of information and knowledge. WFMS may also be employed to manage and reengineer the information system processes that underlie business activities. WFMS-type application platforms, such as Enterprise Learning Systems (ELS), are also utilized to store and manage the flow of organizational and external knowledge to and among individuals in much the same manner as enterprise resource planning (ERP) systems manage resource flows, production processes and personnel within organizations.

While it is often evidenced in system integration projects that cross-generational intra-firm legacy technology may likely serve as a constraint preventing the effective integration or full utilization of current-generation systems capabilities, some generational technology mixes may actually support intra-firm knowledge flows. For example, cross-generational technology may complement modern *intraflow* technologies by providing both a data source and repository from legacy data warehouses and WFMS-type ELS and ERP platforms for modern analytical CRM (eCRM) and analytic tools to interact with and to search, recombine and deploy intraorganizational knowledge.

Therefore, leveraging KBV perspectives on the role of generating and transferring knowledge within the organization as a means of increasing firm performance, and given technology's ability to enhance these activities, we make the following proposition regarding IT-enabled (*intraflow*) processes and firm performance:

Proposition #2: *Firms utilizing IT-enabled information and knowledge analysis and processing capabilities, in the presence of some technology combinations and supportive organizational processes, will experience increased intra-firm knowledge flows and knowledge generation benefits, compared to firms not utilizing IT-enabled information and knowledge analysis and processing capabilities, or firms utilizing it in non-supportive technological environments.*

Organizational Knowledge Outflows

Knowledge outflows consist of the firm's efforts to organize, recombine and deploy knowledge assets to create and support revenue-generating activities and opportunities for the organization. These processes may involve the exploitation of opportunities; strategic communication and positioning activities; and interactions with customers, partners, suppliers and competitors in the external environment.

IT systems supporting these activities include business to business (B2B), business to consumer (B2C) and business-to-government (B2G), public and private exchanges, Internet sales channels, cross-organizational workflow platforms and extranets. The control and protection of such flows from unwanted extra-firm knowledge transfers and leakage may also be moderated or deterred to some extent through the use of information security (INFOSEC). The existence of high degrees of IT cross-generational heterogeneity and/or extensive use of legacy-generation technology may present substantial constraints to desired knowledge outflows (limited capabilities and managed control of outflows) while challenging current-generation information security and facilitating unwanted extra-firm knowledge flows (leakage).

Therefore, based upon the KBV-motivated perspective that codified or partially codified tacit knowledge and information leakage will undermine firm sustainable competitive advantage (Grant, 1996; Kogut & Zander, 1992), as well as RBV motivations on the importance of resource rareness, value, inimitability and cost to substitute (Barney, 1991), and the technology's ability to facilitate as well as deter leakage, we make the following proposition regarding IT-enabled *outflow* processes and firm performance:

Proposition #3: *Firms utilizing IT-enabled information and knowledge dissemination capabilities, in the presence of some technology combinations* *and supportive organizational processes, should experience increased productive knowledge outflows. If unwanted extra-firm knowledge outflows (leakage) are minimized, these firms should experience greater performance compared to firms not utilizing IT-enabled knowledge capabilities, firms using unsupportive IT combinations or processes and/or firms not utilizing effective information security.*

IMPLICATIONS AND FUTURE TRENDS

So why might the issues raised in this chapter be important to future research in strategic management and information systems? Firm theory based upon the KBV accepts tacit knowledge as the source of sustainable competitive advantage within the firm (Grant, 1996; Kogut & Zander, 1992). Further, many scholars extend the RBVof the firm to include knowledge as a resource from which competitive advantage may derive (Eisenhardt & Santos, 2002). As proponents of KBV argue that once knowledge is codified, competitive advantage is subsequently unsustainable, what issues will the evolving codification capabilities of IT systems pose to this view? So, the main implications for organizational knowledge and the management of such knowledge rely in the internal structure of the firm and its support mechanisms (Grant, 1996). Further, the organizational capability to transfer and aggregate knowledge is also a key determinant of the organization's ability to grow and sustain competitive performance. Therefore, if we are to assume that organizational growth and performance are moderated by the firm's ability to manage and internally transfer and allocate organizational knowledge, and that knowledge capable of sustaining competitive advantage tends to be tacit by nature, then a firm's effectiveness at acquiring, generating and managing strategic, proprietary and complex competitive tacit knowledge should be positively related to firm growth and performance (Grant, 1996; Kogut & Zander, 1992). Thus, IT systems enabling these activities should theoretically have the potential to contribute to a firm's performance.

KBV holds that while improved knowledge flows may increase organizational performance, once competitive knowledge is codified, it can no longer be a source of sustainable competitive advantage, since replication, transfer and application of the knowledge can facilitate imitation by competitors (Grant, 1996; Kogut & Zander, 1992). Therefore, KBV predicts conflicting outcomes from technically enhanced knowledge capability: (1) A positive relationship with performance from IT-enabled capability in the short- to near-term; but (2) theoretical destruction of a firm's basis of sustaining competitive advantage in the long-term from the codification, replication and transfer of tacit knowledge. However, RBV further confounds this dichotomous theoretical prediction through its central premise that the competitive advantage derived from a resource may be sustainable as long as the resource is valuable, sufficiently protected from external leakage and unwanted outflow, and imperfectly imitable (Barney, 1991).

Regarding our propositions, given this apparent conflict between RBV and KBV, we are unsure of what assumptions to make regarding implications of IT-enabled capability on long-term performance. However, careful consideration could suggest an RBV argument that increased IT-enabled knowledge flow would not necessarily lead to a loss of long-term sustainable competitive advantage, under some conditions. Therefore, we propose that IT-enabled knowledge capability should not, in and of itself, lead to a corresponding decrease in a firm's ability to sustain competitive advantage on that knowledge in the long term. Based on these theoretical arguments from RBV and KBV, we feel that IT-enabled knowledge capabilities will facilitate opportunities for increased firm performance. However, significant further work is needed to develop and model the implications of this for strategic management theory, as well as to test these proposed implications empirically.

CONCLUSION

This chapter offered an exploration of the evolution of IT-enabled KM capabilities, and a comparison of RBV and KBV suggested implications of these advances on firm performance and sustainable competitive advantage. We argued that IT resources may enable new KM capabilities, which may, in turn, affect firm performance. However, codification and potential leakage of valuable tacit knowledge has the potential to undermine longer-term sustainable competitive advantage. Based on RBV assumptions, and the arguments put forth in this chapter, we feel that this rigid KBV argument is likely not supportable under some circumstances.

Conversely, following an RBV premise, we argue that codified tacit knowledge may be a sustainable source of competitive advantage if knowledge remains valuable, sufficiently rare (protected), imperfectly imitable (uncodifiable components) and non-substitutable. If the codified competitive knowledge is sufficiently protected/deterred from unwanted extra-firm knowledge transfers and leakage, IT-enabled KM may significantly enhance an organization’s ability to transfer intra-firm knowledge and, hence, improve competitive advantage and subsequent resulting firm performance.

However, these arguments shouldn’t necessarily limit aspects of a KBV perspective, and conversely, may point to KBV’s continued relevance by highlighting areas for extension and further refinement. Recent work advocates that the real value of KBV may be in the processes for knowledge sourcing, transferring and integration within and across organizations (Eisenhardt & Santos, 2002). In concurrence with Grant (1996) and Eisenhardt and Santos (2002), theory extension of KBV may require a more comprehensive competency-based view of the firm, which should embrace IT-enabled knowledge capabilities.

Finally, this chapter provided a starting point for examining the relationships among IT-enabled knowledge capability, firm performance and longer-term sustainable competitive advantage. We argue that through the adoption and integration of evolving IT-enabled KM, organizations may have the opportunity to significantly expand their knowledge-based capabilities. Such capability enhancement may serve as cause for reexamination of strategic management theory and its possible extension to handle these implications arising from advances in MIS research and related IT systems.

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Chapter 6.2

Building the IT Workforce of the Future:

The Demand for More Complex, Abstract, and Strategic Knowledge

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ABSTRACT

The software development process has undergone a considerable amount of change from the early days of spaghetti code to the present state of the art of development using strategic patterns. This has caused not only changes in the toolkits that developers use, but also a change in their mindset—the way that they approach and think about software development. This study uses revealed causal mapping techniques to examine the change in mindset that occurs across the procedural to OO development transition, and lays the foundation for future studies of the OO/pattern cognitive transition. The results indicate that there is not only increasing complexity in the cognitive maps of the OO developers, but also that there is a need for the developer to shift from routine, assembly line coding to more abstract thought processes.

INTRODUCTION

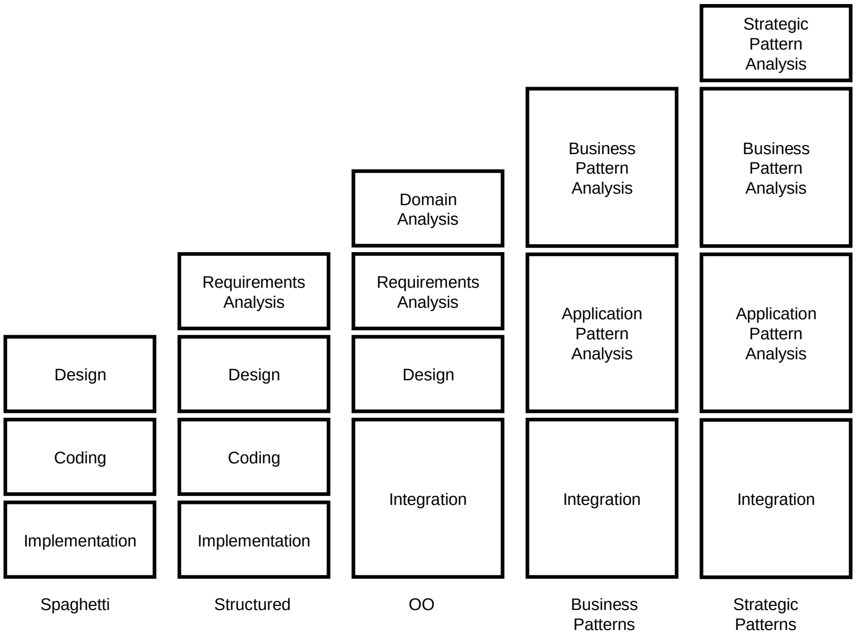
No one doubts that the software development process has undergone a profound transformation. Twenty years ago, the state of the art was the waterfall model of the systems development life cycle. The project planning and feasibility study steps were followed by systems analysis and requirements gathering, system design, coding, integration and testing, and finally installation and maintenance. The waterfall model fit very nicely within the rigid hierarchical organizational structures of the time. Functional silos and economies of scale drove software development. Systems analysts created data flow diagrams and ER diagrams and passed these to the designers. Designers would create functional decomposition diagrams and relational data models and pass these to the coders. Finally, the coders rendered all these into COBOL, FORTRAN, or a number of other procedural programming languages and database management systems. The constant translation from model to model enforced a sequence on the development process (Coad & Yourdon, 1991), with the side effect of keeping each different kind of developer in his or her place. Expert coders could not easily transition to the more abstract world of the designer and the analyst (Crowder, 1976).

The software development revolution of the 1990s began with the need for easier modeling, increased code reuse, higher quality, and easier to maintain software (Johnson, Hardgrave, & Doke, 1999). The structured programming paradigm focused on simplifying and controlling the development process (Martin & McClure, 1988) as well as increasing the efficiency and effectiveness of the development team. Where the design, code, and implementation steps of the "spaghetti code era" was replaced with a structured software engineering approach, the object oriented (OO) programming methods focus more on reuse of tested software, flexibility, and ease of maintenance with a more seamless integration of the analysis, design, and implementation development steps. This results in a development process that is incremental, concurrent, iterative, and evolutionary (Xing & Stroulia, 2005). The changes in the development process from spaghetti to structured to OO and beyond are shown in Figure 1.

The blurring of the boundaries and the smooth iteration between analysis and design in OO combined with the iterative, if not concurrent, performance of these activities has led to a cognitive blurring as well. While coders had to move to the more abstract world of analysis and design, designers had to become more analytical. Analysts, in turn, needed to move from relatively limited requirements analysis to the much more extensive domain analysis and the development of organizational information architectures (Evernden, 1996). Further, the breakdown of the barriers between the analyst and the designer and the use of models that span the lifecycle (for example, UML, Booch, Rumbaugh, & Jacobson, 1999) has created the need for more extensive project management skills. The shift from "doing analysis" then "doing design" structured by the different models in use has been replaced by an iterative and seamless development life cycle. However, just as coders have difficulty transitioning to the more abstract world of analysis, expert analysts have difficulty transitioning to the strategic world of the project planner (Nelson & Nelson, 2003).

This trend is continuing with the beginning of another software development revolution. One of the causes of recent technology project failures is the disconnect between organizational strategy and technology (Luftman & Brier, 1999; Luftman, 1996). An example of this disconnect can be found in the implementation of enterprise resource planning (ERP) systems. ERPs were sold as strategic enterprise solutions, even though at their core is a set of integrated, somewhat standardized business processes (Lee, Siau, & Hong, 2003). This approach to product development had virtually no strategic intent, and therefore ERPs, while sometimes solving process level problems,

Figure 1. The shift to the more abstract and the more strategic



often create more strategic problems than they solve (Davenport, 2000; Ezingeard & Chandler-Wilde, 1999).

The new revolution is shifting the balance of technological power from the technologists that create the technology to the managerial organizations that use technology. This revolution is creating methods for developing emerging technologies, written in a language that business decision makers understand and can control. By articulating business technology needs through understandable and consistent strategy-oriented methods (patterns), business will start to drive competitive needs down to the technologists to configure, rather than attempting to "mate" with what the technologists present to them.

A pattern-oriented development process has considerable advantages over traditional structured or OO development processes. For example, an organization encounters many problems in its day-to-day operations and in its strategic positioning against other organizations. These problems occur repeatedly in slightly different forms but with the same fundamental characteristics. A pattern is a "core of the solution" to these common problems (Alexander, Ishikawa, Silverstein, Jacobson, & Angel, 1977). Recognizing that a problem has been seen before and applying a semi-customized solution pattern to it allows faster reaction times and it "enables efficiency in both the communication and the implementation of software design, based on a common vocabulary and reference" (Adams, Koushik, Vasudeva, & Galambos, 2001).

Figure 1 shows this continuing trend. The OO revolution shifted the development process as a whole to the more abstract. The pattern revolution has again shifted the development process, first to a more organized higher-level form, then to the more strategic. While the effect on developers was well documented in the structured revolution and research is continuing on the cognitive effects of the OO revolution, the pattern-based approach to development has so far had an unknown effect on the analysts who must transition from abstract technical to abstract strategic thinking.

This article is the first step in a two-step research program that explores the cognitive differences across the OO revolution and the pattern revolution. Revealed causal mapping (RCM) techniques are used to explore how expert procedural programmers and expert OO developers exhibit expertise in their internal cognitive structures and examine the similarities and differences between the two programming paradigms. While there are general models of IS expertise (Batra, 1992; Koubek, Salvendy, Dunsmore, & LeBold, 1989; Nelson, Nadkarni, Narayanan, & Ghods, 2000), little is known about the cognitive structures of expertise that expert procedural developers and expert OO developers have and use during the software development process. Insights from this "cognitive lens" allow us to understand the differences between the two paradigms and add insight into how an individual thinks, learns, and reasons, and how his or her cognition relates to the quantity of knowledge and relationships among knowledge elements (Kraiger, Ford, & Salas, 1993). Understanding the underlying cognitive differences between the procedural and OO approaches is a first step in understanding the learning difficulties and in subsequently designing more effective relearning methods.

The second, future study examines the cognitive differences between expert OO developers and expert pattern developers to anticipate differences that may be encountered across this new revolution.

The remainder of the article is organized as follows: The second section provides an overview of prior research in software development expertise. The third section discusses the research methods used, and the fourth section provides the results. Finally, the fifth section discusses the implications of the study and suggests future areas for research.

BACKGROUND

Software development is knowledge work where the most important resource is expertise (Faraj & Sproull, 2000). There are many definitions of expertise from a cognitive perspective: the possession of a large body of knowledge and procedural skills (Bedard, 1991); an organized body of conceptual and procedural knowledge that an individual can readily access and use (Glaser & Chi, 1988); and the combination of knowledge and ability as well as the capability to use knowledge to achieve results (Nelson et al., 2000). Common to all these definitions is the idea that expertise *is a body of organized knowledge used to achieve results*. The expertise identified in this study was focused on procedural and OO software development. Procedural software development uses a set of principles in which top down design is used to develop a process-oriented, functional, modular program structure (Richardson, Butler, & Tomlinson, 1980). On the other hand, OO software development uses a set of principles where information (data) and processing (behavior) is manipulated in a manner similar to real-world objects (Brown, 1977).

The implementation phase of OO development is a cognitively incremental change from the implementation phase of procedural development (Sircar, Nerur, & Mahapatra, 2001). For example, when looking at programming in the small, an OO *method* is similar to a procedural *function*. While OO programming may appear to be simply an evolutionary development of procedural programming, it does represent a considerably different mindset for analysts (Agarwal, Sinha, & Tanniru, 1996; Boehn-Davis & Ross, 1992; Lee & Pennington, 1994). During the analysis and design phases, OO development represents a more revolutionary change from procedural development (Fichman & Kemerer, 1992; Sircar et al., 2001). The seamlessness of the models, the data-based object oriented viewpoint rather than the process-oriented viewpoint, and the shift to more abstract thinking represents a departure from procedural programming methods. Therefore, to get a holistic picture of the differences in mindsets between procedural and OO experts, this study utilized experts in all phases of the development process rather than simply one phase.

Most studies of expertise focus on the differences between novices and experts within the same software development mindset, such as the differences between novice and expert procedural programmers. In those studies, novices typically are "true novices" with little or no previous software development experience. Novices tend to form a more concrete representation of program function during software analysis, whereas experts tend to form more abstract representations (Adelson, 1981; McKeithen, Reitman, Rueter, & Hirtle, 1981; Vitalari, 1985). As a developer becomes more experienced he or she not only stops thinking in the concrete and begins thinking in the abstract, but also develops larger and larger chunks of information to represent important functional units or structures. It appears that expertise is not just a volume of knowledge, but also a way of thinking about the problem based on how that knowledge is organized (Vitalari, 1985).

From a cognitive perspective, the chasm between the procedural and OO approaches appears vast. To successfully develop software using OO requires a divergence from the procedural approach, especially during the initial phases of development. A review of the literature suggests that a systematic identification of the major constructs of procedural and OO software development expertise and the organization of those constructs has yet to receive significant attention. The studies by Sheetz and Teagarden (Sheetz, 2002; Sheetz & Teagarden, 2001) are the only ones found that explored OO developer cognitive structures; and those focused only on specific components of the OO approach. To understand the cognitive differences between expertise in procedural development and expertise in OO development we examine three key questions:

- What are the concepts that constitute expertise in procedural and OO software development knowledge?
- How are these concepts organized into cognitive structures?
- What are the similarities and differences in cognitive representations between the two software development approaches?

The answers to these questions will increase the understanding of the structural differences in the two approaches and aid the development of effective methods for retraining expert procedural developers in the OO approach.

METHOD

The purpose of this study was to understand what knowledge expert procedural and OO software developers possess and how that knowledge was organized, in essence to understand their cognitive structures. These structures are programming language-independent and relate to the conceptual, high-level abstractions that define each mindset. In order to understand these internal cognitive structures, the individuals' external cognitive representations must be examined (Pennington, 1987). With few theories in this domain available to guide the research, an exploratory approach was deemed appropriate for this study (Nelson et al., 2000).

Causal mapping, a collection of techniques used to elicit and analyze the structure and content of cognition (Axelrod, 1976; Fiol & Huff, 1992) is a qualitative research method that is suited for capturing cognitive structures and causal assertions. To understand the expert cognitive representations, *revealed* causal mapping (RCM) (Narayanan & Fahey, 1990) was used because what was captured in the maps were the concepts and causal connections that the developer revealed during the interview. RCMs are consistent with an exploratory research setting, can be used to elicit group level cognition (Bougon, Weick, & Binkhorst, 1977; Eden, Jones, Sims, & Smithin, 1981; Fiol & Huff, 1992; Narayanan & Fahey, 1990), and have been successfully used in a software development context (Nelson et al., 2000).

The task in this study was to elicit the relevant knowledge of expert procedural and OO software developers and cast it into appropriate structural representations. To accomplish this, expert procedural and OO software developers were identified, relevant knowledge was elicited, and the knowledge was cast into structural representations. The following sections describe this procedure.

Participants

Respondent organizations were selected based on their identification of available "expert software developers" in the procedural or OO software development approach and their willingness to participate. Over 15 organizations of various sizes (from 15 to 10,000 employees) and industries (e.g., telecommunications, manufacturing, and services) provided access to their software developers. The participants were expert procedural and OO software developers, as acknowledged by their peers using the snowball sampling technique (Shanteau, 1987, 1992).

In causal mapping research, the point of redundancy among the subjects represents the point at which further data collection would not lead to the identification of additional concepts (Axelrod, 1976). As the concepts emerge from the experts (rather than being imposed by the researchers), the point of redundancy serves to establish the adequacy of the sample. However, the point of redundancy is not calculated until after the interviews have been completed and the classification scheme has been developed. If redundancy is not reached, additional interviews are conducted. The point of redundancy was reached at 7 participants for procedural concepts and at 15 participants for the OO concepts. This indicates that the sample of 17 procedural experts and 24 OO experts was more than sufficient to capture all of the relevant concepts in the sample.

Elicitation

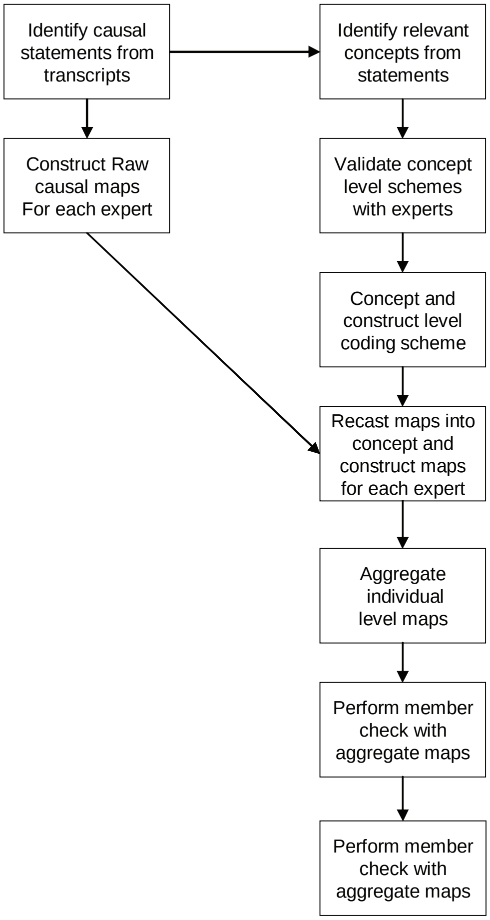
The interview process consisted of open-ended interviews with probes (Rossi, Wright, & Anderson, 1983) using an interview guide that was adapted from a previous study (Nelson, Armstrong, & Ghods, 2002). The guide was validated by two researchers, one with extensive revealed causal mapping experience and the other a software development expert. Each respondent was asked the same set of questions from the interview guide and included questions such as: "When a friend asks you what is object-oriented (procedural) development, what do you say?" Based on the respondent's answer to the question, follow up probes were asked to elicit further details regarding their software development thought process (e.g., "What did you think about next?"). Each interview lasted from 30 to 90 minutes. The range of interview lengths occurred because the interviewer did not constrain the responses to the questions. The interviews were transcribed into a document format ranging from 4 to 14 pages.

Deriving Revealed Causal Maps

Revealed causal mapping (RCM) (Narayanan & Fahey, 1990; Nelson et al., 2000) is a form of causal mapping, a collection of techniques used to explicate and assess the structure and content of knowledge structures (Axelrod, 1976; Fiol & Huff, 1992). Revealed causal maps provide a frame of reference for an expert's knowledge, how that knowledge is exhibited, and the reasoning behind the expert's actions. RCMs are consistent with exploratory research and have been successfully used in the software development context by Nelson, Nadkarni, Narayanan, and Ghods (2000). Figure 2 provides a flow chart of the revealed causal mapping process. Each phase in the process is described briefly.

Step 1: Identify causal statements. The first task is to identify the causal statements from the interview transcripts. Causal statements are

Figure 2. Revealed causal mapping process



statements that imply a cause-effect relationship. Some of the key words used in identifying causal statements are "if-then," "because," "so," and so forth. Consistent with Narayanan and Fahey (1990), all the statements in the form of concepts and relationships were captured in the language of the experts. To establish the reliability of the identification procedure, interview texts were coded by the primary researcher and one of the three raters who were not participants in any portion of the study. There were two rounds of coding that covered 12 interviews (six object-oriented and six procedural interview texts). Comparisons were made for agreement and disagreement between the researchers. Where disagreement occurred, the discrepancies were resolved through discussion. The reliability between the researchers was calculated by measuring the level of agreement on terms and linkages and averaged 0.80, suggesting an acceptable level of reliability.

Step 2: Construct raw causal maps. The causal statements identified in the first step were separated into causes and effects to construct the 'raw causal maps.' The Kruskal-Wallis significance test was performed to compare the causal statements elicited for the two groups of experts (procedural and object-oriented). The two groups were determined equivalent in terms of the causal statements they produced (b= .011, df =1, p= ns). Thus the two groups could be treated similarly for coding purposes.

Step 3: Develop coding scheme. The relevant concepts are identified from the statements (Narayanan & Fahey, 1990) by grouping frequently mentioned words in the statements. A word or word group was created that captured the essence of the statement. For example, the phrase, "You group the requirements document items based on functions" was labeled 'functions'. A second researcher who also is a software development expert reviewed the statements and independently placed them into conceptual categories. The level of agreement between the raters on the conceptual categories averaged 0.81. The level of agreement was slightly higher for the object-oriented concepts than the procedural but not significantly different. Three object-oriented and one procedural expert validated the concept level scheme. Validation was accomplished by an electronic card sort. The level of agreement between the raters averaged 0.77. There were a total of 28 concepts identified (17 object-oriented and 11 procedural). A construct level classification scheme was then developed from a composite classification scheme encompassing the favorable aspects of the most appropriate schemes. The scheme was validated by a total of six individuals, three object-oriented and three procedural software development experts. The reliability between the respondents was calculated by measuring the level of agreement on the card sort. The average level of agreement was 0.70.

Step 4: Recast the 'raw' maps into revealed causal maps. The causal statements for each respondent were placed into the appropriate concept and construct level categories. The result is a concept and construct level revealed causal map for each respondent. The individual maps were then aggregated (Axelrod, 1976; Bougon et al., 1977) at the concept level and the construct level. A member check was performed using the aggregated maps to ensure accurate and comprehensive representation (Lincoln & Guba, 1985). The member check was performed at the aggregate level because the emphasis of this research study was on the mindset level. No significant modifications were made to the aggregated maps based on the member check.

Step 5: Create measures for the maps. The analysis of the maps in this study was based on past research in causal mapping (Bougon et al., 1977; Ford & Hegarty, 1984; Huff, 1990; Narayanan & Fahey, 1990). The measures used were borrowed from the social network analysis field (Knoke & Kuklinski, 1982) and include the adjacency and reachability matrices, centrality, and density measures.

An *adjacency matrix* is a matrix representing the association of direct linkages between two constructs (Knoke & Kuklinski, 1982). For this study the interest is in the presence or absence of a causal relationship between concepts and thus the adjacency matrix contains only "0's" and "1's" (Carley & Palmquist, 1992). The *reachability matrix* indicates the cumulative direct and indirect effects of a variable on all other variables and allows for a more holistic picture of the causal relationships. The reachability of each linkage is reported on the linkage between the nodes on the revealed causal map. For a detailed explanation of adjacency and reachability matrices see Nelson et al. (2000). *Density* is a characteristic of the overall map and is a measure of how connected the concepts or constructs in the map are. It is a proportion that is calculated as the number of all linkages occurring in the matrix divided by the number of all possible linkages (Knoke & Kuklinski, 1982). *Centrality* is a measure used for the individual concepts or constructs within a map. In this study, it is a measure of how central or involved the construct is to the map. Centrality is a ratio of the aggregate of linkages involving the concept/construct divided by the total linkages in the matrix (Knoke & Kuklinski, 1982). Together these measures provide a systematic comparison of the RCMs in which all of the information contained in the map is utilized.

However, the structural measures of density, centrality, and reachability should be used with caution. While the validity of complexity and centrality have been demonstrated in an educational setting (Nadkarni & Narayanan, 2005), in causal mapping research efforts to establish the validity of the structural measures are still in the embryonic stages (Narayanan, 2005).

RESULTS

The OO and procedural software development concepts and constructs evoked in this study are shown in Table 1. The first two constructs for OO and procedural development are very much as expected. The structure construct contains foundation elements for each of the development techniques. OO development is structurally based on abstraction, encapsulation, and inheritance, generally implemented through objects, classes, attributes, and instantiation. Procedural development is structurally based on functional decomposition and interaction, implemented through functions and subroutines.

The second set of foundational constructs is behavior for OO and linear processing for procedural development. Where the structure construct captured the more static nature of the paradigms, these constructs capture their more dynamic natures. Object orientation is based on

Table 1. Construct level classification scheme

Object Oriented		**Procedural**	
Construct	**Concepts**	**Construct**	**Concepts**
Structure	Abstraction	Structure	Interaction
	Attribute		Functions
	Class		Functional Decomposition
	Encapsulation		Subroutine
	Inheritance		
	Instantiation		
	Object		
Behavior	Collaboration	Linear Processing	Linear Flow
	Message Passing		Linear Form
	Method		Linear Program
	Polymorphism		Linear Structure
	Relationship		Monolithic
OO Modeling	Identifying Objects	Functionality	Input-Process-Output
	Object Model		Data Modification
OO Development	OO Development		
	Layer		
	Patterns		

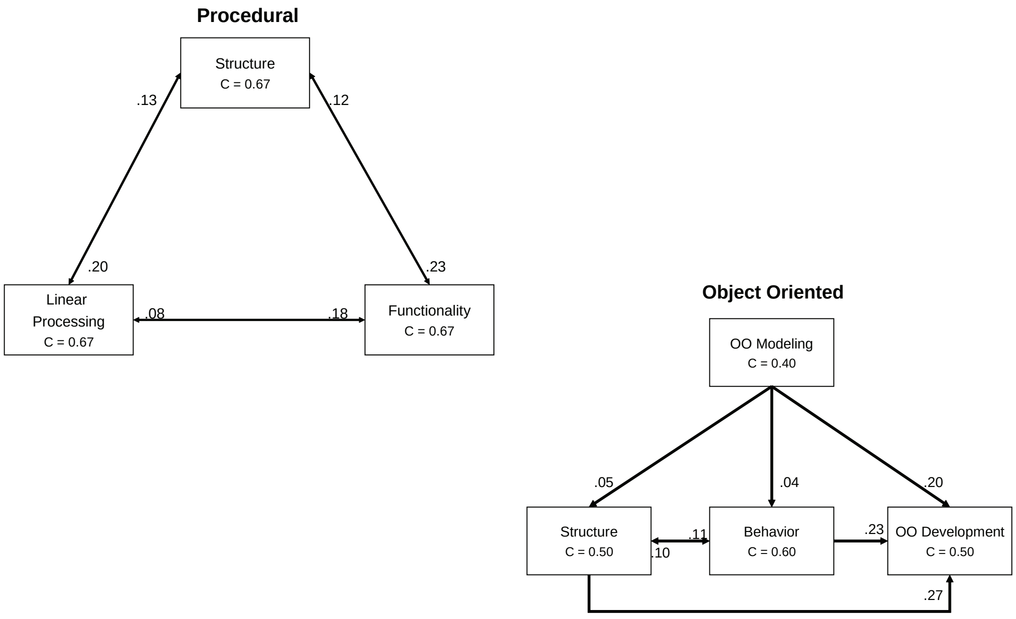
objects interacting with one another by methods passing messages. Relationships, collaboration, and polymorphism are related concepts. The procedural paradigm generally produces monolithic structures that have a linear form and a linear flow through linear structures and linear programs. These constructs capture the dynamic differences between OO and procedural. Procedural execution is very much top-down whereas OO is much more distributed and difficult to visualize.

The final two OO constructs capture its abstract nature. OO software development is more abstract with an emphasis on modeling: creating an object model by identifying objects. Development proceeds in layers, identifying and implementing patterns. Procedural development is much more concrete and focuses on functionality by modifying data through processes modeled as input—process—output structures.

Figure 3 shows the revealed causal maps for procedural and OO software development expertise. The centrality of each construct was equal (0.67) indicating that there was no central construct, and that all three constructs were all equally important to procedural software development. The aggregated RCM is fully connected has a density of 1.00, which indicates that experts saw strong connections between all of the constructs. The procedural constructs are intertwined with each other and are difficult to separate. There is no exclusive “cause” or “effect” construct, with all three being both causes and effects. The reachability ranged from 0.08 to 0.23 with a fairly equal reachability distribution.

The aggregated construct level RCM for OO constructs is very different from the procedural RCM. OO software development expertise was defined by four constructs: structure, behavior, OO modeling, and OO development. The majority of concepts in two constructs (structure and behavior) correspond to extant literature of OO software development, which suggests that the

Figure 3. Revealed causal maps



key concepts of OO include: abstraction, class, encapsulation, inheritance, message passing, method, object, and polymorphism. The structure construct focuses on the mechanisms that support the class/object structure and has a centrality of 0.50 and the behavior construct has a centrality of 0.60. Combined with the OO development construct with a centrality of 0.50, these three constructs occupy a central role in OO development. The OO modeling construct has a slightly smaller centrality of 0.40 suggesting a lesser role in OO software development. The importance of the OO development construct, its underlying concepts, and its connection to the foundational OO constructs (structure and behavior) has not been noted previously and is the focus of future research.

While the range of centrality measures was not large (0.40 – 0.60) the difference does underscore the differences in the roles that the constructs are assigned in OO development. This contributes to the complexity of learning OO development because developers not only need to learn the OO concepts but also where the different concepts fit into the OO development mindset. The density of the OO map was 0.83 indicating a high interconnectedness of constructs, which adds to the complexity of OO development.

In addition to complexity, the aggregated RCM reveals that experts saw OO modeling/analysis as a cause construct (all arrows originate from the construct) and OO development concepts as an effect construct (all arrows terminate into the construct). The structure and behavior constructs were mixed (both cause and effect constructs). The OO modeling/analysis (cause) construct was comprised of trigger concepts (e.g., identifying objects), that instigate the OO development process and trigger the use of other concepts. The OO development concepts (effect) construct was comprised of result concepts (e.g., OO development) that do not cause any further action. The structure and behavior constructs were mixed (both cause and effect) thus indicating the iterative nature of OO development in which both structure and behavior play key roles on an ongoing basis.

The OO map reachability values ranges from 0.04 to 0.27. The weakest connection was from OO modeling/analysis to behavior, and the strongest from structure to OO development concepts. There was a mutual connection between the structure and behavior constructs but the strongest reachability occurs for the linkages in which OO development concepts was the effect construct.

Object-Oriented versus Procedural

The OO approach was slower to reach redundancy than the procedural approach. This result could be attributed to the OO approach being less parsimonious than the procedural approach, or perhaps the more complex nature of OO (Shanteau, 1987). The content (similarity of concepts) was the next comparative measure. While there was some carryover of concepts from procedural to OO (e.g., abstraction), the procedural developers in this study did not address these as concepts associated with procedural development. There was negligible overlap in the concepts elicited for each approach. The cognitive distance between the two approaches appears to be significant, thus increasing the cognitive load on the developer making the transition to the OO approach (Morris, Speier, & Hoffer, 1999).

The OO map was more centralized with a hierarchical structure. In this study, it was found that the OO approach emphasized behavior (including concepts such as methods, message passing, and polymorphism) as a central theme (centrality 0.60). This is consistent with the definition of OO software development provided earlier. also It was also found that the OO development concepts and structure constructs had the next highest centrality (0.50). The centrality of the structure construct was consistent with the definition of OO and the concepts involved (e.g., object, class, encapsulation) were central to the approach. An interesting finding was that the centrality of the OO development concepts (e.g., layer) was higher than the centrality of the OO modeling/analysis construct (e.g., identifying objects). The OO modeling/analysis construct was expected to be more central because one "difference" between procedural and OO software development is how you think about the problem (Nelson et al., 2002). It appears that the different "approach" aspect was captured in the OO development concepts construct. As one developer stated,

> It took me a while to stop thinking linearly or procedurally and start looking at the things. Once I did that, started seeing the things, then I knew I was doing OO…. The biggest problem with the switch to OO is people that know procedural development are thinking in processes not objects.

In contrast to the OO map, the procedural constructs were all centrally placed (centrality 0.67). Thus, while the OO map was hierarchical with regard to the differences in centrality of the constructs, the procedural map was flat. This is not to say that the procedural concepts were of less importance, but that the program structure, program functionality, and linear processing nature of procedural development were so central to the essence of procedural development, it was difficult for the experts to cognitively separate them.

Looking at the connections between the constructs, the procedural map was perfectly dense (1.00) and the OO map was less dense (0.83), indicating the OO approach was more disconnected and compartmentalized. The procedural map was completely connected with all constructs, both causes and effects. With the OO map there was only one mutual arrow (arrow with two heads) between the structure and behavior constructs with the remaining connections having unilateral arrows (arrowhead with one head). The structure and behavior constructs were both causes and effects, which speaks to the interconnected nature of the OO approach. In contrast, the OO modeling/analysis construct was a cause construct only and OO development concepts was an effect construct only. Again, with OO modeling/analysis starting the development process it made sense that it would drive the remaining constructs. Similarly, the finding that the OO Development Concepts construct was a "result" of the OO development process is consistent with the emphasis of the construct on the system level aspects of development.

The last point of comparison was the elaboration of constructs. The higher elaboration of constructs for the OO approach (4.3 versus 3.7) indicated a slightly higher degree of chunking surrounding the constructs. Chunking occurs when a series of actions or grouping of concepts is abstracted into a conceptual chunk (e.g., Adelson, 1981). It appears that the OO developers abstracted more concepts into a chunk that the procedural developers.

DISCUSSION

The practice of software development is changing. The very early "spaghetti code" era gave way to the more disciplined structured/procedural development paradigm based on the process model: input—process—output. As the environment changed, this paradigm shifted to a more continuous, seamless development environment. This new paradigm emphasizes abstraction and modeling and deemphasizes the more linear processes of coding. This study examined the cognitive representations of expertise in both OO and procedural software development. When individuals think about developing software in these two paradigms, not only is the knowledge content different between procedural and OO development, but the structure and organization of that knowledge is also different.

The results of this study (the concepts, constructs, and their cognitive structure) provide a starting point for empirically representing the knowledge structure of expertise for each approach and for extrapolating the knowledge structures required as the next, strategic, revolution begins to take shape. The correspondence of the empirically evoked concepts to the theoretical constructs of procedural software development suggests that the RCM technique has empirical validity in the task of knowledge representation. On the other hand, the RCM technique not only uncovered concepts identified by extant OO literature such as encapsulation and object, but added important concepts to our understanding of OO expertise with the possible extension to patterns.

The representation of procedural and OO software development expertise contributes new constructs and concepts to the body of literature within the OO mindset. The concepts identified in this research not previously discussed as essential to OO development were patterns, layer, and OO development. Patterns are defined as collection of objects or classes that function in a certain way and can be reused with other projects (Johnson, 1997; Shull, Lanubile, & Basili, 2000). Layer is defined as the process of building a system in stages. The emphasis on "development" has not been previously captured as a focus of the OO mindset. The OO development concept evoked in this study acknowledges the importance of this cognitive focus. These concepts not previously identified as fundamental to the OO approach add to the understanding of OO development within the context of the larger system. While these contribute to the understanding of OO development, further research is needed to validate these new concepts and constructs before generalizations can be made.

In addition to theoretical contributions, several practical implications can be drawn from this study. Organizations switching to the OO approach need developers to put the new techniques into practice. One solution to this problem is to hire external OO developers, but while universities are turning out new employees who know OO programming, hiring these programmers is not an optimal solution because they do not possess the business domain knowledge that is necessary for successful OO development. A more workable solution is to retrain existing developers in the OO approach.

The results of this study show some of the difficulties and confusion that expert procedural programmers have when transitioning to OO development. For example, Table 1 shows the constructs and concepts discovered in interviews with expert OO and procedural developers. At the lowest, "programming in the small" level, the two mindsets are really quite similar and it is easy to transition from one to the other.

On the surface, the structure of the OO mindset is familiar to the procedural developer. Classes, objects, encapsulation, instantiation, and attributes are all familiar concepts and are all discovered through the process of functional decomposition and the identification of subroutines and the associated data that the subroutines operates upon. Data was not addressed as a procedural concept, primarily due to the clear data/process split in the procedural mindset. Data in the form of objects and classes is a fundamental part of the OO mindset so it is not surprising that it appears as a structural OO concept.

Moving on to the second part of programming in the small, the OO behavior and the procedural linear processing constructs are also similar on the surface. However, this is where the OO/procedural mindsets begin to differ. To those who see OO as an evolution of procedural development, message passing, methods, collaboration, and relationships are really no different than the linear programming, form, and flow of procedural functions and subroutines. However, the revealed causal map shows that the expert OO developers see OO structure and OO behavior as very different than expert procedural developers see procedural structure and procedural linear processing. OO structure and behavior are both effects of OO modeling with all three leading to OO development. Procedural causal maps have structure, linear processing, and functionality, all tightly related and connected.

The difference between the procedural and OO approaches is substantial. Clearly, not only the concepts used in these two approaches are different, but the cognitive organization of these concepts is also different. This is consistent with the arguments of some (Agarwal et al., 1996; Boehn-Davis & Ross, 1992; Fichman & Kemerer, 1992; Lee & Pennington, 1994) that at the conceptual phase of software development, the transition from procedural to OO represents a radical change. The transition to OO software development requires not merely a shift in tools and techniques, but also a fundamental shift in the way developers think about IS problems and solutions.

The combination of the revealed causal maps and the construct/concept table indicate that the OO mindset is truly a shift in thinking and not an extension of procedural development. The practical implications to this leads to the suggestion that the best method for transitioning programmers is a deep immersion into OO theory followed by a practical application of the OO language rather than trying to develop the OO theory by learning and then practicing the OO extensions to the language. For example, learning C then adding on the C++ extensions. While the transition works structurally in the small, this will interfere with learning the more abstract OO modeling and OO development constructs.

LIMITATIONS AND FUTURE RESEARCH

Although using practicing experts as respondents enhances the relevance of the results, external validity of the study is somewhat limited due to the sample size and snowball sampling technique utilized. The snowball sampling method is a non-probability method and consequently there is a potential for sample bias. Familiarity bias results from the person who is known to more people having a higher probability of being mentioned than the person known only to a few others (Sudman, 1976). This bias was minimized for this project because software development professionals were asked to identify others in their area with expertise (Abdolmohammadi & Shanteau, 1992). Thus selection was based on acknowledged expertise and not familiarity. Future research employing large samples is required to validate, refute, or modify the maps developed in this study. One potential limitation of the study was the use of retrospective recall in the data collection. During the interviews the developers were asked to think of their most recent software development experience as a reference for the questions. With any retrospective recall there is always a chance of inaccurate recall, but as acknowledged experts were used and the experts in the study completed an average of almost seven OO projects and 51 procedural projects, their recollections should provide an accurate reflection of expert conceptual knowledge.

The greater layering (complexity) of the OO approach map, one of the pieces of evidence unearthed by this study, suggests that the procedural and OO approach require very different mindsets. An alternate explanation is that the differences in complexity may be partly due to the differences in maturity of the software development approaches. While there are differences in the maturity of both mindsets, the OO approach has been in existence since the early 1960s. Perhaps the lack of maturity is a function of the complexity and not vice versa. Another possible explanation is that the findings were merely a function of the sample. As with any sample, there is a potential for bias. While the participants were experts as acknowledged by their peers, perhaps their expertise was insufficient to adequately capture the essential OO/procedural concepts. Although this is possible, it is not very likely because of the point of redundancy achieved for each sample was well below the number of experts interviewed. The list of concepts for each approach was exhausted well before the last participant was reached.

One of the first avenues for future research is replication with a large sample study. The cognitive structures of procedural and OO development expertise could be tested against the cognitive structures of a large sample of software developers. Another avenue for research would be to survey individuals who are expert OO software developers with no procedural experience. An analysis of their cognitive structures would not only be interesting but also would affirm or rebut the findings of this research. At this time, there are no expert OO software developers without any procedural experience, but perhaps in the future this avenue will be available. A third avenue for future research could include the retraining of expert procedural software developers. A laboratory experiment could be conducted in which retraining based on the constructs and linkages found in this study is tested against traditional retraining techniques.

This is the first part of a two part study. Future research will examine the cognitive structures of expert strategic, pattern-based software developers to determine how their mindsets differ from expert OO developers. It may be expected that the transition from abstract to strategic thinking will be just as difficult as the transition from procedural to abstract thinking.

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Chapter 6.3

IT Infrastructure Capabilities and Business Process Improvements:

Association with IT Governance Characteristics

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ABSTRACT

It has been widely discussed in the management information systems (MIS) literature that the outcomes of information technologies (IT) and systems may be subject to the influence of the characteristics of the organization, including those of the IT and business leadership. This study was conducted to examine the relationships that may exist between IT infrastructure capabilities (ITC), business process improvements (BPI), and such IT governance-related constructs as the reporting relationship between the chief executive officer (CEO) and chief information officer (CIO), and senior management support of IT and BPI projects. Using a sample of 243 multinational and Hong Kong-listed firms operating in Greater China, this study yielded empirical support for the perceived achievement of capabilities in some dimensions of the IT infrastructure in the companies under study. It was found that the BPI construct was related to the reporting relationship between the CEO and CIO (CEO-CIO distance), and to the levels of senior management support. The dimensions of the ITC construct were also investigated and identified by an exploratory factor analysis (EFA). Associations were found between the selected organizational constructs and the ITC dimensions, except in two hypothesized relationships. Those between CEO-CIO distance and the ITC dimensions of data integration and training were not supported at the significance level of 0.05.

INTRODUCTION

The last decades have seen generous investment in information technologies (IT) by companies around the world (Mitra, 2005; Strassman, 2002), and expenditures for IT infrastructure are estimated to account for almost 60% of a company's IT budget (Byrd & Turner, 2000). As IT has increasingly been perceived as a critical business enabler, companies are eager to take advantage of IT to support their operational and strategic objectives. Despite the huge investments made in IT in recent decades, the effects of such investment are less than satisfactory in terms of organizational benefits (Dasgupta, Sarkis & Talluri, 1999; Hu & Plant, 2001). One of the reasons for this paradox is the mismanagement of IT projects, as shown in a number of notorious examples of IT failures (Grossman, 2003; Spitze, 2001). Against this background, a series of sensible questions can be asked. What are the factors that would favorably affect the outcomes of such investments in IT initiatives? What are the proper types and amounts of IT investment a company should make? The first one points to many aspects of IT planning, implementation and management while the second relates to the proper investment decisions that need to be made, perhaps jointly, by the senior IT and business leadership (Ein-Dor & Segev, 1978; Ross & Weill, 2002).

The IT literature has presented many organizational factors relevant to the successful adoption of IT, ranging from project management issues to user involvement, and senior management support (Caldeira & Ward, 2002; Chatterjee, Grewal & Sambamurthy, 2002). Ignoring or mismanaging these factors may subject the projects to the risk of failure (Sumner, 2000). Among the many organizational issues that are said to affect the investment, deployment and use of IT, are IT governance-related factors. As defined by Sambamurthy & Zmud (1999), "IT governance arrangements refers to the patterns of authority for key IT activities in business firms, including IT infrastructure, IT use, and project management" (p. 261). "The patterns of authority" could have many implications to the investment decisions, and running of the enterprise-wide IT initiatives. For instance, it may affect how much recognition and support an IT project could receive from the various levels of the organizations, and whether appropriate funding and resources would be allocated. In our article, the term "IT governance characteristics" focuses on the (a) reporting relationship between the chief executive and the IT leader, (b) the support and commitment of top management received by the IT projects, and (c) the support and commitment of top management on business process improvement. The former is used as a surrogate for the seniority of the IT leader as will be explained and discussed further in the next section. A review of the literature about enterprise IT and systems adoption indicates that many of the enterprise IT projects would not be successful unless the deployment of IT is accompanied by changes to business practices and processes (Davenport, 1998; Sumner, 2000; Wu, 2002). Thus, senior management's attitudes and commitment on business process changes would also be critical to the success of enterprise IT projects.

While many studies have discussed, and some empirically investigated the relationships among IT adoption, business process changes and such organizational factors as senior management support and the seniority of IT leadership, there is still a need for additional empirical evidence to support these concepts (Grover, Teng, Segars, & Fiedler, 1998). On the other hand, such studies mostly examined the relationships at a coarse level, and have not attempted to investigate what aspects of IT are affected by these IT governance factors and what aspects are not. It would be more interesting to investigate these associations with IT at finer granularities, that is, considering the various dimensions of IT. Therefore, the primary goals of this study are (a) to conduct a thorough literature review on the selected IT governance factors in relation to enterprise IT and business process initiatives, (b) to explore more deeply the concept of IT infrastructure capabilities and define its constituent dimensions, (c) to produce a conceptual model highlighting the relationships between the IT governance-related constructs and these two types of initiatives, and (d) to conduct an empirical study to substantiate or disconfirm the relationships.

The remainder of this article is organized as follows. A review of the literature and the conceptual model are presented, the methodologies and guidelines of the study are discussed, the analysis and the findings are presented, and concluding remarks are made following a discussion of the findings and their implications.

LITERATURE REVIEW

IT Infrastructure Capabilities

IT infrastructure is important to an organization as it embodies many of the components necessary to support the organization's overall information architecture (Allen & Boynton, 1991; Mudie & Schafer, 1985). It has also been argued in the MIS literature that the enterprise architecture of an organization is composed of the technical, data, and application architectures; which jointly enable the processing, sharing and management of data resources across divisional and organizational boundaries (Spewak & Hill, 1993).

This broader view of IT infrastructure has earned the acceptance of many authors in IT or MIS (Mitchell & Zmud, 1999; Weill & Broadbent, 1999). Generally speaking, IT infrastructure capabilities (ITC) would consist of a wide spectrum of components, including the IT platforms, standards, and policies, and different types of service arrangements that support the information-related activities of an organization. Included in this definition are corporate network infrastructure, hardware platforms, common business systems such as data management and project management systems, and IT management and support services. Among the latter is education and training (Weill & Broadbent, 1999). In fact, training has been considered an important issue by studies in IT investment and management (Brancheau, Janz & Wetherbe, 1996; Mahmood & Mann, 1993; Palvia & Wang, 1995; Sakaguchi & Dibrell, 1998). Many of these studies (Mahmood & Mann, 1993) put the focus on training IT staff, while some (Sakaguchi & Dibrell, 1998) considered IT training for users to be a key construct of the measurement model of the global use of information technology.

In summary, the construct of ITC is a multidimensional concept that may include many aspects of IT, ranging from the network infrastructure that enables communications within and across organizational boundaries, a portfolio of hardware and system software that supports transaction processing and information analysis, documentation that clearly defines the policies and procedures of IT management, expertise in managing the IT platforms and various stakeholders, and the training of IT staff and users.

In recognition of the contribution of IT to organizational performance, IT capabilities measures such as the monetary measures of IT investment and perceptual ratings have been used as surrogates in research on the business value of IT. Attempts have been made in such studies to explore the impact of IT capabilities on an organization. The studies of Bharadwaj (2000), and Santhanam and Hartono (2003) have confirmed the relationships between IT capability and the financial performance measures of profit- and cost-related ratios. In both studies, IT capability was defined using a dichotomous variable, by which a value of 1 denotes a firm that has been elected by InformationWeek as an "IT leader," and a value of 0 denotes a non-IT leader. In the study of Andersen and Segars (2001), the effects of IT on the decentralization of the decision structure and on the financial performance of firms in the apparel and textile industry were empirically investigated. The instrument for IT measured the extent to which electronic mail services, electronic data transmissions, the company-owned telecommunication network, and fiber distributed data interfaces are used in a company (Andersen & Segars, 2001). Other studies found that IT infrastructure such as electronic data interchange (EDI) and network infrastructure had a significant impact on improvements in business processes (Bhatt, 2000, 2001). In Bhatt (2000), two aspects of information system integration were measured: the degree of data integration, and the use of network communications. The use of EDI in Bhatt (2001) was measured using the following three items: (a) the extent to which the firm and its primary suppliers were linked by EDI, (b) the extent to which information on products and services could be distributed to suppliers by senior management using information systems, and (c) the extent to which information on products and services could be shared between the firm and its suppliers. Likewise, the relationships between IT diffusion and perceived productivity gain, and the mediating effects of the business process redesign construct for different types of information technologies such as electronic mail, relational database management systems, expert systems, imaging, and local area networks were examined and confirmed in the study of Grover et al. (1998).

The preceding literature review leads to two points that deserve further discussion. First, IT adoption or diffusion and business process changes are inter-related, according to the studies that have been discussed. Second, the instruments that were developed primarily measure the use of individual IT platforms, rather than multiple dimensions of the IT infrastructure. In fact, there is a paucity of studies on the development of standardized multi-dimensional instruments for measuring the ITC of firms. The development of such an instrument would be conducive to IT studies in that it would assist with the repetitive and systematic measurements of ITC (Santhanam & Hartono, 2003).

Business Process Improvements and IT Adoption

Business process redesign refers to the revolutionary approach of process changes, which often requires "rethinking," and a drastic transformation of current business practices and processes. This approach is also called business process reengineering (BPR) (Earl & Khan, 1994; Hammer, 1990). Academic studies have also found that many firms have successfully made use of a "milder" evolutionary approach, which is referred to as business process improvements (BPI) (Harkness, Kettinger, & Segars, 1996; Stoddard & Jarvenpaa, 1995). This latter approach calls for less drastic changes to existing practice and processes.

Regardless of the approach adopted, changes in business process aim at the betterment and simplification of current practices and processes, and are considered critical for the deployment of IT systems in many circumstances. The interrelationships between IT and BPR have been widely discussed in the academic studies on MIS and business process management (Wu, 2002). IT enables new practices that would have been impossible before the advent of the technologies or systems. A lack of, or poor, IT infrastructure will limit or jeopardize the success of business process changes. Conversely, deploying IT without proper changes to business processes could compromise the outcomes. Many have considered business process redesign to be an important organizational construct with the potential to affect the outcomes of IT adoption (Grover et al., 1998). While there is plenty of theoretical discussion of the relationship between IT and business process changes in the literature, many of the studies are qualitative in nature, each involving very few cases, and therefore lack of generalizability (Grover et al., 1998). On the other hand, some studies discussed the issues with very limited empirical support (Grover et al., 1998). This points to a need for further studies to gather empirical evidence across firms for the abovementioned relationship.

Organizational Factors for IT Adoption and Business Process Changes

The MIS literature is abundant in the discussion of organizational factors and how they may affect the outcomes of IT adoption and business process changes. These studies have explored a wide variety of organizational issues in different system contexts (Caldeira & Ward, 2002; Davenport, 1998; Chatterjee et al., 2002; Ein-Dor & Segev, 1978). To name a few as examples, organizational issues or factors discussed in these studies include the seniority of IT leaders (Ein-Dor & Segev, 1978), senior management support and attitudes (Caldeira & Ward, 2002; Counihan, Finnegan, & Sammon, 2002; Davenport, 1998; Wixom & Watson, 2001), IT governance and decisions (Ross & Weill, 2002), and many project management practices (Ahituv, Neumann, & Zviran, 2002; Kimberly & Evanisko, 1981; Wixom & Watson, 2001).

Support and Commitment of Top Management

Among the aforementioned organizational factors, those concerning the roles and behavior of top management may matter a great deal and probably be increasingly important since many IT initiatives nowadays are enterprise-wide projects, analogous to what is described as Type III IS Innovation in Swanson's (1994) taxonomy of IS innovations. This type of project would require a clear strategy and institutionalized efforts to mobilize the functions and its stakeholders across the organization to participate in the adoption process (Swanson, 1994). In many circumstances, the attitudes and actions of the company's leadership would help facilitate and shape the adoption process (Chatterjee et al., 2002; Swanson, 1994). Many IT initiatives such as ERP, are boundary-spanning efforts which often require a wide range of stakeholders to participate, and to accept changes to the business practices and processes. Unswerving support from the top management is necessary to resolve any conflict of interest among the various parties involved (Davenport, 1998; Grover, Jeong, Kettinger, & Teng, 1995; Ross & Weill, 2002). A lack of such support would likely pose a threat to the projects (Bingi, Sharman, & Godla, 1999; Sumner, 2000).

That said, the IT leadership may have an important role to play within an organization, for instance, in marketing an IT or business process initiative to the organization and to secure the support and resources for the initiative. The seniority of the IT leadership is one of the "IT governance characteristics" to be investigated in this study. The following subsections will explore into the concepts about the roles and the seniority of the IT leadership as found in the IT-related literature.

The Roles and Seniority of IT Leadership

The seniority of the IT leader within an organization is considered an important factor in the success of the abovementioned projects (Ein-Dor & Segev, 1978). The IT leader, called the IT manager, IT director, or CIO, is the most senior executive responsible for the IT function of an organization. In this study, we shall use the term CIO to refer to IT heads regardless of their formal job titles. A summary of relevant discussions about the ranks and roles of the IT leadership are provided in Table 1.

IT heads in some organizations are positioned under the finance function (Jones & Arnett, 1993). As reported by a survey conducted in 1990, 40% of the CIOs who participated in the survey reported to the COO, and a much smaller percentage reported to the CEO (Rothfeder, 1990). In other organizations, this leader is often a member of the senior management team, shares the responsibility of business planning, enjoys a senior status and, equally important, is perceived as a senior executive (Rockart, Bullen, & Ball, 1982). It was found

Table 1. Findings and discussions about the IT leadership

Findings and Discussions	References
Seniority–Hierarchical Position	
• Seniority of the IT executive is one of the factors affecting IT/IS adoption.	(Ein-Dor & Segev, 1978)
• The use of IT for competitive advantages must be supported by the rank and role of the IT leader.	(Karimi et al., 1996)
• "Proximity" between CEO and CIO would help to secure resources and support.	(Jain, 1997)
• Reporting relationship ("CEO-CIO distance") moderates outcomes of IT investment.	(Li & Ye, 1999)
• The position of IS affects IT/IS adoption.	(Marble, 2003)
• CIO's rank is conducive to business process reengineering	(Teng et al., 1998)
Seniority–Membership of TMT (Top Management Team)	
• CIO's participation in top management team enhances business knowledge.	(Armstrong & Sambamurthy, 1999)
• CIO's membership in TMT is more important than his reporting relationship.	(Earl & Feeney, 1994)
• CIO is a member of TMT and it is equally important to be perceived as senior executive.	(Rockart et al., 1982)
Responsibilities and Skill Requirements	
• CIO should possess competencies in four areas: business leadership, technology leadership, organizational leadership and functional leadership.	(Earl, 1989)
• CIO markets, and changes the perceptions about the IT function.	(Earl & Feeney, 1994; Lucas, 1999)
• CIO pro-actively communicates with and solicits support from the TMT.	(Lucas, 1999)
Problems Encountered	
• A junior IT leader finds it difficult to communicate with top management.	(Cash et al. 1992)
• Many IT leaders are not accepted by others in the TMT as senior executives.	(Rothfeder, 1990; Runyan, 1990; Strassmann, 1994)

in a survey conducted in 2002 that 51% of CIOs reported to the CEO (Field, 2002). This shows a trend that an increasing number of companies recognizes the strategic role of the IT leader and the IT organization, and places him or her higher in the corporate structure.

The CIO bears full responsibility for promoting the use of IT to improve or transform the current business practices of an organization, building relationships and soliciting support from the CEO and other executives (Lucas, 1999). In fact, one of the CIO's most challenging responsibilities is to manage the CEO's perceptions about IT—that is, to persuade the CEO to think that IT is an organizational asset, rather than a cost (Earl & Feeney, 1994; Lucas, 1999).

These responsibilities require quality bilateral communications with the chief executive and others in the top management team to achieve an appropriate degree of mutual understanding (or convergence) with each other (Johnson & Lederer, 2003). As the CIO does not possess authority over any of his or her peers in the senior management team, he or she must achieve these objectives through "influence behavior," rather than through authority. For instance, rational persuasion and personal appeal are the most effective forms of influence behavior in soliciting support from the senior management team (Enns, Huff, & Higgins, 2003).

However, many CIOs have reportedly failed to obtain the acceptance from their peers and are considered outsiders to the senior management team (Rothfeder, 1990; Runyan, 1990; Strassmann, 1994). This may create hurdles to their efforts in communicating with the senior executives, or participate effectively in strategic planning. One may find the communication problem more serious for a junior ranking CIO, or in firms with a culture of informal communications (Cash, McFarlan, Mckinney, & Applegate, 1992). Moreover, a low-ranking CIO may put his/her focus on handling daily operations, and managing his or her subordinates (Ives & Olson, 1981), likely at the expense of the more strategic responsibilities.

This problem has led to the view that a formal senior position in the organizational hierarchy would give the IT executive more authority and influence within the organization (Jain, 1997; Hambrick, 1981). Though some academics argue that a full membership in, and effective communication with the top management team are more important than a formal senior position, others believe that a formal place in the top management team would give the CIO many advantages in terms of closer bilateral communications, and enhanced understanding of business strategies (Feeny, Edwards & Simpson, 1992; Gupta, 1991; Raghunathan & Raghunathan, 1993; Watson, 1990). Some empirical studies seem to support the formal approach. Karimi, Gupta & Somers (1996) pointed out that successful competitive strategies must be supported by the rank and role of the CIO. Li and Ye (1999) also found that a closer reporting relationship between the CEO and CIO would be conducive to the productive use of IT. Accordingly, it is likely that a direct reporting relationship with the CEO may help a CIO execute his/her duties effectively.

Given these discussions, it would be interesting to determine how these IT governance characteristics would affect the achievement of IT infrastructure capabilities and business process improvements in the companies under study.

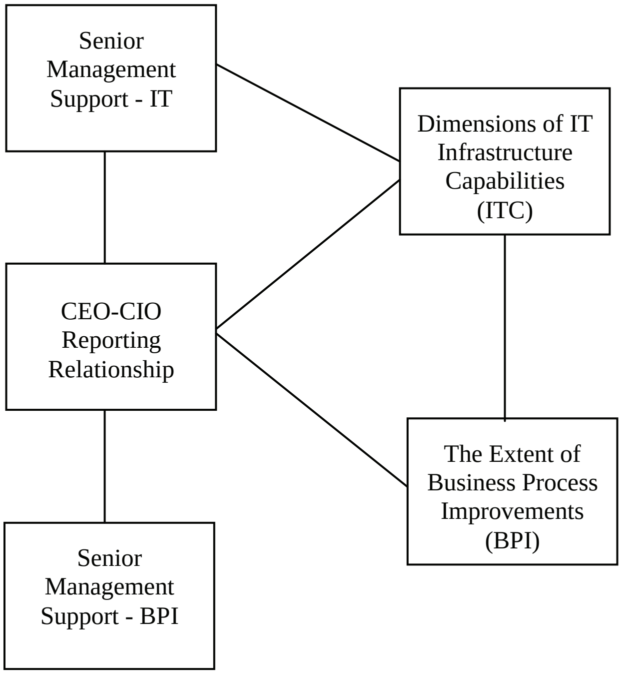
RESEARCH MODEL

To fulfill the objectives of this study, a research model is formulated to represent the key constructs and the conceptualized relationships, which will be discussed further in subsequent subsections. As depicted in Figure 1, the ITC dimensions and the extent of BPI are related, and these constructs are believed to be associated with the IT governance constructs of senior management support and CEO-CIO reporting relationship.

IT Infrastructure Capabilities

Following the broader definition presented in the last section (Weill & Broadbent, 1999), the construct of ITC is conceptualized to include items from five dimensions: network communications, data integration, hardware and system software, IT management and support, and training. The items of the first two dimensions, network communications and data integration, are based on a subset of items in the studies of Bhatt (2000, 2001); while training is derived from the study of Sakaguchi and Dibrell (1998) with modifications. The items of the dimensions of hardware and software, and IT management and support were developed after a thorough search through the literature on the subject (Allen & Boynton,

Figure 1. The conceptual model



1991; Sambamurthy & Zmud, 1999; Spewak & Hill, 1993; Weill & Broadbent, 1999).

It must be noted that this construct and its subordinate dimensions aim at measuring the perceived "realized" capabilities of IT infrastructure, rather than what is anticipated by the respondents.

The Extent of Business Process Improvements

The extent of BPI refers to the perceived degree to which changes in processes have been implemented to improve the efficiency and effectiveness of a company. The construct includes five items to measure process improvement in terms of error prevention, quality, ease of use, and intra- and inter-firm coordination. The first three items have been adopted from the study of Bhatt (2000), while the items concerning intra- and interfirm coordination have been added in recognition of the increasingly important concepts of cross-boundary coordination (Kogut, 1985; Stock, Greis, & Kasarda, 1998).

This study supports the assumption that a relationship may exist between IT deployment and process improvements. IT can be an enabler of changes to business processes, while the latter is necessary in many circumstances of IT deployment because automating inefficient processes would at best result in suboptimal outcomes (Hitt & Brynjolfsson, 1996; Stoddard & Jarvenpaa, 1995). Therefore, we put forward the following hypotheses:

$H_0$1: The perceived extent of a company's BPI and the perceived level of individual dimensions of ITC are positively related.

Senior Management Support and CEO-CIO Reporting Relationship

In this study, we have placed our focus on three IT governance-related constructs, namely senior management support of IT, senior management support of BPI, and the CEO-CIO reporting relationship. Senior management support is considered by many to be an important organizational factor for enterprise-wide IT and BPI projects (Ein-Dor & Segev, 1978; Grover et al., 1995; Sumner, 2000). The success of enterprise-wide projects requires the involvement of the user communities and the proper investment of resources (Nah, Zuckweiler, & Lau, 2003). The political roles played by senior executives in mitigating resistance to change and resolving conflicts between various interest groups must be accorded unequivocal importance (Davenport, 1998). Moreover, a supportive senior management team may influence the rest of the organization to take actions in favor of enterprise-wide initiatives. Senior management support in this study is a perceptual assessment, by the respondents, of the degree of support that top management gives to projects involving IT and BPI.

As a measure of the reporting relationship, the variable of CEO-CIO distance reflects how close or far apart the CIO is from the chief executive in the organizational structure. It can, therefore, be regarded as a surrogate of the seniority of the CIO. It is supposed that a CIO who reports directly to the chief executive will have a closer working relationship with him or her, and enjoy a higher status within the organization, than one who reports to other senior executives such as the COO or CFO.

We speculate that a high-ranking CIO would very likely have more opportunities to engage in high-quality two-way communications with the CEO and other senior executives, and a better understanding of business strategies than his or her low-ranking counterparts because of frequent participation in top management activities (Cash et al., 1992; Ives & Olson, 1981). This would be very important to the CIO in terms of the alignment of business and IT strategies, and his or her relationship with the senior management team. In addition to issues concerning communication and convergence between the senior IT and business leadership, having an IT governance structure in which the CIO is closer to the CEO and other senior executives may make it easier to implement the appropriate measures to secure from the rest of the organization the support and cooperation necessary for the success of an enterprise-wide initiative. For instance, a project bonus or award may be presented to the top performers of a project, or the contribution to the project may be considered as one of the important factors in annual staff performance appraisal.

We therefore posit that a CIO who enjoys a more senior position will be able to solicit stronger support for initiatives on IT and BPI, leading to more satisfactory outcomes for both types of projects. As the CIO is the head of the IT function, the status or importance of the IT function within the company is implied by his or her status. The following hypotheses are formulated:

H_0*2: CEO-CIO distance as a measure of the CEO-CIO reporting relationship is negatively associated with the perceived level of senior management support of IT projects.*

H_0*3: CEO-CIO distance as a measure of the CEO-CIO reporting relationship is negatively associated with the perceived level of senior management support of BPI projects.*

H_0*4: The perceived level of the individual IT infrastructure capabilities dimensions of a company is positively associated with senior management support for IT projects.*

H_0*5: The perceived level of the individual dimensions of the IT infrastructure capabilities of a company is negatively associated with the CEO-CIO distance used as a measure of the CEO-CIO reporting relationship.*

H_0*6: The perceived extent of the BPI of a company is positively associated with senior management support for BPI projects.*

$H_0$7: The perceived extent of the BPI of a company is negatively associated with the CEO-CIO distance used as a measure of the CEO-CIO reporting relationship.

RESEARCH METHODOLOGY

Data Sources

Perceptual data were collected by a postal survey. A survey package, containing a cover letter, a questionnaire booklet, and a return envelope with prepaid postage was sent to companies operating in different business sectors, including manufacturing, finance, logistics, wholesaling and retailing, and services. The 3,377 firms in the mailing list included 852 firms listed in the Stock Exchange of Hong Kong, and 2,525 multinationals operating in Hong Kong and China.

The cover letters, addressed to the chief executives or managing directors, solicited their support by explaining the objective of the research and the rules of confidentiality and anonymity, and asked them to forward the survey package, preferably to the IS executives, or to any officers nominated by them as appropriate to respond to the survey. A reminder postcard was sent to each nonresponding company at the end of the second week, and followed by telephone calls. These measures were taken to improve the response rate. In designing the study, serious consideration was given to the low response rates (around 10%) for social surveys conducted in Asian societies. This led to the decision to use a larger sampling frame for the survey.

Validity Guidelines and Research Procedures

Generally accepted guidelines in research (Churchill, 1979; Nunnally, 1978) were followed throughout the study, especially in the development of multi-item constructs. Items of individual constructs in this study were developed based on previously validated instruments and on a thorough review of the relevant literature. To ensure its face and content validity, the questionnaire was subject to a review and pretest, and then a pilot test.

An EFA was conducted for the sample, collected from the postal survey, on the ITC and the extent of BPI constructs to ascertain the convergent and divergent validity of the items under the dimensions (or subordinate constructs) in each construct. Items with factor loadings of 0.6 or above were retained for the constructs (Tracey, Vonderembse, & Lim, 1999), and those slightly below this cut-off point were reviewed for their importance and relevance to the objectives of the study following Dillon and Goldstein's (1984) guidelines. Internal consistencies were validated, and Cronbach's alpha coefficients equalling or exceeding 0.7 were considered acceptable (Kerlinger, 1973). In the purification process, items with corrected-item total correlations (CITC) of less than 0.5 were eliminated, or rephrased if they were important, following Churchill's (1979) recommendations.

This study followed a two-stage approach. An EFA was first performed to determine the dimensions of the high-level constructs, namely, the ITC and the extent of BPI constructs. Subsequent to the EFA, firm-level indices were calculated for individual ITC dimensions, and for the extent of BPI respectively. For example, the BPI index of a firm was derived by averaging the firm's perceptual inputs to the five BPI question items. The index for the training dimension of ITC was computed by taking the average of the firm's inputs to the three training items and so on. A data analysis was then conducted using a nonparametric correlation analysis (Spearman's rho) to test the relationships between the ITC dimensions, and the other constructs.

Instrument Development and Pilot Test

Instruments for soliciting perceptual ratings of ITC and the extent of BPI were developed based on a review of the literature, and on pretested instruments used in prior studies. The ITC instrument contains 16 items: four on network communications, three on data integration, three on hardware and system software, three on IT management and support, and three on training. The network communications and data integration items were based on the studies of Bhatt (2000, 2001) with adjustments to the wording. The training items included IT training for staff and users and were based on the study of Sakaguchi and Dibrell (1998). The items of hardware and software, and those of IT management and support measured the perceptual assessment of the capacities of the hardware and software facilities, administrative standards and procedures, and support services. These items were considered important to achieving a comprehensive ITC construct (Allen & Boynton, 1991; Mitchell & Zmud, 1999; Mudie & Schafer, 1985; Spewak & Hill, 1993; Weill & Broadbent, 1999).

The extent of BPI consisted of five items to capture assessments of realized process changes in terms of error prevention, process quality, ease of use, and inter- and intra-firm coordination. The first three items were derived from Bhatt (2000), with adjustments to the wording, and the items of coordination were added to improve the comprehensiveness of the instrument.

The instrument items are based on a 5-point Likert scale, with 1 being equal to *strongly disagree,* 2 to *disagree,* 3 to *neutral,* 4 to *agree,* and 5 to *strongly agree*. As discussed previously, these instruments were reviewed and pretested by six MIS executives and two academics, followed by the pilot test involving 60 evening MBA students. Their comments concerning the comprehensiveness and wording of the questionnaire items led to improvements of the instruments. Cronbach's alpha coefficients were computed using the 51 usable cases collected from the pilot test. The ITC instrument demonstrated acceptable internal consistency (Kerlinger, 1973). The alpha coefficient of the BPI items was below the cut-off value of 0.7; these items were therefore rephrased.

Measures of the IT Governance Constructs

As discussed, this study used the reporting relationship between the CEO and CIO as a surrogate for the status of the CIO (and the IT function). The questionnaire included a question with four options. The question reads "The head of IT in your company reports to (1) the CEO, (2) the CFO, (3) the COO, and (4) others, please specify". The responses to option 4 were to be analyzed to determine the levels of the IT head and his or her supervisor within the structure of the organization. This question was recoded to form the CEO-CIO distance variable, whose values were 1 for a CIO who directly reported to the CEO, 2 for a CIO who reported to a senior officer other than the CEO, 3 for a CIO who reported to a manager on the next level downward in the organizational hierarchy, and so forth, to reflect the reporting distance of the IT head from the CEO. This coding method was adopted and expanded from that used in Li and Ye (1999).

Two questions were included to solicit perceptual ratings on senior management support: one for IT and the other for BPI projects. Both were 5-point Likert scale questions, with 1 indicating *strongly disagree,* 3 *not certain*, and 5 *strongly agree.*

To operationalize the nonparametric tests for the relationships between the IT governance constructs, ITC dimensions, and the extent of BPI construct, the BPI index (labeled BPI_I) and indices for the individual ITC dimensions (labeled ITC_IFC, ITC_DI, ITC_FM and ITC_TR) were computed, after the EFA, for each firm based on its responses to the survey.

ANALYSIS AND FINDINGS

Profiles of the Respondents

Three hundred and six questionnaires were returned, giving a response rate of 9.1%. For the sake of data quality, returned questionnaires with missing data and those filled out by relatively junior staff such as programmers were dropped. Therefore, 243 usable cases were retained in the sample, yielding an effective rate of 7.1%. Among the 243 responding companies, 65 (26.7%) were listed in Hong Kong, 64 (26.3%) in Europe, 41 (16.97%) in North America, and 60 (24.7%) in other parts of Asia. The demographics of the respondents are presented in Table 2.

Exploratory Factor Analysis and Internal Consistency

Following the screening of returned questionnaires, an EFA was performed separately on the ITC and the extent of BPI items. Maximum likelihood was used as the extraction method and Varimax as the rotation method in this study. Items with factor loadings of less than the cut-off value of 0.6 were dropped from the construct (Tracey et al., 1999). The dimensions and their items (indicators) that satisfied the criterion are shown in Tables 3 and 4.

The EFA not only led to the elimination of some indicators from the ITC construct but also to the merger of two conceptualized dimensions. Two items concerning intra-firm communications under the "Network Communications" dimension ("NC3: Personnel can efficiently exchange information using e-mail systems," and "NC4: Company units can readily access data and applications on the network") were found to have insignificant factor loadings. One item, "HS3: Both hardware and system software are upgraded frequently," under the "Hardware and System Software" dimension was also dropped for low loading. The indicators initially conceptualized

Table 2. Profiles of the respondents

Personal Attributes	Frequency	
Years of Age		
25–30	49	(20.2%)
31–40	109	(44.9%)
> 40	76	(31.3%)
Unknown	9	(3.7%)
Total	243	(100.0%)
Education Level		
Secondary	1	(0.4%)
Post-secondary certificate/ diploma	25	(10.3%)
Bachelor's degree	125	(51.4%)
Master's degree	85	(35.0%)
Doctoral degree	2	(0.8%)
Unknown	5	(2.1%)
Total	243	(100.0%)

Personal Attributes	Frequency	
Years in Present Profession		
Less than 3 years	13	(5.3%)
3 to 6 years	45	(18.5%)
7 to 10 years	59	(24.3%)
11 to 14 years	44	(18.1%)
More than 14 years	79	(32.9%)
Unknown	3	(1.2%)
Total	243	(100.0%)
Seniority Level		
Chief executive	22	(9.1%)
Senior management	44	(18.1%)
Middle management	111	(45.7%)
Front-line supervisors & project leaders	53	(21.8%)
Unknown	13	(5.3%)
Total	243	(100.0%)

Table 3. The four factors of the IT infrastructure capabilities construct

Item	Description	IFC	DI	FM	TR	Alpha
NC1	Networks link the firm and its main suppliers.	0.772				
NC2	Networks link the firm and its main customers.	0.795				0.8222
DI1	The same information in the database is shared across the firm.		0.761			
DI2	Duplication of data is eliminated.		0.769			0.8206
DI3	Definitions of data elements are standardized.		0.629			
HS1	Server platforms have sufficient capacity.			0.652		
HS2	Regular preventive maintenance minimizes down time.			0.684		
MS1	The firm has the expertise to manage IT facilities.			0.713		0.8848
MS2	Users are happy with the IT services.			0.663		
MS3	IT administration standards and procedures are well defined.			0.613		
TR1	The company has effective IT training programmes.				0.752	
TR2	Training for users is sufficient.				0.799	0.8841
TR3	Training for IT personnel is sufficient.				0.771	

Note. IFC = interfirm communications, DI = data integration, FM = IT facilities and management, TR = training, Alpha = Cronbach's alpha (α).

Table 4. The extent of business process improvement construct and factor loadings

Item	Description	BPI	Alpha
BP1	Process changes help prevent defects and errors.	0.663	
BP2	Process standards are raised periodically.	0.728	0.8395
BP3	New processes are easier to work with.	0.738	
BP4	Work processes are improved to facilitate coordination within the firm.	0.814	
BP5	Work processes are improved to facilitate coordination with external parties.	0.644	

Note. BPI = the extent of business process improvement, Alpha = Cronbach's alpha (α).

under the "Hardware and System Software" and "IT management and support" dimensions were identified as belonging to a single factor, renamed "IT Facilities and Management." Consequently, the ITC construct was found to be composed of four dimensions: "Interfirm Communications" (IFC), "Data Integration" (DI), "IT Facilities and Management" (FM), and "Training" (TR). An EFA found that the extent of BPI is unidimensional and that all five items loaded under a single factor.

The items under the extent of BPI, and those under individual dimensions of the ITC construct were analysed separately for internal consistency (refer to Tables 3 and 4). The Cronbach's alpha coefficients for the ITC dimensions exceeded the cut-off value of 0.7 (Kerlinger, 1973). The Cronbach's alpha coefficient of the BPI construct was 0.8395, thus satisfying the threshold value of 0.7 (Kerlinger, 1973). In addition, the CITC (i.e. corrected-item total correlations) value of each item under these two constructs exceeded 0.5, meeting Churchill's (1979) guidelines.

Hypothesis Testing

Subsequent to the purification of measures and the EFA, the firm-level indices, namely BPI_I (for the extent of BPI construct), and ITC_IFC, ITC_DI, ITC_FM and ITC_TR (for the individual ITC dimensions) were calculated for each responding firm. The responses concerning the reporting relationship of the IT leadership were analyzed before recoding. In this sample, 128 (52.7%) IT leaders reported directly to the CEO or managing director, 68 (28.0%) to the chief financial officer (CFO), and 44 (18.1%) to the chief operating officer (COO). Three respondents indicated that their IT leaders reported to supervisors other than the CEO, CFO, and COO. Based on the job titles entered by respondents, we determined that these supervisors were one level below that of the CEO/Managing Director. Responses to this question item were then recoded to form the CEO-CIO distance variable (CC_DIST), which reflected how far the IT leader was from the CEO/Managing Director in the organization chart. As a result, 128 IT leaders in the sample were assigned a value of "1," and the rest were assigned a value of "2" in the CEO-CIO distance variable (refer to Table 5).

In addition, the descriptive statistics of variables used in this study were computed and presented in Table 6, showing that the data does not conform to the assumption of normal distribution. This characteristic of data distribution and the fact that many variables are "ordered categories" justify the use of nonparametric statistical methods (Norusis, 2003).

Recall that the objectives of this study are to investigate whether the perceived level of ITC dimensions, and extent of BPI of a company are interrelated, and whether associations exist between the former constructs and the IT governance-related constructs of senior management support, and the status of the IT leader within that organization (using CEO-CIO distance as proxy). To fulfill these objectives, nonparametric tests were conducted. The findings are presented in Tables 7 and 8.

Using a nonparametric correlation analysis (Spearman's rho), the associations between the indices of individual dimensions of the ITC construct and the variables representing other constructs were tested. The indices computed for the individual ITC dimensions (namely, ITC_IFC, ITC_DI, ITC_FM, and ITC_TR) were first correlated to the BPI index (BPI_I), yielding statistical support for hypothesis 1 (refer to Tables 7 and 8 for the findings for $H_0$1a, $H_0$1b, $H_0$1c, $H_0$1d). The relationships between the individual indices of ITC dimensions and the variable of management support of IT projects (MS_IT) were tested, confirming hypothesis 4 (refer to Tables 7 and 8). Then,

Table 5. Reporting relationships of IT leadership

Title of Supervisor	Frequency	CEO-CIO Distance Encoded
CEO/Managing Director	128 (52.7%)	1
Chief Financial Officer (CFO)	68 (28.0%)	2
Chief Operating Officer (COO)	44 (18.1%)	2
Others[1]	3 (1.2%)	2
	243 (100.0%)	

Note. Three job titles entered by the respondents indicated positions that are one level below the CEO.

Table 6. Constructs, variables created, and descriptive statistics

Constructs	Variables Created	*N*	Mean	Std. Deviation
ITC Interfirm Communications	ITC_IFC	243	3.4486	0.91387
ITC Data Integration	ITC_DI	243	3.8299	0.75780
ITC IT Facilities and Management	ITC_FM	243	3.7407	0.74153
ITC Training	ITC_TR	243	3.1920	0.85960
The Extent of Business Process Improvement	BPI_I	243	3.4313	0.62272
Senior Management Support of IT Projects	MS_IT	242	3.8100	0.99200
Senior Management Support of BPI Projects	MS_BPI	242	3.8000	0.93500
CEO-CIO Reporting Relationship	CC_DIST	243	1.4733	0.50031

Note. ITC_IFC = Index of the ITC Interfirm Communication dimension, ITC_DI = Index of the ITC Data Integration dimension, ITC_FM = Index of the ITC IT Facilities and Management dimension, ITC_TR = Index of the ITC Training dimension, BPI_I = BPI Index, MS_IT = Management Support of IT, MS_BPI = Management Support of BPI, CC_DIST = CEO-CIO Distance.

Table 7. Correlation analysis (Spearman's rho)

Variables	ITC_IFC	ITC_DI	ITC_FM	ITC_TR	BPI_I	MS_IT	MS_BPI	CC_DIST
ITC_IFC	---	---	---	---				
ITC_DI	---	---	---	---				
ITC_FM	---	---	---	---				
ITC_TR	---	---	---	---				
BPI_I	0.333**	0.331**	0.548**	0.510**	---			
MS_IT	0.264**	0.298**	0.454**	0.355**	0.371**	---		
MS_BPI	0.279**	0.317**	0.424**	0.386**	0.445**	0.574**	---	
CC_DIST	-0.141*	-0.125	-0.187**	-0.114	-0.178**	-0.188**	-0.172**	---

Note. ITC_IFC = Index of the ITC Inter-firm Communication dimension, ITC_DI = Index of the ITC Data Integration dimension, ITC_FM = Index of the ITC IT Facilities and Management dimension, ITC_TR = Index of the ITC Training dimension, BPI_I = BPI Index, MS_IT = Management Support of IT, MS_BPI = Management Support of BPI, CC_DIST = CEO-CIO Distance.
** Correlation is significant at the 0.05 (2-tailed) level.*
*** Correlation is significant at the 0.01 (2-tailed) level.*

these indices for individual ITC dimensions were correlated to the variable of CEO-CIO distance (CC_DIST), and it was found that hypothesis 5 was only partially supported. While the negative associations between CC_DIST and ITC_IFC and ITC_FM were statistically supported, the ones between CC_DIST and ITC_DI and ITC_TR were not (Refer to $H_0$5a, $H_0$5b, $H_0$5c, and $H_0$5d in Tables 7 and 8).

Nonparametric correlation analyses were also performed respectively for the relationships between the variables of CEO-CIO distance (CC_Dist), and senior management support of IT projects (MS_IT); between the variables of CEO-CIO distance (CC_Dist), and senior management support of BPI projects (MS_BPI); between the variables of BPI index (BPI_I) and senior management support of BPI projects (MS_BPI);

Table 8. Summary of findings

	Hypothesis	Finding
$H_0$1a:	ITC_IFC and BPI_I positively related	S[a]
$H_0$1b:	ITC_DI and BPI_I positively related	S[a]
$H_0$1c:	ITC_FM and BPI_I positively related	S[a]
$H_0$1d:	ITC_TR and BPI_I positively related	S[a]
$H_0$2:	CC_Dist and MS_IT negatively related	S[a]
$H_0$3:	CC_Dist and MS_BPI negatively related	S[a]
$H_0$4a:	ITC_IFC and MS_IT positively related	S[a]
$H_0$4b:	ITC_DI and MS_IT positively related	S[a]
$H_0$4c:	ITC_FM and MS_IT positively related	S[a]
$H_0$4d:	ITC_TR and MS_IT positively related	S[a]
$H_0$5a:	ITC_IFC and CC_Dist negatively related	S[b]
$H_0$5b:	ITC_DI and CC_Dist negatively related	NS
$H_0$5c:	ITC_FM and CC_Dist negatively related	S[a]
$H_0$5d:	ITC_TR and CC_Dist negatively related	NS
$H_0$6:	BPI_I and MS_BPI positively related	S[a]
$H_0$7:	BPI_I and CC_Dist negatively related	S[a]

Note. ITC_IFC = Index of the ITC Interfirm Communication dimension, ITC_DI = Index of the ITC Data Integration dimension, ITC_FM = Index of the ITC IT Facilities and Management dimension, ITC_TR = Index of the ITC Training dimension, BPI_I = BPI Index; MS_IT = Management Support of IT, MS_BPI = Management Support of BPI, CC_DIST = CEO-CIO Distance, NS = Not Significant.

[a] *Significant at $p < 0.01$.* [b] *Significant at $p < 0.05$ (2-tailed).*

and between the variables of BPI index (BPI_I) and CEO-CIO distance (CC_Dist). The resulting correlation coefficients (Spearman's rho) were statistically significant, hence confirming hypotheses $H_0$2, $H_0$3, $H_0$6, and $H_0$7.

DISCUSSIONS AND IMPLICATIONS

Discussions of Findings

This study demonstrated the positive correlation between the capabilities of individual dimensions of IT infrastructure and the extent of BPI, reinforcing the symbiotic relationship widely discussed in the MIS literature. As an extrapolation from this finding, we would like to point out that the special relationship of these constructs needs to be given special attention. In IT deployment projects, business process issues need be properly managed, or vice versa. As is often discussed in the literature, IT deployment without process amelioration might be a waste of opportunities for efficiency gains and IT investment, as in the cases of implementing an ERP, or a document management/workflows system. On the other hand, IT would give business process redesign initiatives new possibilities in business practice and methods. For instance, the installation of networking and communications facilities (and the Internet) would give a firm the opportunities to reexamine how to organize its project teams and work processes. Therefore, we incline towards the viewpoint that the role of each of these interacting constructs varies in different situations and according to enterprise objectives. It would be difficult to ascertain the cause–effect relationships between them. Given the mutual influence between IT and business process changes, success factors for both constructs need to be considered thoroughly and managed properly if improvements are to be made to IT and process management practices. Ignoring such factors will render the management model incomplete, thus exposing the project to the risk of failure.

Higher levels of management support and a closer reporting relationship between the CEO and CIO were found to be associated with better performance in BPI, and some dimensions of ITC, as perceived by the respondents. In parallel to these findings, a closer CEO-CIO reporting relationship was also associated with higher levels of senior management support. The statistical results appear to suggest that, regardless of company background, management support and the status of the IT leader (and that of the IT function) are among the key factors to successful outcomes in achieving the objectives of ITC and BPI. The reporting relationship of the CIO is initially dictated by the organizational structure of a company. A closer direct reporting relationship, indicating a senior ranking, might possibly put the CIO in a better position to communicate with and influence senior business executives in comparison to an indirect reporting relationship (Cash et al., 1992; Hambrick, 1981; Jain, 1997). As an executive has said in a survey of CIOs (Field, 2002), whom the CIO reports to does matter a great deal. A CIO who reports directly to the chief executive is perceived as being more important than one who does not, and what he says would therefore carry more weight among the audience (Field, 2002). The findings of this study have shed light on the general belief that positioning the CIO and his or her team prominently in the organization structure may help the organization achieve better performance in IT and BPI projects. The findings of this study are in alignment with the propositions of Ein-Dor and Segev (1978).

The finding that who a CIO reports to is important is also consistent with what has been discussed in the ERP literature (Davenport, 1998; Willcocks & Sykes, 2000). These studies emphasized the importance of the support from senior executives in enterprise-wide projects, which often require changes to boundary-spanning processes. Business leaders should play a key role in mediating between different divisions to defuse difficult political situations concerning the interests of various stakeholders in these cases (Davenport, 1998). It would be of interest to IT practitioners and academic researchers to explore this issue further. However, we need to take note of the other school of thought that considers communication quality and membership in top management team as more important than a formal senior job title (Earl & Feeney, 1994). Earl and Feeney's opinion may not be in conflict with that of the other academics espousing a formal senior hierarchical position for the IT leader. A formal senior position may mean a greater chance to participate in the top management team. Moreover, it must be reminded that a closer reporting relationship in the organizational structure works only if the CIO is in possession of the right attributes to effectively perform his/her job (such as the personality, skills and commitment necessary for building a good and trustful working relationship with the business leaders). Violating this assumption may render the CIO unfit for the organization.

Noteworthy is the attempt in this study to understand and pinpoint the dimensions of the ITC and the extent of BPI constructs. An EFA showed that the latter is unidimensional and the former consists of four dimensions, namely inter-firm communications, data integration, IT facilities and management, and training.

Subsequent to the EFA, this study demonstrated the associations of each dimension of the ITC construct with the BPI construct and management support of IT projects. That is, the perceived levels in the extent of BPI, and senior management support are related to perceived levels of these individual aspects of IT. The CEO-CIO reporting relationship was found to relate significantly to the ITC dimensions of interfirm communications and IT facilities and management. These showed the associations between the organizational characteristics, particularly the chosen IT governance-related constructs, and enterprise IT capabilities. The reason for the insignificant relationships between the CEO-CIO reporting relationship and the ITC dimensions of data integration and training is unknown. Rather than contributing a speculative explanation, we would like to attribute these findings to data issues, and suggest that these relationships be retested using a different sample. As a consolation, the relationships were supported at the significance level of 0.10, indicating weak associations.

Academic and Professional Contributions

This study contributes to research by gathering empirical evidence on the associations between contextual constructs (such as senior management support and CEO-CIO reporting relationships), and the perceived levels of achievement in the various dimensions of ITC and BPI in Hong Kong-listed and multinational firms operating in Hong Kong and China. The influence of these constructs has been discussed in many studies, in some cases with limited empirical support, or in others with empirical findings that are weak in generalizability. The findings of this survey help fill the gaps that exist in the literature.

Executives and IT leaders are advised to learn to manage organizational constructs in conjunction with their enterprise-wide initiatives of IT adoption and BPI. Such organizational constructs as senior management support and CEO-CIO reporting relationship must be accorded paramount importance and managed cautiously. This also implies that firms that regard IT and business process management as important capabilities should place their CIOs and IT functions in prominent and influential positions (Karimi, Gupta, & Somers, 1996). Moreover, the CIO and CEO should work closely together to produce a synergistic effect on the strategic alignment of business and IT, and in securing support from other senior executives.

While this has important implications for business and IT executives, academic researchers in the disciplines of MIS and business management need to appreciate these findings and view them as pointers to more in-depth studies in the future.

Finally, in this study the concept of the ITC construct was empirically explored and those of its dimensions, comprising not only capabilities in communications and systems management but also those in data integration and training, were identified. An attempt was also made to investigate which of these ITC dimensions were associated with the organizational constructs under study.

Limitations

Although generally accepted guidelines and principles in research were followed in this study (Churchill, 1979; Nunnally, 1978), it has some potential limitations. First, this study relied on the perceptual inputs of the same respondents for the multiple variables in the research model; therefore, the likelihood of common method bias cannot be entirely ruled out. Second, this study is limited by its cross-sectional sample. The empirical findings, therefore, have substantiated correlational, but not necessarily causal relationships. For instance, while it is known that CEO-CIO distance and senior management support are negatively related, it cannot be determined whether higher levels of senior management support are the result of a closer CEO-CIO relationship, or vice versa.

Further Studies

Consequently, it must be added that a longitudinal study would help clarify and reinforce the relationships reported in this study. The findings of this study also point to many opportunities for further research. Practitioner reports have pointed to an upward trend over the last decade of placing the CIO directly under the chief executive (Field, 2002; Rothfeder, 1990). This practice may have hinted that more companies are treating IT as a strategic asset, rather than a cost to an organization. Studies should be conducted to examine whether there exists an association between the positioning of the CIO and the objective of using IT as an enabler of competitive capabilities in the business world as Karimi et al. (1996) suggested. Similarly, it would be of interest to ascertain whether the abovementioned trend in CIO positioning has actually contributed to the effective use of IT in supporting business strategies.

As a last note on the further advancement of MIS research, we would like to advise that academic researchers should continue to strengthen the theoretical explanations for the influence of the organizational constructs mentioned above. On the further development of the ITC construct, we would like to suggest that the ITC items and conceptualised dimensions be validated using another data sample as a further confirmation of its dimensionality. Additional efforts in this area would contribute to the development of a comprehensive standard instrument for measuring ITC that supports repetitive and systematic studies across contexts (Santhanam & Hartono, 2003).

Conclusion

This study has yielded empirical findings that demonstrate the associations between the perceived levels of achievement in some ITC dimensions and the organizational constructs, namely the BPI and IT governance constructs. Such associations may be regarded as hints that it is necessary for firms to properly manage these organizational factors, in the course of planning and executing any IT adoption and business process management initiatives. An in-depth understanding of the influence of various organizational factors may contribute to the further refinement of practice, and to better outcomes in IT adoption and business process management.

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Chapter 6.4

The Contingent Role of Innovation between IT Management Sophistication and Strategic Alignment

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ABSTRACT

To provide deeper insight into IT managerial adaptive processes considered in strategic alignment mechanisms, we propose, using contingency theory, that the degree to which IT management sophistication contributes to a company's success is contingent upon its adaptive innovated behavior. Results suggested that Taiwanese companies could succeed when IT management sophistication is appropriate for a certain innovation. Our research model was generic for foreign companies' strategic behavior because, based on contingency theory, these companies make dynamic adaptations toward their particular environment for a competitive IT-based innovation. Implications of results are discussed. [Article copies are available for purchase from InfoSci-on-Demand.com]

INTRODUCTION

What certain sophisticated level of information technology (IT) management practices is more critical to the effectiveness of a particular innovation? Such a question has widespread practical, as well as theoretical, ramifications because a company's success may be realized only when appropriate IT is used to underlie a certain innovated business orientation (Kamal, 2006; Lacity, Willcocks, & Feeny, 1996).

IT management sophistication means evolution of a company's IT management practices such as information systems (IS) expenditure, IT use experience, IS function, and so forth (Gupta, Karimi, & Somers, 1997). It reflects the extent to which IS strategy can be formally pursued to support overall company goals, indicating that IS strategy should be progressively aligned with other strategies as the company grows over time toward maturity (Slaughter, Levine, Ramesh, Pries-Heje, et al., 2006). This implies that a company's success can be measured by a greater strategic alignment (Hirschheim & Sabherwal, 2001; Kearns & Lederer, 2004; Luftman, 2003; Luftman & Brier, 1999). Strategic alignment means achievement of cohesive goals across IT and other organizational functions (Luftman, 2000).

Various components of "strategic alignment" have been examined in different areas of IS research. For example, in IT governance, a control mechanism concerning decision-making, alignment, and communication is used to ensure the successful use of IT (Weill & Ross, 2004, 2005). In operations management, sustainability depends on internal consistency between companies' strategies and their manufacturing operations (Krajewski & Ritzman, 2005). In the role of senior executives in IS planning, top management support facilitates the effectiveness of IT assimilation (Liang, Saraf, Hu, & Xue, 2007). In the strategic IS planning process, analytical and administrative approaches are used to align strategic management to IT management through a set of capabilities (e.g., governance, technical, and personnel) (Henderson, Venkatraman, & Oldach, 1996; Venkatraman, Henderson, & Oldach, 1993). More recently, the impact of strategic alignment between IS function, IT infrastructure, organizational infrastructure, and business planning processes on company performance has been widely studied (Sabherwal & Chan, 2001; Sabherwal, Hirschheim, & Goles, 2003; Tallon, Kraemer, & Gurbaxani, 2000). In the effective use of IT, contextual factors (e.g., environmental uncertainty, information intensity, etc.) have significant impact on business dependence on IT (Kearns & Lederer, 2004). More recently, situational contingencies (e.g., employee training, technical complexity, task interdependence, etc.) influence successful IS implementation (Sharma & Yetton, 2007).

Since these and other studies have described various contexts of alignment between IS and business strategies, our focus is more macro; that is, we used contingency theory to conceptualize the research model (Figure 1). Contingency theory emphasizes the importance of situational influences on the management of organizations (Govindarajan, 1988; Zeithaml, Varadarajan, & Zeithmal, 1988). In our model, IT management sophistication and innovation play a critical role of contingency (i.e., antecedent and moderator) that influences the posterior: strategic alignment.

In strategic perspective, moreover, we consider variables in our model not only as content but also process-oriented factors because the environment is dynamic. Sabherwal and Chan (2001) noted that "strategy content" concerns aspects of business strategy aligned with aspects of IS strategy while "strategy process" is focused on how a company develops and implements its management practices.

Henderson and Venkatraman (1993) proposed a "logic strategic alignment framework for analyzing strategic choices in enough detail to ensure successful implementation of business, technology, and infrastructure direction" (p. 205). Although this model emphasizes the process of strategic alignment, Tallon (2003) regarded it as a range of managerial and administrative actions that transform the company by aligning the domain of choices contained within the content of strategic alignment. Hence, our model is both process and content oriented.

We treat "IT management sophistication" as process oriented, since it relates to the changing (adaptive) process of IT managerial activities that evolve toward formalization as the company grows over time (Gupta et al., 1997) and "strategic alignment" as content oriented, which refers to the aspect of IS plan to business plan and vice versa (Kearns, 1997).

By "innovation," we refer to a company's adaptation to the external environment, which can be considered as a typical business strategic typology

(Miles & Snow, 1978). With this contingent view, companies that seek innovation are more effective when their information processing requirements (e.g., business strategy) match their information processing capabilities (e.g., IT) (Teo, 1994). As such, innovation is a very social process by which there is awareness through certain channels (e.g., executive meeting, staff meeting, media, etc.) over time among members (e.g., manager, change agent, educated employee and client, etc.) of a social system (Rogers, 1983). Swanson and Ramiller (2004) also noted that "mindfulness plays a role in IT-based innovation by enhancing the recognition of organizational situations demanding inventive response" (p. 556), implying a strategic nature of innovation.

Our research objective is to clarify whether a certain sophisticated level of IT management practices is more important for a certain innovation pursued than for others to achieve a strategic alignment. Grounded on contingency theory, we proposed the strategic alignment framework of company adaptation. This framework addresses the issue: "how IT resources can be strategically used to be an innovative company."

Taiwan is an ideal location to examine the issue. Based on 2007 statistics by the Department of Investment Services, Ministry of Economic Affairs (twbusiness.nat.gov.tw/asp/invest.asp), Taiwan had one of the largest foreign direct investments (ranked third) in ASEAN (Association of Southeast Asian Nations). Moreover, the amount of its direct investment to China has had a substantial increase (21%) since 2006. Taiwanese companies have been facing increased foreign competition (e.g., China, ASEAN) after Taiwan's admission to the WTO in 2001, thereby making it increasingly necessary for them to focus on IT-based innovations in products and market development (Chen, 2003). For example, Singapore has implemented a series of national IT plans and programs to encourage diffusion of IT in both public and private sectors by providing various nationwide electronic networks (e.g., TradeNet, PortNet, MediNet) for business transactions (Thong, 1999). This has drawn the Taiwanese government's attention to retain its overall industry's global competitiveness by launching *e-Taiwan* project under 'Challenge 2008: The six-year national development plan".

However, difficulties such as high cost, technical complexity, and long time lag may contribute to "IT productivity paradox" (i.e., IT does not necessarily generate productivity) (Lucas, 1999). Although the use of IT has likewise evolved in substantial ways and indeed attracts senior management's interest by its importance to innovation, the over-hyped promise has left many senior executives uncertain about the outcome of IT (Lucas, 1999). For example, it was clear that the IT payoff has been identified as the key to the type of IT-based innovation determined in Taiwan (CIO, 2006), implying that using IT strategically (i.e., strategic alignment) becomes a key to Taiwanese executives when pursuing innovation. This local IS management argument is consistent with that in the Western business frameworks with increasing emphasis on the strategic alignment recently (Luftman & McLean, 2004; Maltz & DeBlois, 2005; Prewitt, 2004; Tallon & Kraemer, 2003).

This article extends the cumulative tradition of IS research to emphasize the importance of the contingent role of innovation that changes the relationship between IT management sophistication and strategic alignment directed towards a company's success. By showing how Taiwanese companies adjust the strategic sophisticated positions of IT in accordance with their pursuit of innovation, foreign companies are expected to refer to this adaptation in their IT management practices improvement.

First, we define the contingency theory for the basis of strategic alignment, IT management sophistication, and innovation. Next, we provide our research framework; followed by a description of the factors used to measure strategic alignment, IT management sophistication, and innovation; the method used to collect the data; and a discussion of the results obtained in our study. Finally, we conclude with implications for both researchers and practitioners.

THEORETICAL BACKGROUND

Contingency theory (CT) argues that "effectiveness" depends on appropriate fit of contextual factors with internal organizational designs (Pfeffer & Salancik, 2003). CT has contributed to the quality and productivity of IS function and to the larger company by providing feedback to manage and improve IS function to better fit the business needs (Benlian & Hess, 2007; Langdon, 2003). It argues that an IT-organizational relationship is not a simple linear causal one that can be identified by whether it is a technical or organizational imperative, but a dynamic evolution through organizational practices (e.g., managerial experiences) (Lee & Grover, 1999/2000) that match external characteristics (e.g., environment) (Pfeffer & Salancik, 2003)

In IS literature, several contingency antecedents (e.g., environmental [dynamism], technical [connectivity] or organizational [business knowledge of IS manager, business strategy, information intensity, size, structure, user satisfaction]) have been included in the analysis of a "fit" relationship (Benlian & Hess, 2007; Ducan, 1995; Earl, 1993; Jiang, 2003; Kearns, 2000; Kearns, 2005; Kearns & Lederer, 2004; Wang, 2001). Using these antecedents, IS research examined the problems, benefits, methodologies, and management issues of the IS planning process (Doherty, Marples, & Suhaimi, 1999; Lederer & Sethi, 1996; Ragu-Nathan, Apigian, Ragu-Nathan, & Tu, 2004; Tang & Tang, 1996; Teo & Ang, 2001).

Such an IS planning process generally relates to the sophisticated level of IT management practices emphasizing what contingencies should be included for IS planning approaches (e.g., techniques for identifying and deciding IT investment, and measuring IS success) and thus, affect a company's competitive position (Karimi, Somers, & Gupta, 2001; Saeed, Malhotra, & Grover, 2005; Wang & Tai, 2003).

To fulfill our research objective, using CT, we were able to examine a company's adaptive process for pursuing a competitive IT-based innovation, which is believed to be of interest to Taiwanese and global practitioners. The CT relevant theoretical concept of strategic alignment, IT management sophistication, and innovation are introduced in the followings.

Strategic Alignment

Based on CT, managers must consider (adapt) all kinds of situations to ensure cohesive goals across administrative and technological domains (Pfeffer & Salancik, 2003). Thus, "strategic alignment refers to applying IT in harmony with business strategies, goals, and needs" (Luftman, 2000, p. 3). Despite its criticism that "too fit" between IS and business strategies may reduce strategic flexibility (Jarvenpaa & Ives, 1994), researchers have argued that the inability to realize better business performance from IT, in part, is due to a mismatch between IS and business strategies (Benco & McFarlan, 2003; Croteau & Bergeron, 2001; Henderson & Venkatraman, 1999; Kearns & Lederer, 2003; Tallon, 2003).

While there is little agreement on conceptualizing strategic alignment and its research basis (Avison, Jones, Powell, & Wilson, 2004), Henderson and Venkatraman's (1991) strategic alignment model is believed to be the most influential research that conceptualized the strategic alignment between IT and business requirements. Their model contains four contingencies of business strategy, IS strategy, organizational infrastructure and processes, and IT infrastructure and processes by showing two fundamental "fit" relationships: strategic fit and functional integration. This implies that effective and efficient use of IT requires the alignment of IS and business strategies.

Henderson and Venkatraman (1993) argued that "strategic fit" recognizes the match between internal and external characteristics of the company when pursuing competitive IT-based market position. This "fit" generally leads to "functional integration" or "cross-domain alignment" that emphasizes how IS strategy affects business strategy (Burn & Szeto, 2000; Hu & Huang, 2006). Therefore, as business strategy changes, IS strategy and processes must keep pace (Burn & Szeto, 2000; Earl, 1993; Galliers & Newell, 2003). An effective IT-based market position becomes critical to the company's ability to adapt and successfully leverage technology (Pfeffer & Salancik, 2003). Functional integration provides the company with IT opportunities to gain competitive advantage (Reich & Benbasat, 1996).

After Henderson and Venkatraman's (1991) conceptual work, researchers have developed several alignment models to empirically demonstrate to practitioners the advantages of strategic alignment as shown in Table 1. While these studies focused on the process-oriented mechanics to realize strategic alignment, intellectual (i.e., content) factors are also emphasized. For example, Reich and Benbasat (2000) argued that although in the short term, communication between executives plays a significant role of strategic alignment, shared domain knowledge between IT and business managers may be potential to generate successful IS implementation in the long run. Chan (2002), Kim (2003), and Rathnam, Johnsen and Wen (2004) also noted that intellectual contingencies such as communications, trust, vision, and culture are important to strategic alignment as the company grows over time. More recently, Bassellier, Reich and Benbasat (2003) noted that a CEO's IT competence contributes to the effective use of IT. In support of that, Broadbent and Kitzis (2005) emphasized that collaboration between the CIO with the CEO is crucial to effective strategic alignment.

Table 1. Key empirical works of process-oriented strategic alignment

Contributors	Type of Alignment	Results
Byrd, Lewis & Bryan (2006)	IS-Business Alignment	Investigating moderating role of strategic alignment between IT investment and performance, indicting there is a synergistic coupling between strategic alignment and IT with company performance.
Hu & Huang (2006)	IS-Business Alignment	"Relationship management" has a significant impact on IS and business strategies alignment, using balanced score card.
Peak, Guynes & Kroon (2005)	IS-business Alignment	The planning process based on a case study is found to help align IT with business strategies and improve and facilitate the communication on IT project management.
Avison, et al. (2004)	IS-Business Alignment	Validating a strategic alignment framework that allows executives determine current alignment levels and monitor future alignment required.
Pollalis (2003)	Integration (Technological, Functional, Strategic)	Co-alignment improves overall organizational performance
Hartung, Reich & Benbasat (2000)	Business-IS Alignment	The lack of connection between business and IT planning due to the relatively immature business planning processes within the forces.
Kearns & Lederer (2000)	IS-Business Alignment Business-IS alignment	Both IS-business and business-IS predict the use of IT for competitive advantage.
Tallon, Kraemer & Gurbaxani (2000)	Business-IS Alignment	Strategic alignment and IT evaluation contribute to high-perceived value of IT business value.

Some researchers attempt to demonstrate to practitioners how to accomplish strategic alignment. For example, Luftman and Brier (1999) proposed a six-step approach to achieve greater strategic alignment by identifying contingencies (both enablers and inhibitors [also see Burn [1997]; Hsaio & Ormerod [1998]; Yetton [1997]]) in a survey of corporate executives of large U.S. companies. Luftman (2003) proposed five levels of IT-business alignment benchmark over six categories that cover business and IT issues to help executives assess the maturity of strategic alignment. Some researchers also argued that IT governance may help in aligning IS strategy to business strategy. For example, Weill and Ross (2004) proposed the executives' decision-making and accountability models to seeking appropriate IT investments. Brown and Grant (2005) further proposed a logistical IT governance framework to find an appropriate mechanism to govern corporate IT investments.

Realizing the strategic alignment is a difficult, complex, and long-term task (Hu & Huang, 2006). To facilitate this task, Weiss, Thorogood and Clark (2006) suggested that internal organization and external market factors should both take into account the alignment thinking in terms of technical resource, business enabler, and strategic weapon. In this sense, to respond to a dynamic environment, properly exploiting IT as a strategic resource has been viewed as important for sustaining competitive advantage (Chung, Rainer, & Lewis, 2003; Porter & Millar, 1985). To fulfill this expanded mission, the IS strategy must be in alignment with business strategy (Kohli & Devaraj, 2004).

IT Management Sophistication

IT management sophistication (ITMS) is defined as the progression toward increasingly formalized management of IS function (Karimi, Gupta, & Somers, 1996). Thus, ITMS is used to examine the extent of formalization (effectiveness) to which IT management practices can be pursued and linked to business strategy (Gupta et al., 1997).

Since its relevance to IS strategy, ITMS involves the changing process of how contextual factors can be appropriately matched to achieve effective IS planning and implementation (Kearns & Lederer, 2000). Kim (2003) argued that such a process can be viewed as being a strategic alignment process, seeking to the "fit" among contextual factors within an organization to demonstrate that a company's success is contingent upon those factors (Devaraj & Kohli, 2002).

The theoretical basis of ITMS has two forms. First, Nolan's (1979) studies on the stage hypothesis developed six growth stages construct—initiation, contagion, control, integration, data administration, and maturity—indicating that IS expenditure follows the path of an S curve over time from computer (less formal IT management [the first three stages]) to information management (more formal IT management [the last three stages]). Second, McFarlan and McKenney's (1982) technology assimilation model is an extension of the stage hypothesis model and attempts to provide a more detailed contextual view of the overall IT diffusion process and the evolution of IT management through four phases: investment, learning and adaptation, control, and widespread (Lu, Liu, Jing, & Huang, 2005).

Research on IS stage hypothesis and the technology assimilation model suggests using managerial practices (i.e., various stage-based adaptations in the face of environmental pressures) concerning IT-based activities as benchmark variables to measure the progression of a company's move towards a certain level of ITMS (Karimi, Bhattacherjee, Gupta, & Somers, 2000). Based on the two models, Karimi et al. (1996) classified ITMS benchmark variables into four contingencies: planning, control, organization, and integration to examine the extent of evolution of formalized management of IS functions that support a company's business need. Gupta et al. (1997) noted that the evolutionary role of IT and the extent to which IS strategy can be effectively pursued depend on the ITMS of a company.

As such, the ITMS contingency framework indicates significant variations between companies to the extent to which their IS strategy has been aligned with their business strategy (Karimi et al., 2000). These variations are reflected in three evolutionary roles (operational, strategic, and integrated) of the IT-based resources within a company (Gupta et al., 1997). Teng, Cheon, and Grover (1994) argued that a business strategy should be linked to this evolution. A greater ITMS represents a significant formalization of planning (Duh, Chow, & Chen, 2006;), control (Duh et al., 2006), organization (Palanisamy, 2005), and integration (Teo & Ang, 2001) of a company's IT-based activities, indicating that the IS function in a company evolves from computer data processing into a strategic IS orientation (Gupta et al., 1997), and then is more closely integrated into the company's business strategy (Lu et al., 2005).

Innovation

Innovation is defined as, "Implementing new ideas that create value" (Linder, Jarvennpa, & Davenport, 2003), and generally refers to the various types of innovation that can take place, such as product development, deployment of a new process technology, and/or innovative management practices (Zott, 2003). In the innovation literature, theoretical models such as Rogers' (1983) diffusion of theory (DOT) and Davis' (1989) technology acceptance model (TAM) have been widely used and are believed to be the most influential theories in explaining and predicting IT use and innovation (Chen & Tan, 2006).

DOT explains five stages (initiation [stage 1-2] and implementation [3-5]) of the decision process of adopting an innovation (Rogers, 1983), concerning contingencies such as relative advantage, compatibility, complexity, triability and observability that are associated with the adoption (Rogers, 2003). Based on these contingencies, the category of adopter is determined and helps predict the possibility and the rate of innovation adopted (Chen & Tan, 2006).

TAM is designed to explain the determinants of user acceptance of end-user computing technology, positing that perceived usefulness and perceived ease of use are the key to the adoption (Davis, Bagozzi, & Warshaw, 1989). This model hypothesizes that IT use is influenced by the user's behavior, which is in turn affected by the user's attitude to use and thus beliefs about new IT (Chen & Tan, 2006).

Based on both TAM and DOT, Chen, Gillenson and Sherrell (2002) found significant consumer behavior in a virtual store. Huang, Lu and Wong (2003) extended TAM and found that cultural factor "power distance" significantly moderates the relationship between subjective norms on perceived usefulness of e-mail. Hsu, Lu and Hsu (2007) further used DOT and found there was a significant difference between potential adopters and users by examining users' perceptions of adopting mobile Internet.

Besides the individual adoption, some researchers argued that innovation adoption can be made at the organizational level (Fichman & Kemerer, 1997). For example, Lucas, Ginsberg and Schultz's (1990) two-step model indicated that organization members' adoption of innovation depends on their higher authority (senior manager) decision after identifying objectives to change aspects of business and finding available innovation that fits company objectives (Gallivan, 2001).

Therefore, innovation is an organizational process of pursuing new IT to business (Gallivan, 2001). Swanson and Ramiller (2004) called this process an organizing vision that forms the notion of "mindfulness" of a company to determine the rate of innovation adoption. This organizing vision involves experiences, ideas, and beliefs of many diverse interests when adopting new IT (Swanson & Ramiller, 1997) and evolves innovation decision from material toward more company-oriented (Scott, 2000).

Since our research issue is strategic by nature, the term "innovation" would focus on the organizational process of management objectives and intentions for change and can be viewed as a business strategic process (Miles, Snow, Meyer, & Coleman, 1978). Based on CT, it drives a company to adapt to its environment through continuous strategic adjustments (e.g., business process, alliance, mergers and acquisitions) using innovation in technology and administrative processes (Patrakosol & Olson, 2007; Srivardhana & Pawlowski, 2007). Knott (2003) noted that innovation and business strategy are intertwined in the efforts to sustain competitive advantage. However, Shoham and Fieganbaum (2002) argued that the need exists for an additional integrated theory to link organizational (strategic) context with innovation.

Although there are many dimensions of strategic behavior (e.g., Porter's [1985] generic strategies), we used the Miles and Snow (1978) typology, since innovation is one of the principal drivers of prospectors. Having a strong theoretical and empirical foundation (Ghoshal, 2003), the Miles and Snow typology focuses on the dynamic process of adjusting to environmental changes and uncertainty (DeSarbo, Benedetto, Song, & Sinha, 2005). The key concept underlying Miles and Snow's typology is the rate at which a company changes its products/services or markets to sustain competitive advantage (Singh & Agarwal, 2002). In IS planning literature, it is often used as a surrogate for measuring the extent of a company's strategic orientation in conducting IT-based innovation (e.g., Kearns [2005]). The Miles and Snow typology is relevant to this study on strategic alignment, since IT is related to both strategic response and organizational systems (Hambrick, 2003).

Hence, "innovation" may be viewed as a company's adaptation that is a typical business strategy (Blumentritt & Danis, 2006). CT views this adaptability as "management flexibility" that emphasizes the influence of IT on organizational structure and its fit with the environment (Porter & Millar, 1985; Tallon, 2003). Various levels of executives perceived that environmental complexity and uncertainty give rise to different types of adaptation, and thus, different types of companies (Miles et al., 1978). Each type of company has an opportunity to succeed, as long as IT is effectively used to facilitate the characteristics of that type of company to match the complexity and uncertainty it perceives (Blumentritt & Danis, 2006).

Miles and Snow (1978) proposed alternative ways that companies define their product/market domains and construct mechanisms (i.e., structures and processes) to pursue those domains through the adaptive cycle. Using CT, the adaptive cycle focuses on the "fit" and conceptualizes three intricately adaptive problems—entrepreneurial, engineering, and administrative—that senior executives need to simultaneously and continually solve to maintain an effective alignment with its environment (O'Regan & Ghobadian, 2006; Shortell & Zajac, 1990). As shown in Table 2, the three adaptive problems are confronted within each of the four patterns in a company's adaptation (the strategic type)—defenders, prospectors, analyzers, and reactors—describing various levels of innovativeness pursued to respond to business dynamics (Miles & Snow, 1978).

Based on Table 2, a defender tends to provide relatively stable products/services, doing the best job in its area of expertise. It emphasizes tight control and continuously seeks to operate efficiently at lower costs. A prospector frequently adds and changes its products or services, being the first mover in the market. It tends to stress innovation and flexibility to quickly respond to market changes. An analyzer, which is a combination of the defender and prospector traits, emphasizes formal planning processes and balances cost containment and efficiency with risk taking and innovation. A reactor basically lacks any consistent strategy.

Both defenders and reactors are concerned with cost reduction and efficiency (Conant, Mokwa,

Table 2. The miles and snow typology

Strategic Type	Domain Concern (Solutions to Entrepreneurial Problem)	Technical Concern (Solutions to Engineering Problem)	Alignment / Innovation Concern (Solutions to Administrative Problem)
Defenders (Stable): Low Adaptive	✓ Follow a major shift in the market ✓ Create a stable set of products and customers	✓ Continuously improve a single core technology ✓ Protect that core technology by requiring technological problems to remain familiarity and predictability	✓ Maintain strict control for efficiency ✓ Achieve production and cost control efficiency with little or no new environment scanning
Prospectors (Flexible): High Adaptive	✓ Allocate and exploit new product and market opportunities ✓ Protect the company from a changing environment ✓ Deal with low profitability and overextension of resources while sustaining product and market innovation	✓ Avoid long-term commitment to a single technology and to manage a multiple technologies ✓ Maintain a good technology flexibility ✓ Maintain decentralized control	✓ Facilitate and coordinate numerous and diverse operations ✓ Maintain flexibility and effectiveness in decentralized units ✓ Manage risk associated with low profitability and overextension of resources
Analysers (Balanced): Hybrid	✓ Locate and exploit new product and market opportunities while maintaining a traditional products and customers base ✓ Minimize the risk while maximizing the profits by imitating successful products or market innovations ✓ Keep the balance between stability and flexibility	✓ Achieve and protect an equilibrium between conflicting demands for technological flexibility and for stability ✓ Deal with technological base that is not efficient or effective	✓ Differentiate the company's structure and process to accommodate both stable and dynamic operations ✓ Coordinate intensive planning between marketing, production, and engineering ✓ Maintain a moderately centralized systems with vertical and horizontal feedback loops
Reactors (Unstable): Non-Adaptive	✓ Articulate company's strategy ✓ Adjust to an environment that is both inconsistent and unstable	✓ Control cost	✓ Maintain the company's structure and processes despite overwhelming environmental changes

Note: Modified by the author based on Gupta et al. (1997), Hirschheim and Sabherwal (2001), Miles and Snow (1978), and Shortell and Zajac (1990).

& Varadarajan, 1990). However, a defender has a clear strategy to control costs, depending on its internal resources (Matsuno & Mentzer, 2000). An analyzer must also engage in environmental scanning, like a prospector (Kearns, 2005). Since both prospectors and analyzers engage heavily in environmental scanning (Kearns, 2005), IT may play a more strategic role (Gupta et al., 1997).

The most important differences among the strategic types were the change in product/market domain, environmental and organizational features of that domain (Miles & Snow, 1978), and the existence of a continuum of adaptation starting from the defender as a low adaptive company, prospector as a highly adaptive company, analyzer as a hybrid company, and reactor as a non-adaptive company (Shosham, Evangelista, & Albaum, 2002).

DEVELOPMENT OF RESEARCH FRAMEWORK

Research Concept and Model

Our integrated research concept derives that the company becomes success (i.e., towards strategic alignment) when there is a fit between the external market response (e.g., strategic types of innovation) and the internal resources and skills (e.g., IT management practices) possessed by the company (Porter, 1991). Since various strategic types cause different forms of IT use (Kettinger, Grover, Subanish, & Segar, 1994; Porter, 2001), we proposed that the degree to which IT management practices may contribute to a company's success (strategic alignment [SA]) is contingent upon its adaptive innovated behavior (business strategy [BS]), showing that ITMS increases the understanding between senior business and IS executives regarding the strategic value of IT-based resources, which can be used as a determinant of the effective use of IT to distinguish and support various levels of innovation pursued (Figure 1).

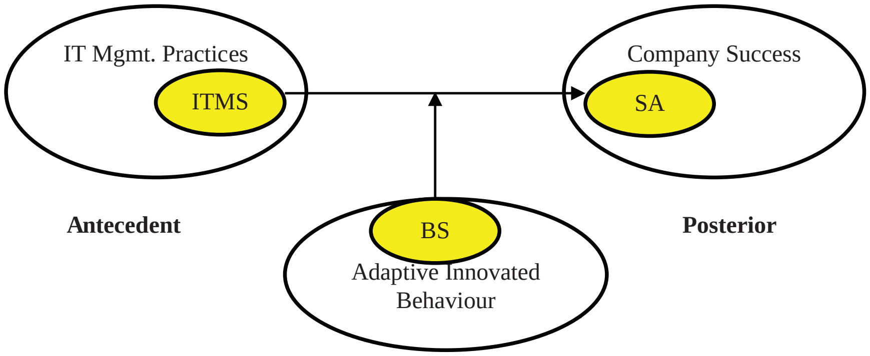
Research Hypothesis

To achieve competitive strategy, prospectors are usually aware of the changes and innovation of products or services and spend more time in scanning the uncertainty of customers and rivals' actions, toward opportunities for products, services, and market differentiations (Chong & Chong, 1997). They are likely to be first to the market place and seek to exploit this advantage; they also have a tolerance of risk and an acceptance of change, empowerment, and flexibility (O'Regan & Ghobadian, 2005). A prospector strategy requires organic features (e.g., coordination committee) to be effectively implemented (Karimi et al., 2000). This organic context will foster innovation relevant to prospecting and differentiation (Garcia-Dastugue & Lambert, 2003).

Prospectors require more sophisticated configuration of IT-based resources to handle divergent interests and heterogeneous points of the parties in the value chain (Kearns, 2005; O'Regan & Ghobadian, 2006). They emphasize the strategic alignment through business leadership and choose an IS strategy that allows them to both create and change the market (Hirschheim & Sabherwal, 2001). This IS strategy normally prefers "infusion" of IT into innovation (Segev, 1989). Specifically, the role of IT is proactive and opportunistic in innovating the business need (Hirschheim & Sabherwal, 2001).

Defenders spend less time in environmental scanning since the environment where they operate is more stable and predictable (Hambrick, 2003). Govindarajan and Fisher (1990) argued that a defender strategy could be more effective with mechanistic features such as less user in-

Figure 1. Contingency framework of IT management practices and company success



volvement and less motivation (less innovative). Under mechanistic features, a physical structure for the defender usually emphasizes rigid and cost-effective configuration appropriate for strict control and strong efficiency (Das, Zahra, & Warkentin, 1991; Matsuno & Mentzer, 2000). Miller (1987) found that strict control procedures, mechanistic administrative policies and output controls correlate with high performance for companies with more defensive and conservative orientation. Defenders favor IT developed internally and acquire transactional IT-based resources to manage their control and efficiency priorities effectively, reflecting less distributed and sophisticated types of IT-based resources utilized (Karimi et al., 1996; Kearns, 2005; Lu et al., 2005).

This is in contrast to prospectors who are externally postured and tend to acquire more computational, analytical, and decisional IT-based resources to scan the uncertain environment for managing complexity effectively (Crichton & Edgar, 1995). Teng et al. (1994) argued that defenders do not search outside their domain for new IT opportunities and sometimes overlook new IT development. They must rely on a few core technologies to offer high quality products or services at low prices and rarely adjust their organizational structure and technology (Sabherwal & Chan, 2001). Hence, defenders emphasize the strategic alignment through low cost delivery and choose an IS strategy that supports business through the most economical vehicle for the provision of current products or services and is based on a centralized IS function (Hirschheim & Sabherwal, 2001).

Combining a prospector's innovation and a defender's efficiency, analyzers use a comprehensive organizational structure and a dual technologies core, seeking effectiveness through both efficiency and new products or services and markets innovation (DeSarbo et al., 2005). Nevertheless, Gupta et al. (1997) argued that the company might fail to demonstrate one or both, since these conflicting demands are difficult to address simultaneously.

Despite that, analyzers usually can observe the market avidly and respond very quickly to the changes, since successful imitation is accomplished through high levels of internal and external analysis performed (Shortell & Zajac, 1990). They make strategic choices typical to prospectors in the newer and more dynamic endeavors (e.g., spending more time in IS planning activities) (Gupta et al., 1997) while adopting a strategy typical to defenders in the traditional and stable business lines (Teng et al., 1994). This requires a balance of locating new business opportunities and maintaining existing customer bases (Hambrick, 2003).

In the absence of clear strategic orientation, reactors make decisions in a reactive rather than a proactive way (Miles & Snow, 1978). Reactors seldom do environmental scanning for long-term forecasting because they believe that the environment will favorably support anything they do or not do (Zahra & Pearce, 1990). Reactors will not follow a specific strategy to secure IT-based resources (DeSarbo et al., 2005). Reactor IS executives are expected to spend more time in organization-related IT activities than to spend more time in impacting the company's competitive strategy (Matsuno & Mentzer, 2000).

Consequently, when a company emphasizes innovation, the company's IT management practices are likely to spend more time in adopting more complex decision-making tasks and have greater incentive for information processing in the form of scanning, planning, analysis, and consultation (Hambrick, 2003). On the contrary, when a company adopts a conservative strategy, the company's IT management practices are likely to spend more time in seeking to perform effective operational and managerial control (DeSarbo et al., 2005). For those companies in intermediate situations, they are likely to spend more time in promoting strategic control and synergy and providing the main benefits of the aforementioned both (Kearns, 2005). The following hypotheses are formulated.

H1: *Relationship between IT management sophistication and strategic alignment will be contingent on the strategic type of innovation pursued.*

H2: *To sustain competitiveness, the strategic type of innovation pursued will differ with respect to the degree of IT management sophistication.*

We assumed that the above relationship should be true in Taiwan's context since Wang and Tai (2003) have evidenced that Taiwanese organizations' strategic planning (i.e., how companies adapt to business environment [innovation]) mediates the relationship of internal organizational characteristics (e.g., formalization [planning], centralization [control], future role of IS [integration]) and IS planning effectiveness (organizational co-alignment). Based on CT, this hypothesized relationship also can be true in other countries since companies tend to seek to appropriate IT capabilities (e.g., IT management practices) for a better IS-business "fit" relationship while pursuing competitive innovation (e.g., Benedetto & Song's (2003) study in China).

METHODOLOGY

IS executives were selected as respondents because they were perceived as the most knowledgeable about the company with regard to strategic positioning and IT-based resources and activities (Gupta et al., 1997). For ease of discussion, we defined the term *CIO* (chief information officer) as the senior IS officials with various given titles. Respondents used a seven-point Likert scale ("7 = strongly agree" to "1 = strongly disagree") to record their responses on a questionnaire.

Measures

SA was measured by both alignment of IS strategy with business strategy (ISBUS) and alignment of business strategy with IS strategy (BUSIS) (Kearns & Lederer, 2004). Since it is content-oriented as noted, the former was measured by "IS plan reflects the business plan," "the recognition of external environment," and "the necessity of an IS plan because of resource constraints" (Kearns & Lederer, 2004; McFarlan & McKenney, 1982; Zviran, 1990). The latter was measured by "business plan reflects IS plan," "performance of IT," "use of IT to guide business strategy," "use of strategic capability of IT," and "reasonable expectations of IT" (Goldsmith, 1991; Premkumar & King, 1991, 1994).

Based on Karimi et al. (1996), we used 20-item containing four dimensions: planning IT (PLN), control IT (CTR), organization IT (OGN), and integration IT (ITR) to assess ITMS. "PLN" measures IS planning process characteristics by "types of IT," "strategic IT opportunities," "the current or potential use of IT," "the coverage and quality of IT," and "arrangement of IT project priorities" (Earl, 1993; Gupta et al., 1997; Premkumar & King, 1994). "CTR" measures manager's control over budgeting, priority setting, and resource planning for the IS function by "responsibility and authority," "development and operation," "proper appraisal of IT projects," "monitoring of IT performance," and "clear IS function" (Cash & Konsynski, 1985; Cash et al., 1992; Gupta et al., 1997). "OGN" measures the influence of IS department on the company by "special attention of user's ideas," "awareness of business and the organization," "coordination," and "good relationships between IT specialists and end users" (Cheney, Mann, & Amoroso, 1986; Gupta et al., 1997). "ITR" measures how IT integrates for various business functions through top-down planning process by "perceived strategic importance of future IT," "linkage between

IS planning and business needs," "IT resource available to business needs," and "adaptation and adoption of new technology" (Gupta et al., 1997; Johnston & Carrico, 1988).

To assess BS (i.e., innovation), the self-typing approach was used since the CIO is up-to-date on the company's direction and may identify intended innovation (Kearns & Lederer, 2000) and has been widely treated as an appropriate method to measure business strategy (Conant et al., 1990). We adopted paragraph descriptions of the four archetypes in Miles and Snow's (1978) typology: defenders, prospectors, analyzers, and reactors to assess company's strategic orientation. Accordingly, the respondents were asked to place their companies on a seven-point scale questionnaire that reflects a continuum of products or services innovation (Shortell & Zajac, 1990).

Sample and Pre-Tests

We examined companies grouped by Taiwan SIC (social industrial classification) (see general results in Table 6). Although this is a single country research, based on CT, the generalization of our research model to other countries is expected in terms of "fit" relationship that every country's business and IS executives should seek between business and IT-based resources.

The sample groups have been regarded as knowledge and information-intensive and use IT within all aspects of management and global implication, which is suitable for this kind of study (Sabherwal & Chan, 2001). *The Year 2006 Largest Corporations in Taiwan-Top 5000*, published by the China Credit Information Service, Ltd. (www.credit.com.tw), was used to search for companies. *The Year 2004 Top 1000 Firms in Taiwan*, published by "Commonwealth" magazine (www.cw.com.tw), provided the supplemental sources. After careful screening, 874 companies qualified for inclusion in the sample after satisfying five requirements (autonomy in selecting strategies, size over 250 employees, a structural position [IS manager], operation over three years, and implications of global business [overseas branches or affiliations]).

The development of questionnaire involves a series of refinement using IS doctoral students, IS professors, and IS practitioners. Changes in the wordings of certain items to improve clarity and minimize ambiguity were made. Forty-six face-to-face CIO interviews were completed over the one-month period of pre-test. A measure of internal consistency was calculated for each of four dimensions underlying ITMS construct and each of two dimensions underlying SA construct, respectively generating an acceptable Cronbach's Alpha value of 0.513~0.920 and 0.839~0.922 (Nunnally, 1978) and showing no significant difference from the comments received during the questionnaire refinement.

Survey Execution and Non-Respondent Bias Test

The survey was sent to CIOs in 874 sample companies via e-mail and post. During the survey, 209 useable questionnaires resulted, an overall response rate of 24% (209 of 874 surveys), regarded as a reasonable good rate that is corresponded with findings (20~28%) from previous Western IS planning research (Griffith & Finlay, 2004; Gupta, et al., 1997; Zahra & Covin, 1993). However, in contrast to 12~16% from local IS studies (Wang & Tai, 2003), our response rate is higher. This is perhaps because we are the first local study to examine the contingent effect of innovation on the strategic use of IT that draws Taiwanese companies' attention and our in-depth tracking and monitoring the completion of questionnaires reminded and encouraged non-responding CIOs to complete their surveys. Characteristics of respondents and non-respondents were compared for differences in terms of company type (chi-square = 5.33 [9 df, p = 0.804]), sales revenue (chi-square = 2.12 [6 df, p = 0.902]), and company size (chi-square = 7.03 [4 df, p = 0.134]). No significant differences were found at the .05 level of confidence ($p > 0.05$).

Reliability and Construct Validity of ITMS and SA Domains

Principal component analysis was used to retain the theoretical structure of factors ITMS and SA. Items with factor loadings below 0.5 on any factor or with factor loadings above 0.5 on more than one factor were dropped (Hair, Anserson, Tatham, & Black, 1998). When loading onto more than one factor, the varimax-rotated factors were used for subsequent analysis if they were statistically interpretable and theoretically meaningful. Items loadings in the rotated factor matrices were used to interpret and label the factors emergent. Eigenvalues for variation examined the number of factors largely responsible for variation in the data. The cut-off for the number of factors was one eigenvalue (Kaiser, 1974).

Based on this rule, the theoretical structure of factors "CTR" and "OGN" underlying ITMS and factors "ISBUS" and "BUSIS" underlying SA were confirmed (Table 3). Factor "PLN" extracted out two separated factors "AWR" (awareness) (F1, [PLN3 and PLN4]) that concerns the awareness of the outside changing the IT environment and "ISP" (IS plan) (F2, [PLN1, PLN2, PLN5~6]) that concerns the aspect of how the organization copes with the business environment through the IS plan. Emerging from factor "ITR," "TDW" (top-down) (F1, [ITR1 and ITR2]) concerns the aspect of IS top-down integrating process whereas "BUP"

Table 3. Rotated component matrix

Dimension (1st order)	Item Measuring	F1	F2
Planning IT			
PLN1 (A1)	Support of IT objective to business objective		0.854
PLN2 (A2)	Continuous examination of IT opportunity		0.608
PLN3 (A3)	Adequate info about competitor use of IT	0.946	
PLN4 (A4)	Adequate info about competitor IT potential	0.938	
PLN5 (A5)	Adequate coverage and picture of our IT		0.750
PLN6 (A6)	Satisfaction of how IT project priorities set		0.543
Eigenvalues		3.159	1.066
Cumulative Variance Explained (%)		36.611	70.471
Control IT			
CTR1 (A7)	Clear responsibility/authority of IT direction	0.880	
CTR2 (A8)	Clear responsibility/authority of IT operation	0.866	
CTR3 (A9)	Confidence in IT project properly appraised	0.901	
CTR4 (A10)	Constant monitoring of IT performance	0.787	
CTR5 (A11)	Clear goals and responsibilities of IT function	0.809	
CTR6 (A12)	Clear criteria of IT performance evaluation	0.798	
Eigenvalues		4.248	

Note 1: The letters and numbers in parenthesis indicate the questionnaire item number.
Note 2: Only factor loadings greater than 0.5 are shown.

continued on following page

Table 3. continued

Cumulative Variance Explained (%)		70.792	
Organization IT			
OGN1 (A13)	Due attentions to user ideas	0.749	
OGN2 (A14)	Understanding business and organization	0.846	
OGN3 (A15)	Fit of IT structure with the organization	0.819	
OGN4 (A16)	Constructive relation between IT and business	0.780	
Eigenvalues		2.555	
Cumulative Variance Explained (%)		63.878	
Integration IT			
ITR1 (A17)	Perception of Future IT strategic importance	0.925	
ITR2 (A18)	Top down planning process for IS-business	0.914	
ITR3 (A19	Place of some IT resources within bus. unit		0.884
ITR4 (A20)	Introduction or experiment of IT within unit		0.865
Eigenvalues		1.943	1.310
Cumulative Variance Explained (%)		42.703	81.331
IS-Business Alignment			
ISBUS1 (B21)	IS plan reflects business mission	0.906	
ISBUS2 (B22)	IS plan reflects business goals	0.899	
ISBUS3 (B23)	IS plan reflects business strategies	0.927	
ISBUS4 (B24)	IS plan recognize external force	0.897	
ISBUS5 (B25)	IS plan reflects resource constraints	0.897	
Eigenvalues		4.098	
Cumulative Variance Explained (%)		81.964	
Business-IS Alignment			
BUSIS1 (B26)	Business plan refers to IS plan	0.911	
BUSIS2 (B27)	Business plan refers to a specific IT app.	0.949	
BUSIS3 (B28)	Business plan refers to a specific IT	0.933	
BUSIS4 (B29)	Business plan utilizes IT capabilities	0.875	
BUSIS5 (B30)	Business plan contains IT expectations	0.885	
Eigenvalues		4.150	
Cumulative Variance Explained (%)		82.997	

Note 1: The letters and numbers in parenthesis indicate the questionnaire item number.
Note 2: Only factor loadings greater than 0.5 are shown.

(bottom-up) (F2, [ITR3 and ITR4]) measures the aspect of IS bottom-up integrating process. Factor analysis was repeated to test the theoretical structure of each emergent factor. Correlation analysis was also conducted for two-item factors. Items for all respective individual emergent factors loaded onto a single factor, as expected, and item correlations for two-item factors were significant (0.01 level of confidence), thereby confirming the theoretical structure. Table 4 shows each (emergent) factor's loadings and acceptable Cronbach's coefficient alpha ranging 0.700~0.948 (Nunnally, 1978).

The representativeness of dimensions for ITMS and SA were tested by repeatedly dropping the factor with the smallest communality until the remaining factors loaded onto a single factor they represent (Chang, 2001), maximizing the percentage of variance (Bryman & Cramer, 1997). For each case, multiple items of a dimension were averaged into a single score that was used to compute factor loading. Consequently, a better ITMS factor structure including ISP, CTR, OGN, and TDW, which loaded onto a single factor (R^2 = 0.695, Table 5), was generated. ISBUS and BUSIS were used to reflect SA, which loaded onto a single factor (R^2 = 0.641, Table 5), indicating that they well captured the aspect of strategic alignment.

ANALYSIS AND DISCUSSION

Sample Characteristics

Table 6 contains several interesting general information about the companies. For example, sixty-five percentages of IT applications were implemented with cost reduction and efficiency as the primary purpose. Cost and efficiency remained the dominant objective for Taiwanese companies' strategic use of IT for innovation, although the Western IS literature has found effectiveness more often than efficiency as goals (Ward & Peppard, 2002). One plausible explanation is that Taiwanese companies are usually concerned with cost as they need to compete with companies in the region (e.g., China, Indonesia, Malaysia, Thailand, and Vietnam) where costs of doing business are generally less than that of Taiwan. Table 6 also shows 89% of CIOs wore the title managers or higher. This result suggested that responding executives were familiar with the strategic factors addressed in this survey. More than 60% of

Table 4. Uni-dimensionality of factors underlying ITMS and SA

Factor Original	Factor Emerged	Uni-Dimensionality	Cumulative Variance Explained (%[R^2])	Alpha Value	Correlation Between Two Items	# of Item Drop	# of Item Remain
PLN (6)	AWR (2)	Confirmed	94.938	0.946	0.899**	0	2
	ISP (4)	Confirmed	55.771	0.720		0	4
CTR (6)		Confirmed	70.792	0.916		0	6
OGN (4)		Confirmed	63.878	0.810		0	4
ITR (4)	TDW (2)	Confirmed	85.319	0.827	0.706**	0	2
	BUP (2)	Confirmed	77.164	0.700	0.543**	0	2
ISBUS (5)		Confirmed	81.964	0.944		0	5
BUSIS (5)		Confirmed	82.997	0.948		0	5

Note 1: Numbers in parenthesis identify the number of questionnaire item.
*Note 2: ** Correlation was significant at the 0.01 level of confidence.*

Table 5. Representativeness of ITMS and SA

Construct (Higher Order)	Representativeness of Dimension	Cumulative Variance Explained (% [R²])	# of 1st Order Factor	# of 1st Order Factor Drop	# of 1st Order Factor Used
ITMS	Confirmed	69.453	6	2	4 ISP (0.850) CTR (0.884) OGN (0.815) TDW (0.768)]
SA	Confirmed	64.066	2	0	2 ISBUS (0.843) BUSIS (0.816)

Note: Numbers in parenthesis indicate factor loadings.

Table 6 . General information about companies and personal information about CIOs

A. General Information							
Company Type							
Computer/ Communication	26%	Financial Service	20%	Health Care	1%	Utilities	2%
Hotel/Restaurant/ Entertainment	11%	Logistics/ Transportation	9%	Professional Services	11%		
Real Estate	7%	TV/news/ Publishing	5%	Wholesales/ Retail	8%		
Company Size		**Annual Sales (US$)**		**IS Dept. Size**		**IS Dept. History**	
250-800	39%	<=100 MM	53%	<=50	39%	<=10	36%
801-1000	22%	101-300 MM	17%	51-100	21%	11-30	39%
1001-3000	22%	301-1000 MM	16%	101-300	23%	>30	20%
3001-5000	7%	1001-3000 MM	4%	>300	13%	Unknown	5%
Over 5000	10%	>3001 MM	10%	Unknown	4%		
No. of IT App. Used		**Using IT App. History**		**Users of IT App.**		**Purpose of IT App.**	
<=10	44%	<=10	67%	Customer	35%	Cost Reduced	38%
11-30	24%	11-30	24%	Internal	59%	Efficiency	27%
>30	26%	>30	5%	Suppliers	4%	Differentiation	19%

continued on follwoing page

Table 6 . continued

Unknown	6%	Unknown	4%	Unknown	2%	Unknown	16%
Scope of IT App.							
Entire Range P/S	76%						
Only a Segment	21%						
Unknown	3%						
B. Personal Information							
Age		**Gender**		**Education**		**Title**	
<=30	1%	Male	87%	Bachelor	53%	CIO	10%
31-40	33%	Female	5%	Master	37%	VP/EVP/SVP	13%
41-50	35%	Unknown	8%	Others	7%	AVP	30%
>50	24%			Unknown	3%	Mgr/S.Mgr	36%
Unknown	7%					Others	2%
						Unknown	9%
Company Experience		**Industry Experience**		**Reporting Level to CEO**			
<=5	25%	<=10	28%	One down	80%		
6-10	30%	11-20	33%	Two down	11%		
11-20	23%	21-30	18%	Others	6%		
>20	16%	>30	15%	Unknown	3%		
Unknown	6%	Unknown	6%				

participating CIOs had acquired considerable work experience in the company (mean = 10 years) and within an industry (mean = 16 years). Overall, these CIOs were knowledgeable about their companies and industries. Eighty percent of senior IS officials were reported as one-step junior to the CEO (chief executive officer), suggesting that the relationship between the majority of CIOs and CEOs was more familiar than distant. Thus, Taiwanese CIOs expected to have easy access to shared decision making and assist in selecting innovation strategies, which would not markedly bias the results of this study.

The self-typing approach yielded the following breakdown of innovation: 46 defenders, 94 prospectors, 57 analyzers, and 12 reactors, supporting our expectation that all four strategic types were pursued within Taiwan industry context. In other countries, based on CT, the mix of strategic types of innovation should be expected since executives may have different adaptations to the environment (Miles & Snow, 1978). The distribution of innovation supports the basic assumptions relating to the existence of significant linkage between innovation and company type (chi-square = 44.748 [27 df, $p<0.05$]) and between innovation and company size (chi-square = 44.497 [9 df, $p<0.05$]), implying that innovation pursued in different business sectors or different company sizes can be successful in a given environment when the company acts consistently in innovative business strategy (i.e., strategic alignment). Based on the "fit" concept of

CT, this also should be applicable in other countries. Our result is consistent with studies done in the United States, which found that innovation of financial institutions had a significant relationship with company size and type (e.g., Karimi et al. [1996]; Gupta et al. [1997]).

Contingent Effect Test

To explore contingent or moderating effect, Sharma, Durand and Gur-Arie's (1981) moderated regression analysis (MRA) typology shows the moderating effects of variable Z on variables X (predictor)-Y (criterion) relationship. Through MRA, if a significant interaction between Z and X is found, then determine whether Z is significantly related to Y or X. If it is significantly related, Z is a quasi moderator. Otherwise, Z is a pure moderator. If a non-significant interaction between Z and X is found, then determine whether Z is significantly related to Y or X. If it is significantly related, Z is not a moderator. Otherwise, split the total sample into subgroups based on the moderator and then do a test of significance for differences in predictive validity across sub-groups. If significant differences are found, Z is a moderator (homologizer). Otherwise, Z is not a moderator and the analysis is concluded. To carry out MRA, the regression models are formulated as the below:

$$Y = a + b1\ X + b2\ S + e$$
$$Y = a + b1\ X + b2\ S + b3\ Z + e$$
$$Y = a + b1\ X + b2\ S + b3\ Z + b4\ X*Z + e$$

Where Y is the criterion variable, b_i is the regression coefficient, X is the predictor variable, S is the company size, Z is the moderator, and X*Z is the interaction of X with Z. In IS literature, the company size is a very important variable that may influence IS-business relationship (Das et al., 1991) and was included in the model as a control variable.

Given the above procedures, the moderating effect of BS (Z) on ITMS (X) –SA (Y) relationship was tested. Since reactors have been ignored in the majority of previous studies (Hirschheim & Sabherwal, 2001; Sabherwal & Chan, 2001; Zahra & Pearce, 1990), this type was not included in the following analysis. Two dimensions: CTR and OGN underlying ITMS were significantly interacted with BS (interactive β=-1.196 and -1.808 respectively, $p<0.05$) while the other two dimensions: ISP and TDW were not (Table 7). Further tested by correlation analysis (Table 8), BS was found significantly correlated with either SA (0.148, $p<0.05$) or CTR (0.285, $p<0.01$), indicating that "innovation" is a quasi-moderator that impacts the form of the relationship between CTR and SA and between OGN and SA and simultaneously, has significant relationship with SA and CTR. As for those non-significant interactions between ISP and BS and between TDW and BS, BS has a significant correlation with either SA, ISP (0.195, $p<0.01$), or TDW (0.241, $p<0.01$), implying that "innovation" is not a moderator but a predictor that has a direct positive relationship with SA regardless of the degree of ISP or TDW.

Thus, H1 was partly supported, evidencing that although Taiwanese companies generally tend to be adaptive (i.e., innovative) in nature and perceive the importance of all four modes of IT management sophistication to their company success, two modes of "control IT" and "organization IT" substantially lower the degree of strategic alignment. For example, based on CT, IT management for prospectors is supposed to be more decentralized (low control IT) and more end user's involved (high organization IT) for the exploration of rapidly changing or prototypical technology to maintain technological flexibility. However, the evidence shows that some of their IT management practices have not yet evolved to an appropriately strategic maturity (i.e., "alignment" not well realized because IT is not decentralized enough for this proactive innovation). This was unexpected.

One plausible explanation is that because of cost disadvantage relative to ASEAN or China,

Table 7. Moderated regression analysis for bS, ITMS, and their interaction

	BS	ITMS	Size	Interaction	R^2	F	ΔR^2
ISP							
RM1	0.055	0.483*	-0.044		0.240	21.645**	
RM2	0.407	0.578*	-0.043	-0.385	0.238	16.301**	-0.002
CTR							
RM1	-0.024	0.610*	-.0.045		0.360	37.714**	
RM2	1.011*	0.962*	-0.028	-1.196*	0.379	30.903**	+0.019
OGN							
RM1	0.121	0.408*	-0.057		0.182	15.549**	
RM2	1.834*	0.852**	-0.037	-1.808*	0.208	13.869**	+0.026
TDW							
RM1	0.051	0.411**	-0.079		0.176	14.934**	
RM2	0.171	0.471*	-0.079	-0.148	0.172	11.168**	-0.004

Criterion: Strategic Alignment (SA)
*Note: ** Significant at 0.01 level, * Significant at 0.05 level*

Table 8. Correlation matrix for BS, ITMS, and SA

	BS	SA	ISP	CTR	OGN	ITR
BS	1.000					
SA	0.148*	1.000				
ISP	0.195**	0.497*	1.000			
CTR	0.285**	0.606*	0.639**	1.000		
OGN	0.070	0.421*	0.586**	0.663**	1.000	
ITR	0.241**	0.424*	0.502**	0.580**	0.405**	1.000

Note: *** Significant at 0.01 level, * Significant at 0.05 level*

Taiwanese executives may tend to be conservative in approving expensive IT investment and thus prefer to centralize their IS function (more cost efficiency), while they have sensed the importance of aggressive innovation to keep global competitiveness. This should be true for other countries since Teo (2007) argued that companies, "who compete globally, regardless of their country of origin, are also concerned with cost as it is often linked to competitiveness of products/services offered" (p. 108). Consequently, conflicts may exist between intended innovations and realized IT management sophistication, leading to a poor strategic alignment.

ANOVA Test

A one-way ANOVA was carried out to provide a more micro view of our research hypothesis that how innovative strategic type differs with respect to the degree of ITMS. Several interesting and significant findings can be discerned from the results summarized in Table 9 and 10.

Defenders, analyzers, and prospectors are known to focus on different innovative behaviour of companies in products/services and market that may rely on IT (Kearns, 2005). So each of the companies should have its own appropriate inno-

Table 9. ANOVA of BS and ITMS

ITMS	Defenders Mean (SD)	Analysers Mean (SD)	Prospectors Mean (SD)	F-Value
ISP	5.608 (0.763)	5.513 (0.581)	5.880 (0.635)	6.350*
CTR	5.392 (0.941)	5.409 (0.836)	5.914 (0.695)	10.132**
OGN	5.859 (0.680)	5.737 (0.674)	5.947 (0.587)	1.943
TDW	5.261 (0.815)	5.009 (0.815)	5.846 (0.883)	13.384**

*** Significant at 0.01 level, * Significant at 0.05 level*

Table 10. Scheffe's test of mean differences in ITMS by BS

ITMS	Defenders vs. Analysers	Defenders vs. Prospectors	Analysers vs. Prospectors
ISP	0.095	-0.272	-0.367**
CTR	-0.017	-0.523**	-0.505**
OGN	0.122	-0.008	-0.210
TDW	0.252	-0.585**	-0.837**

*Note 1: ** significant at 0.01 level*
Note 2: In addition to similarity between defenders and analysers, it should be noted that the reason for there were no significant mean difference between defenders and analysers for any of IT management sophistication dimensions may be explained by competitive strategy.

vation pursued on ITMS. This argument is partly supported by the fact that there were significant mean differences (F statistics = 6.350, p<0.05; 10.132, p<0.01 and 13.384, p<0.01) across the strategic types in ISP, CTR, and TDW underlying ITMS, implying that Taiwanese companies generally differ in their emphasis on the sophisticated level of IT management in planning, control, and integration depending on innovation.

To further identify which pairs of mean score are significantly different, Scheffe's test shows that defenders and prospectors differed on CTR (MD [mean difference] = -0.523, p<0.01) and TDW (MD = -0.585, p<0.01) while analyzers and prospectors differed on ISP (MD = -0.367, p<0.01), CTR (MD = -0.505, p<0.01), and TDW (MD = -0.837, p<0.01).

It was expected that there was no significant difference in ISP between defenders and analyzers because the two types share some similar characteristics of cost efficiency. However, the emphasis on ISP did significantly vary between analyzers and prospectors (MD = -0.367, p<0.01), indicating that a higher level of IS planning is essential for prospectors. This finding was expected because one of key characteristics for prospectors is diversity of information needs, a higher level of planning of IT-based activities is required to facilitate and coordinate numerous and diverse business operations and decisions (Kearns, 2005; Sabherwal & Chan, 2001).

Similarly, there was no significant difference in CTR between defenders and analyzers. However, it was found that prospectors place more substantial emphasis on control IT than defenders and analyzers (MD = -0.523 and -0.505, p<0.01), which was unexpected because prospectors are supposed to have decentralized control because they rely on flexible and multiple technologies (low degree of routinization and mechanization) to respond to changing environment rapidly, defenders are supposed to have a centralized control (Matsuno & Mentzer, 2000) and vertical IS because they depend on a single-core IT and continuous improvements in IT (Hambrick, 2003), and analyzers are supposed to have mid-range control level somewhere in between because they attempt to minimize the risk associated with new technologies while maximizing the opportunity for profit (DeSarbo et al., 2005).

Mean difference in OGN was found non-significant (F statistics = 1.943, p>0.05) across all strategic types, implying that Taiwanese companies tend to place an equal emphasis on OGN regardless of innovation pursued. Nevertheless, this was unexpected. The reason for this is perhaps because some CIOs did not report this item questionnaire based on "realized" but "intended" perspective (Tallon, 2003). Perhaps when initially building IT infrastructure, there is a high involvement of non-IT members (i.e., decentralized) regardless of innovation pursued. However, concomitantly, the requirement or importance of OGN is changing from time to time during company's adaptation toward a certain dynamic environment. With this initially recognized importance of organization IT, some CIOs are likely to neglect the actual level of OGN that is required or realized under current innovation pursued and thus failed to appropriately report the requirement of a certain level of OGN in accordance with that evolved innovation.

Regarding TDW, it was expected that defenders have similar level of top-down integration IT as analyzers does. It was also expected that prospectors place substantially more emphasis on top-down integration IT than defenders and analyzers (MD = -0.585 and -0.837, p<0.01) because high innovative behavior of prospectors may emphasize external sources over internal sources in acquiring IT (O'Regan & Ghobadian, 2006). Hence, a higher integration IT is essential for prospectors to facilitate exploration of rapid changing technology to continue engagement in new business (Gupta et al., 1997).

Thus, H2 was partly supported, evidencing that Taiwanese companies generally differ in their emphasis on IT management sophistication depending on innovation pursued. This can be true for other countries since based on CT's "dependency" concept, foreign companies may repeatedly and continuously find the ultimate IS solutions- appropriate IT management practices evolved for a certain innovation. Such solutions will be varied during the adaptive process because of different contexts and can be successful when IT is strategically used (Lu et al., 2005). For example, MNCs may have different adaptations (i.e., IT-based innovation) under different global markets (Teo, 2007). Our result is consistent with studies done in the United States, which found that IT management sophistication would differ with innovation (e.g., Karimi, et al. [1996]).

LIMITATIONS

Although based on CT our proposed adaptation model can be generic to other foreign companies' contingent thinking, the generalizability of results still should be primarily limited to Taiwan context. Similar future research in other countries may consider using "case study" approach to increase "trustworthiness" of results. However to avoid research bias, we controlled the industry and size confounding effects on IT usage. Likewise, generalizability of results may be limited due to the low survey response although the response rate of 24% is acceptable in the literature.

To measure "innovation," a self-typing approach was used. However, CIOs may tend to report their companies' intended rather than realized strategies (Snow & Hambrick, 1980). If there is no intended strategy, the CIO may even create one for the benefit of the researcher (Kearns, 2005). This is a common problem faced in the field of social sciences (Nisbett & Wilson, 1977). Moreover, a lack of external validation of self-typing approach exists (Karimi et al., 1996).

Because of the size and the nature of the sample, external confirmation of the self-typing completed by the CIOs could not be obtained (Gupta et al., 1997). In a sense, a key assumption was that these individuals had accurate perception of the overall company's competitive position.

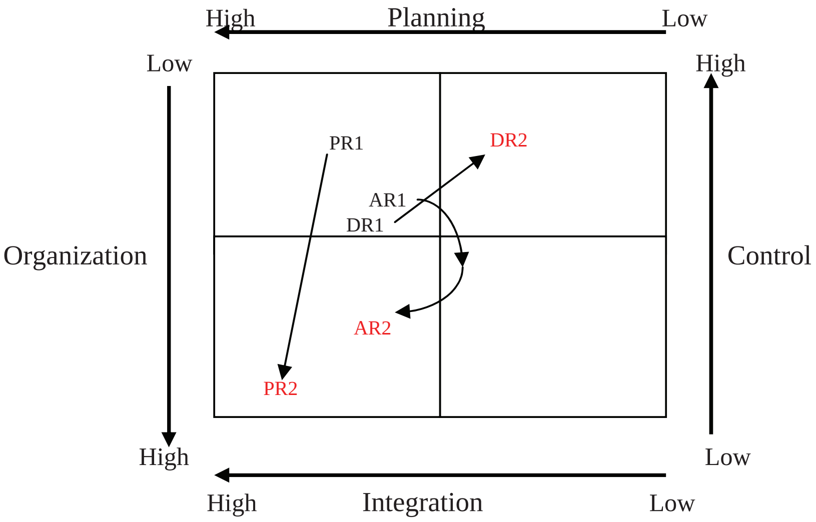
IMPLICATIONS

Theoretically, this study successfully incorporated the Miles and Snow typology to clarify the extent to which IT management sophistication is relatively important to a certain innovation. The results revealed that contextual factor "IT management sophistication" generally facilitates the strategic use of IT, and contextual factor "innovation" generally moderates that strategic alignment effect (Table 7). The results supported CT by showing that Taiwanese companies can succeed when IT management sophistication is appropriately evolved for a specific environmental adaptation (innovation).

Our research model was generic for other foreign companies, because, based on CT; they make dynamic adaptations toward their particular environments for a competitive IT-based innovation vis-à-vis global counterparts. Future research, which could contradict our findings, could examine innovation's role and its impact on the strategic use of IT in other countries. The results also revealed that innovation is a good predictor of a company's success (strategic alignment) (Table 7 and 8). Such results should reassure traditional IS researchers that aggressive companies tend to refer IS plans to business innovation missions and objectives and vice versa, through a more sophisticated planning and integration process. Future research could further examine the sustainability of this IS-business alignment.

A practical implication of the results is the matrix of company adaptation toward strategic alignment (Figure 2). This adaptive matrix provides guidelines to senior executives for allocating their time when making their IT more responsive (evolved) to their company's success. It is a new channel for effective communication between the CIO and senior executive, helping them to decide on the appropriate IT management sophistication consistent with innovation.

Figure 2. Company adaptation matrix for strategic alignment



Note 1: PR=prospectors, DR=defenders, AR= analysers
Note 2: The number "1" denoted as "current level" and the number "2" denoted as "ideal level".
Note 3: The current position of each strategic type is generally indicated based on our results.

Using the matrix, senior executives should generally realize the expected IT position by adjustments toward appropriate management maturity along the four dimensions, given a certain innovation. For example, we found that for prospectors, adjusting the position of IT management sophistication from current "PR_1" to ideal "PR_2" (high planning [more formal process], low control [more decentralization], high organization [more user involvement], and high integration [more reinforced frontline manager IT knowledge and responsibility]) is suggested, while for defenders, moving from "DR_1" to "DR_2" (high control and moderate-low organization) is suggested. Interestingly, we also found that the IT management sophistication of analyzers ("AR_1") was generally lower in "planning" and "integration" than that of defenders ("DR_1"). This, while unexpected, reflected the fact that these so-called "analyzer" participants are conservative in IT spending, although they aggressively explore more new IT-based opportunities for business operations. A plausible explanation is that in practice, analyzer strategy is very difficult to pursue because it shares characteristics with defenders and prospectors. Although "AR_2" (moderate-high in planning, organization, and integration) is preferred, the path from "AR_1" to "AR_2" would not be a simple linear direction and may be adaptive depending on executive's adjustment (i.e., defender-like or prospector-like).

This matrix shows that more than one strategy (no matter whether innovation is aggressive or conservative) can be successful in a given environment (regardless of context or country), provided that the company acts consistently in that strategy (Miles & Snow, 1978). Unfortunately, the move from a current IT position to an ideal one can be long or short, depending on whether communication is effective (Li & Yi, 1999). That is, the adjustment would be affected by IT expectation (e.g., returns) gap between the CIO and senior executive (Ranganathan & Kannabiran, 2004).

Senior executive's IT expectation is often needed to determine whether the company has obtained satisfactory outcomes after the use of IT, which impacts the strategic alignment (Hwang, Ku, Yen, & Cheng, 2004). Based on our participants' report, when pursuing aggressive innovation (e.g., prospector), the CIO expects to obtain more top management support and reported that the whole company has substantially benefited from IT. The senior executive is more concerned about realized IT payoffs when maintaining a good deal of technological flexibility because deploying IT and exploring future IT-based opportunities is a time-consuming, expensive task. Thus, senior executives are often more conservative (i.e., centralizing IS function [high control, mean = 5.914, Table 9]) and careful in evaluating IT for their exploration of new global markets, implying that they tend to be more unsatisfied with the outcomes of current IT.

This situation could be reversed when pursuing conservative innovation (e.g., defender) because senior executives may feel more confident of their IT investments and current positions on a single core technology. They are likely to be more satisfied with outcomes than a CIO, who is likely to receive less top management support, thus leading to lower IT integration. Future research may investigate perceptual differences between the CIO and senior executives concerning overall expected company performance after the use of IT. This would help to determine whether the evolution of IT management sophistication is moderated (or mediated) by those perceptions.

Since more companies have a prospector than a defender strategy (94 vs. 46, respectively), there is a substantial gap in achieving greater IT management sophistication. This provides us an opportunity to reassert that how senior executives perceive IT benefits in terms of efficiency, effectiveness, or strategic advantage is critical to reduce that gap (Silk, 1990). When the emphasis of evaluation of IT benefits shifts from efficient to strategic, there are resulting expectations that a more improved IS planning goal, with positive strategic impact on the profitability, either financial (ROI) or non-financial (synergy), is achievable (Bacon, 1992).

For example, under the e-logistics project (www.elogistics.org.tw/93/index.php), the government encouraged Taiwanese logistics companies to become more innovated in services. Recognizing the strategic potential of IT-enabled intangibles, senior executives of Taiwan Express Logistics Group (39% of participating logistics companies are prospectors) have sought alliances with their Hong Kong, Singapore, and Thailand counterparts to acquire technology know-how and generate synergy through consolidated resources to compete with global logistics counterparts (e.g., FedEx, UPS) (Geng, 2007).

However, as noted in the matrix, their overall current IT management sophistication may not be adequate to sustain the value of alliance strategy as a prospector until IT-based resources are more formally planned, more business oriented, and highly integrated. We suggest that as innovation becomes more aggressive, a more sophisticated evaluation process may be used to ensure that IT align with the companies' business goals, base policies, and procedures associated with control of IT activities.

For example, to evaluate IT projects with intangible benefits, non-financial management and development criteria could be used to balance both quantitative and qualitative forms of the IT investment decision (Silk, 1990). This would also prevent the loss of any associated cash flow due to difficulty of measurement (Chan, 2000), implying that as companies become more familiar with the control process of IT investment decision (i.e., from initiation to review and approval), senior executives are likely to view IT strategically, be committed to IS function, and gain more confidence in managing IT (Kearns, 2000).

Some defenders may also need this sophisticated evaluation process to improve both the alignment and the cost efficiency. For example, in Taiwan, computers/communication and financial services companies (in our sample, 26% were defenders and analyzers) that have been undergoing dramatic changes are now faced with competition from China or India and their relatively cheap labor markets. To defend their familiar products and services, it is also critical for defenders to have excellent external market sensing (mean = 5.608 in planning IT [Table 9]) and multiple electronic linking that helps them sense marketplace requirements from customers and competitors to compete effectively. Thus, a sophisticated evaluation of IT investment would be also needed to make senior executives support the progressive use of IT toward a higher sophistication.

CONCLUSION

Table 11 concludes our ideal IT management sophistication framework across innovation. For example, to increase IT payoff (strategic alignment), large companies must develop more sophisticated IT management practices when pursuing aggressive innovation (prospectors). That is, IS function should be structured more flexibly (responsively) to the company. Planning characteristics of existing and future IT applications should be more sophisticated (formal) and pay attention to the end user's ideas (i.e., high organization oriented). The direction, development, and operations should be co-located in business and IS units (i.e., high integration). As a result, the IS department will be much flatter, with specialized subunits organized around technologies and business needs; it will respond better to end user needs and will leverage IT more effectively. Future research should consider that for prospectors, complete integration might not be possible because of multiple technologies (Gupta et al., 1997) and innovativeness and creativity in the use of IT might be inhibited by too formal planning mechanism (Premkumar & King, 1994). Although the companies that pursue conservative innovation (defenders) tend to have

Table 11. Ideal IT management sophistication framework across innovation

	Level of Innovation		
	(Conservative) Defenders	Analysers	(Aggressive) Prospectors
Attribute of IS Function	Efficiency (Vertical IS)	Adaptiveness	Flexibility (Flat IS)
Level of IT Management Sophistication			
Planning (e.g., Formalization)	Moderate-Low	Moderate-High	High
Control (e.g., Centralization)	High	Moderate-Low	Low
Organization (e.g., Non-IT users involvement in IS)	Moderate-Low	Moderate-High	High
Integration (e.g., Co-location of IS / business resources; business driven IT initiatives)	Moderate-Low	Moderate-High	High

Note 1: Summarized based on "Company Adaptation Matrix" (Figure 2)
Note 2: As noted, "adaptiveness" indicates that the relationship of IS-innovation sometimes can be defender-like, sometimes can be prospector-like, depending on the environment that an analyser situates. This process continues until ideal level of IT management sophistication is reached.

less sophisticated IT management practices, they must improve the ability of the IS department to develop and direct IT (i.e., high control). They should convince the CIO that IT proposals are properly appraised and continuously monitor the IS function based on clear performance criteria, goals, and responsibilities.

Our study provided foreign companies insight into aspects where Taiwanese IT management practices are currently being or need to be developed to create and maintain effective global partnerships. Such insight may help them better focus on the appropriate level of IS functions needed to more strategically allocate IT-based resources when doing business with Taiwanese or even other country's partners. By checking the similarities and differences of innovation versus IT management sophistication position in the matrix, they also can discover the discrepancies in IT vision between two companies and determine whether a collaborative partner is receptive to a certain IT alliance strategy. The value of alliance strategy can be improved over time as two companies become more familiar with each other's IT management practices and manage that IT divide to ensure that the parties share a similar IT commitment and build trust, a long-term relationship, and commitment to shared objectives and risks.

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Chapter 6.5

Inter-Organizational Information Systems and Strategic Alliances:

Symbiosis or Competition?

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ABSTRACT

In this chapter we analyze the relationships between the structures of inter-organizational information systems (IOS) and strategic alliances. The relationships between both structures tends to be framed within a collaborative dynamic in which the IOS serves the objectives of the alliance, thereby reinforcing the links that bind the alliance members together. However, in this chapter we also suggest that there may be a non-collaborative—that is, competitive—relationship between the IOS and the strategic alliance, especially when both structures compete for firms from the same sector and geographical area. To test our hypotheses we have analyzed a sample of 162 firms belonging to the agro-food sector in Spain.

INTRODUCTION

Information and communications technology (ICT) and information systems (IS) have had—and indeed continue to have—growing influence on the way firms are managed and organized. There can be no doubt that the lion's share of the modern organization's value chain has been changed in one way or the other by the introduction of computing, robotics, or telecommunications tools (Porter & Millar, 1986). ICT is likely to have a major impact on the components of the value chain that are most closely related to supplies, transport, or data processing. Moreover, in recent decades most of the primary or support activities of firms' value chains have gone through a process of intensification in terms of their need for information management, so ICT has been playing an increasingly important role within organizations.

However, one component of the ICT revolution that we have experienced (and that is still going on) has not taken place within the limits of the traditional organization, but has originated in the relationships that link organizations with each other. The sharing of resources and the collaboration (at the same time as competition) between organizations has meant that a large part of firms' managerial, financial, and productive resources have begun to acquire a virtual dimension. By means of this virtualization firms can make use of resources and capabilities that are geographically dispersed and, more importantly, that originally belonged to other institutions. The technological revolution therefore leads to a revolution in the relationships between firms and organizations, which put resources and capabilities into common use with the aim of improving individual competitive positions. The main advantage of inter-organizational cooperation comes not only from the possibility of accessing virtualized resources but of doing so much more cheaply than would be the case if these resources were acquired on the market for their individual use.

A direct consequence of this virtualization of resources and of the cooperation between institutions is the appearance of IOS (Kauffman, 1966; Konsynski, 1993) and of strategic alliances and networks (Gulati, Nohria, & Zaheer, 2000). Strategic alliances and IOS have traditionally been regarded as two sides of the same coin. Thus, many strategic alliances and stable cooperation agreements have as their main aim to create or strengthen an IOS (Medina Garrido & Bruque Cámara, 2004; Pigni, Ravarini, Sciuto, Zanaboni, & Burn, 2004). In this way, firms can either reduce the uncertainty inherent in today's complex environments or alternatively cut the transaction costs deriving from their relationships with other organizations (Ciborra, 1990; Gulati et al., 2000; Malone, Yates, & Benjamin, 1987).

However, the literature has shown little interest in situations in which the IOS and the strategic alliance interact competitively. In these cases the appearance of an IOS could actually destabilize the system of psychological or economic incentives that bind the members of a strategic alliance together. The disparity of structures and interests, or simply mutual ignorance, can lead to situations in which the IOS erodes the structure of the alliance. Thus, in this chapter we attempt to gain more knowledge about this question, illustrating the situation that occurs when IOS and alliance act competitively—that is, non-symbiotically—and suggesting some explanations for the problem. These explanations will provide us with the basis for offering a number of implications and recommendations, using data from the olive oil production sector in Spain.

This chapter is organized into five sections following on from this present introduction. In the second section we review the state of the question and propose our working hypotheses. In the third we describe the methods utilized to test the hypotheses. In the fourth we outline our findings. In the fifth section we outline our main conclusions, while in the final section we offer a series of recommendations for firms and public administrations, as well as directions for future research.

BACKGROUND AND HYPOTHESES

The relationship between the use of IOS and opting for the market (autonomy), hierarchy, or strategic alliance, has been widely studied in the literature (Brynjolfsson, Malone, Gurbaxani, & Kambil, 1994). In most previous analyses researchers have demonstrated that the IOS and strategic alliance come into being in a coordinated way with the aim of achieving similar objectives (Henderson & Venkatraman, 1993). The IOS serves to achieve the objectives set down by the alliance in terms of information management and the conversion of this information into knowledge. In parallel, the strategic alliance gives the IOS legitimacy in the eyes of the alliance members, as well as financial and human resources (Ciborra, 1993; Gurbaxani & Whang, 1991; Malone et al., 1987). However, less attention has been paid to the competitive relationship that may develop when a strategic alliance and an IOS interact in the same competitive sphere (or sector). Neither have we found any work comparing the use of the IOS by firms that are not members of strategic alliances and firms that are. These questions may have important implications for the management of these alliances as well as for the evolution of the IOS.

In a strategic alliance the functions of search, selection, analysis, and distribution of information are carried out by the structure of the alliance itself. Strategic alliances, when they take the form of a stable strategic network (Miles & Snow, 1986), tend to develop an ad hoc governance structure (Grandori & Soda, 1995). The governance structure takes responsibility for managing the activities within the remit of the alliance (joint commercialization, research and development, supply chain management, joint supplies, etc.). This ad hoc structure, which is a consequence of the alliance, tends to take the form of a new organization (joint venture, new capital firm, or horizontal cooperative arrangement) (Grandori & Soda, 1995; Gulati, 1998) charged with developing the elements (technological tools, personnel, and departments) required to carry out the activities for which the alliance is responsible.

On the other hand, IOS have been seen as useful tools in firms' management. There is substantial evidence of the various advantages firms can obtain from cooperating in an IOS. The IOS is a cooperation structure in itself; it aims to achieve goals such as reducing operational and management costs, sharing information that is strategic from the competitive perspective, reducing negotiation or information costs in economic transactions, strengthening the links that bind strategic alliance members, developing knowledge management systems that prove useful to all IOS participants, modifying the market structures in order to increase IOS participants' bargaining power, and so forth (Bakos, 1991; Eom, 2005; Kumar & Van Dissel, 1996).

When the information provided by an IOS lies within the decision scope of the alliance, the interface between the IOS and alliance members will be the alliance ad hoc governance structure. In this respect, according to Thorelli (1986), the alliance as a whole can be regarded as a single organization with defined strategic objectives. The ad hoc structure responsible for dealing with questions entrusted to the alliance should obtain, analyze, handle and if necessary, disseminate the information coming from the IOS. Thus, we can say that the information coming from the IOS will be distributed among the firms making up the alliance, respecting the decision and information flows previously established between the ad hoc governance structure and the alliance members. In other words, there should not be any direct use by the firms making up the alliance (individually regarded) of the resources provided by the IOS. In the case of non-alliance members, however, it is the firms themselves that must directly obtain the information and resources they need to carry out their activity. If the IOS proves to be an effective tool, firms outside the alliance will try to access and use the system in order to improve their competitive position in the sector or simply to survive in a complex and dynamic environment. In short, under the conditions discussed previously, firms not belonging to a strategic alliance are likely to use the IOS more than firms forming part of a strategic alliance. This idea is reflected in Hypothesis H1:

Hypothesis H1: Firms not forming part of a strategic alliance use IOS more than strategic alliance members.

The previous hypothesis allows us to infer that firms forming part of a strategic alliance—

individually considered—will have less need to access and use the IOS, since the ad hoc governance structure created by the alliance takes over the functions of obtaining and analyzing information. This ad hoc structure will be responsible for accessing and analyzing the information, and if necessary, distributing it to the alliance members respecting the traditional flows of decision and communication between the ad hoc structure and the member firms. In this case we can say that the IOS does not interfere either with the internal organization or with the decision-making structure operating within the alliance. In other words, there is a concordant relationship between the structure of the IOS and the structure of the alliance.

However, the internal situation of the strategic alliance will not always allow this concordant relationship to arise. The intensity with which firms become involved in their strategic alliances can vary depending on a number of explanatory factors (Medina Garrido, 2003; Thorelli, 1986). Firms in alliances are all formally members of the same structure, but some may behave opportunistically (Gulati et al., 2000), exploiting some of the advantages provided by the alliance on the one hand, and on the other, making key decisions independently and considering only their own individual interests. In these situations alliance members' degree of involvement with the alliance, measured by their delegation of decision making to the governance structure, will decline (Arino & de la Torre, 1998).

Opportunistic behavior appears to be associated with alliance members' reduced involvement with respect to the principles of cooperation and also with respect to the joint operation of the strategic alliance (Álvarez, Barney, & Bosse, 2004). When opportunistic behavior occurs, firms' individualistic orientation in the decision-making process means that they have a greater need to access key information. One of the ways of individually accessing key information for decision making is to make use of IOS (Porter & Millar, 1986). Thus, we would suggest that the reduced involvement that results from opportunistic behavior should lead to greater direct use of the IOS by firms behaving opportunistically. In these cases the flow of decisions and information established between the alliance governance structure and the alliance members will weaken since direct flows between the IOS and some alliance members will emerge; in other words, a discordant relationship develops between the structure of the IOS and the structure of the strategic alliance. In short, under the premise of opportunistic behavior we would expect members to become less involved in their alliance, making them more likely to make direct use of the IOS. In the context of reduced involvement and direct use of the IOS, discordant relationships would emerge between the IOS and strategic alliance structures. This idea is reflected in Hypothesis H2.

Hypothesis H2: Within a strategic alliance, the reduced involvement of member firms with their alliance is associated with an increased direct use of IOS.

METHODS

Data

To test the previous hypotheses we analyzed a sample of firms belonging to the olive oil production sector in the province of Jaén (Spain). This province produces 45% of the total Spanish production of olive oil. Spain, in turn, produces 40% of world production, according to the International Olive Oil Council (Consejo Oleícola Internacional, 2001; Moyano-Fuentes & Núñez-Nickel, 2004a). In 1998 the population of olive oil producing firms in the province of Jaén amounted to 323 organizations (Moyano-Fuentes & Núñez-Nickel, 2004b).

The data collection procedure was based on a questionnaire administered either by telephone or in a face-to-face interview. For this, the research team first contacted the firms selected in order to explain to them the objectives of the research. If the interlocutor was appropriate (chief executive or general manager) and if they agreed to participate in the study, we proceeded to carry out the survey by telephone. In some cases the managers requested that they be able to respond to the questionnaire in a face-to-face interview, so we then arranged for a subsequent interview in which the respondent could complete the questionnaire.

We used random sampling, stratified in proportion to the legal status of the firm (cooperative/non-cooperative)[1] and geographic area (district). We introduced the first stratification criterion in order to keep the same proportion of cooperative firms in the sample as in the global population. This precaution was necessary because cooperatives are more prone to participate in strategic alliances than non-cooperative firms (Torres-Ruiz, 1998). The stratification criterion by geographic areas, in turn, aimed to ensure that responses from urban areas were not over-represented to the detriment of rural areas. The final number of valid responses was 162, which represents 50.15% of the total population. Of the 162 firms participating, 94 habitually use IOS and 61 belong to stable strategic alliances in the form of horizontal cooperative arrangements.[2] These strategic alliances are made up of five organizations on average, and they started to appear in the sector from 1980 onward. The remaining technical specifications of the sample are reported in Appendix I.

As far as the IOS is concerned, we used as reference in this study, the Poolred System, set up by the Olive and Olive Oil Promotion and Development Foundation, which began to operate in January 1997. We chose this system because it is widely used among the firms in the sector and has ample experience in obtaining, analyzing, handling, and disseminating information generated by the markets for bulk olive oil in Spain. At present, the system is used by 541 institutions (producers, public administrations, and bottling firms) in Spain, and in 2003 it handled a volume of information relating to transactions valued at over 1.3 billion euro.

Questionnaire

The questionnaire for the current research contained a total of 39 questions, in which we included open questions, Likert-type closed questions and closed questions of the semantic differential-type. The Likert-type and semantic differential-type scales each consisted of five intervals. This chapter is part of a wider research project, so we have not used all the items included in the questionnaire here. Specifically, we only used the data pertaining to the use of IOS, membership of strategic alliances, and degree of involvement in the alliance.

Variables

In this section we describe the variables used in the research, as well as how they are measured.

Participation in strategic alliances. Dichotomous variable taking value 1 if the firm belongs to a stable strategic alliance (horizontal cooperative arrangement) and 0 if it does not belong to such an alliance.

Use of IOS. Dichotomous variable taking value 1 if the firm uses the Poolred System[3] and 0 otherwise.

Involvement in strategic alliance. These variables were measured using five five-point Likert-type scales. These scales measure the intensity with which the member firm uses the alliance mechanisms in its decision making, especially with decisions having important implications for the performance or survival of the organization. The items are as follows: (1) products are commercialized exclusively through the strategic alliance; (2) there are periodic contacts with the alliance's governance structures for consultation on economic and management aspects; (3) relationships with suppliers are channeled through the alliance's governance structure; (4) the remaining members in the alliance are consulted about economic and management aspects; and (5) relationships with the public administrations are channeled through the alliance's governance structure. In all cases 1 corresponds to never and 5 very frequently.

Analysis

Table 1 shows the means, standard deviations, and correlations between the variables used.

To test the proposed hypotheses we opted to carry out an analysis based on descriptive statistics and non-parametric statistical tests to observe the differences between members and non-members of strategic alliances. Specifically, we used contingency tables and the non-parametric Mann-Whitney U test, to test Hypothesis H1 (see Tables 2 and 3), and descriptive statistics and the Mann-Whitney U test, to test Hypothesis H2 (see Tables 4 and 5).

RESULTS

The results of the analyses carried out here allow us to draw a series of conclusions, which we now outline. With regards to Hypothesis H1, the descriptive statistics appearing in the contingency table (Table 2) support the relationship postulated in Hypothesis H1, although quite weakly. Observing the percentages in Table 2, the results show that 47% of the sample firms that do not participate in alliances use the IOS, while only 33% of alliance members directly use the system. However, the Mann-Whitney U test does not allow us to generalize this result and say that in the population as a whole firms not participating in alliances use IOS more than alliance members, since the differences observed between the two groups have a very weak statistical significance. In short, although the data collected in the sample are coherent with Hypothesis H1, it is only possible to assure that this situation occurs in the global population at the 90% level.

Hypothesis H2 is also only weakly supported by the statistical tests carried out here. At first sight (Table 4) the descriptive statistics appear to support the postulates of Hypothesis H2. The means corresponding to each involvement variable, ordered by groups (in function of whether they use the IOS or not) result in higher values when the firms do not use the IOS than when they do. Only once does this not occur—with the variable measuring relationships with suppliers

Table 1. Descriptive statistics and Spearman correlations

Variable	Mean (sd)	1	2	3	4	5	6
1. Participation in strategic alliances	0.38 (0.49)						
2. Use of IOS	0.42 (0.50)	-0.14					
3. Commercialization through alliance	2.72 (1.50)	--	-0.22				
4. Consultations with governing structure of alliance	3.33 (1.84)	--	-0.08	0.61**			
5. Relationships with suppliers through alliance	2.37 (1.25)	--	-0.02	0.53**	0.43**		
6. Consultations with other alliance members	1.75 (1.16)	--	-0.30*	0.50**	0.37**	0.40**	
7. Relationships with public administrations through alliance	1.89 (1.45)	--	0.03	0.47**	0.32**	0.40**	0.41**

*Correlation significant at 0.05.
**Correlation significant at 0.01.

Table 2. Test of hypothesis H1. Contingency table

		Participation in strategic alliances (%)		Total
		NO	YES	
Use of IOS	NO	53 (53)	41 (67)	94
	YES	47 (47)	20 (33)	67
	Total	100 (100)	61 (100)	161

Table 3. Test of hypothesis H1. Mann-Whitney U test

	Participation in strategic alliances	**No. of firms**	**Mean rank**	**Sum of ranks**	**Mann-Whitney U**	**Asymptotic sig. (bilateral)**
Use of IOS	NO	100	85.33	8533.50	2616.5	0.077†
	YES	61	73.89	4507.50		

† Significant difference at 90%.

Table 4. Hypothesis H2: Descriptive statistics of groups[a]

	Use of IOS	**No. of firms**	**Mean**	**s.d.**
3. Commercialization through alliance	NO	38	3.45	1.77
	YES	17	3.06	2.01
4. Consultations with governing structure of alliance	NO	38	2.92	1.40
	YES	16	2.25	1.65
5. Relationships with suppliers through alliance	NO	37	1.76	1.26
	YES	16	2.19	1.83
6. Consultations with other alliance members	NO	35	2.40	1.19
	YES	16	2.31	1.40
7. Relationships with public administrations through alliance	NO	38	1.89	1.13
	YES	17	1.41	1.18

[a] Calculations only include firms forming part of strategic alliances.

through the alliance (variable 5). Considered overall, the data collected in Table 4 allows us to indicate that for the sample firms the inverse association relationship referred to in Hypothesis H2 is satisfied. That is, and again for the sample, firms belonging to alliances but not very involved in them use the IOS more than the firms that are more involved.

However, the results referred to in the previous paragraph cannot be generalized to the whole population, since the Mann-Whitney U tests do not result in statistically significant differences (this only occurs for the variable measuring involvement through relationships with the public administrations). In short, although the data from the sample is in line with Hypothesis H2, we cannot generalize them to the population as a whole.

SUMMARY

This work is one of the first attempts to link the degree of involvement of alliance members with the extent to which they use IOS. Although the results are not entirely satisfactory from the perspective of statistical significance or the possibility of generalization, they undoubtedly represent a starting point from which we can advance our understanding of the interrelations—sometimes interferences—that can develop between different cooperation structures that coexist in the organizational framework (the same sector). These structures (on the one hand strategic alliances, and on the other IOS) can be used symbiotically, ensuring that one structure reinforces the other. However, as we have been able to observe in this chapter, when the two cooperation structures (IOS or alliance) are set up at different times and backed by different institutions, a negative (or competitive) effect may be induced, which ends up weakening the bonds that exist within the strategic alliance.

The appearance of an IOS can weaken the structure of the alliance in two different but related ways. First, it can undermine some of the motivations encouraging firms to form strategic alliances in the first place. One of these motivations has to do with the access to more and better information, allowing firms to reduce uncertainty in dynamic and complex environments (Ciborra, 1993). If the firm can obtain this information in an IOS that remains outside the alliance it will be less likely to strengthen its links with the alliance. The second motivation concerns the opportunistic behavior of some alliance members, who will feel freer to act independently if they have access to key information autonomously. Taking this situation to the extreme, the disparity between the IOS and the strategic alliance may lead to the breakup of the latter, or even its disappearance. Whether the alliance fails, however, will depend on the degree of rivalry between the governance structures of the alliance and the IOS as well as on the strategic importance of the information managed by the IOS.

In short, this chapter attempts to provide new, useful explanations for the situations in which strategic alliances find themselves weakened by the appearance of cooperation structures (IOS) that erode part of their own responsibilities. Our findings may therefore prove interesting for the research stream analyzing the factors leading to the failure of cooperation between firms, as well as provide appropriate solutions (Harrigan, 1985; Kale, Dyer, & Singh, 2002; Mitchell &

Table 5. Test of hypothesis H2. Mann-Whitney U test

	Use of IOS	No. of firms	Mean rank	Sum of ranks	Mann-Whitney U	Asymptotic sig. (bilateral)
3. Commercialization through alliance	NO	38	28.78	1093.50	293.50	0.561
	YES	17	26.26	446.50		
4. Consultations with governing structure of alliance	NO	38	29.62	1093.50	223.50	0.116
	YES	16	22.47	446.50		
5. Relationships with suppliers through alliance	NO	37	26.69	987.50	284.50	0.791
	YES	16	27.72	443.50		
6. Consultations with other alliance members	NO	35	26.17	916.00	274.00	0.897
	YES	16	25.63	410.00		
7. Relationships with public administrations through alliance	NO	38	30.84	1172.00	215.00	0.024*
	YES	17	21.65	368.00		

* Significant difference at 95%.

Singh, 1996). However, the work may also have implications for managers, particularly at the following three decision levels: the managers of the governance structure of the IOS, the managers of the strategic alliance's governance structure, and public administrations interested in promoting stable cooperation agreements. These management implications, together with possible lines of research for the future and the limitations of the work, are analyzed in the final section.

RECOMMENDATIONS AND FUTURE TRENDS

From the perspective of the management of strategic alliances, managers of these structures should not only be conscious of the opportunities but also the threats represented by the appearance of an IOS within the scope of activity of the alliance. This threat may be greater when the information provided by the IOS is closely linked to the activity controlled by the alliance. In these cases, alliance members can be motivated to behave opportunistically, or even simply to abandon the cooperation structure. The threat of the IOS is also greater when it is set up totally independent of the strategic alliance, that is, when it is backed by institutions outside the alliance, which may even be rivals.

We now offer a series of recommendations that can help to mitigate the situation that has been previously described. In all these limitations we have to take into account that for creating a strong and stable alliance it is necessary to provide value to the members of the alliance. There are several ways to create value such as improving logistics, decreasing production or transaction costs, improving the access to new markets, improving the organization's bargaining power, and so forth. For the case of interactions between IOS and strategic alliances we can provide some recommendations that may prove useful to increase the value transferred by the IOS to the strategic alliance. First, since the threat derives from the difference in the interests and structures between both systems, it is necessary to initiate a process of negotiation between the governance structures of the two systems (alliance and IOS). Thus, there is a need for a process of macro-cooperation between both structures, with the intention of aligning the interests of both systems. The optimal option for the alliance and the least harmful for the IOS would be for a single link between the alliance and the IOS to be formed by the alliance's governance structure itself. In exchange, the strategic alliance could help to strengthen the IOS, providing it with new resources or helping it to obtain, process, and disseminate information. In other words, this strategy of macro-cooperation would have the ultimate aim of establishing a symbiotic relationship between both structures and ensuring that neither interferes negatively with the other. We should point out that in this case the scope of the macro-cooperation could be limited to aspects relating to the strategic implications of the information handled by the IOS, so that both structures could maintain their autonomy in all the remaining areas.

The managers of the IOS governance structure could also benefit from the process of negotiation started with the strategic alliance. In this case, the IOS should weigh up the advantages of the aforementioned strategy of macro-cooperation: the strengthening of the structure itself; greater financial, technical, and human resources; and the broadening of the scope of the IOS itself.

Third, public administrations could play a fundamental role in the process of macro-cooperation initiated between both cooperation structures. In situations of rivalry or divergence of interests the public administrations could intervene to reestablish the balance of power, arbitrate compensation to one or another structure, or simply bring the managers of both cooperation structures into contact in order to facilitate negotiation. The function of the public administration is even more relevant when the sector in which the IOS and alliance operate can be regarded as strategic for the public interest, or when collaboration between the IOS and alliance could serve as a useful example for other key sectors.

With regards to advancing research, we might make some recommendations for the academic and research community. First, it is necessary to further the knowledge of the factors that might provoke the weakening or failure of inter-organizational cooperation structures (alliances or IOS). Greater understanding of the causes of success or failure may have positive implications, since it could inform public and private policies aimed at preventing situations of risk from arising. Second, there is a need to deepen understanding of the factors that encourage firms to become more involved in the various formulas of inter-organizational cooperation, thereby preempting opportunistic behaviors among the cooperating firms. Third, in the particular case of interference between the alliance and IOS, we would recommend that researchers attempt to generalize the results reported in this current chapter. It would be particularly interesting to see further research in other sectors, or in other countries in which differences of national culture may play an important role. Finally, it would be useful to obtain more information about the function that the structure of the sector (size and number of firms, technological development, transparency of market, etc.) may play in the relationships between strategic alliances and IOS.

As we have already mentioned, this work suffers from a number of limitations, which should be borne in mind when judging the significance of the results obtained here. In the first place, the statistical tests carried out are not entirely satisfactory, in the sense that they do not always allow us to confirm the association relationships postulated in the hypotheses. For this reason some conclusions are only applicable to the sample and not to the population as a whole. Second, in the proposed associations another series of moderating variables may play a role in clarifying the causes and effects that intervene in the problem. Thus, the greater propensity to use IOS of firms with little involvement in their alliances could be moderated by the initiation of corrective measures by the governance structure of the alliance. Other variables may also have intervened in this relationship, such as the culture of the organizations participating in the alliance; the existence of a collaborative relationship between the IOS structure and the governance structure of the alliance; or the degree of technological maturity of the institutions involved (governance structure, member firms, IOS management structure, etc.). Third, the design of the measuring instruments (dichotomous and Likert perceptual variables) may have proved inadequate for revealing complex relationships between the constructs under analysis. Fourth, we have analyzed the relationships between IOS structures and strategic alliances in a very specific sector (olive oil production sector in Spain), so we encourage other researchers to analyze this topic in other sectors. Finally, in this study we only analyze one type of strategic alliances (horizontal alliances) so further research is needed in the case of other types of alliances such as vertical alliances, diagonal alliances, or internal networks (Hinterhuber & Levin, 1994).

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ENDNOTES

[1] The cooperative firm is constituted as a democratic organization and its management is based on the principle of one member, one vote. The other organizational forms (capitalist forms) have the characteristic that the number of votes is directly linked to the size of the shareholding (Barron, 1995, p. 138).

[2] A horizontal cooperative arrangement is an alliance made up of firms that are cooperative firms. The objective of a horizontal cooperative arrangement is to jointly manage some activities of the value chain (such as marketing, logistics, R&D, etc.).

[3] The Poolred System is an IOS run by the Foundation for Promotion and Development of Olive Oil. All the firms that are included in the system have to send, online, the data

APPENDIX I. TECHNICAL SPECIFICATIONS

Population	Olive oil producing firms in province of Jaén (Spain) (323 organizations).
Time	December 2003-March 2004.
Type of sampling	Probabilistic, stratified in proportion to legal form (cooperative/non-cooperative) and geographic location.
Sampling units	General manager or CEO.
Sample errors	±5.55% for p = q = 0.5 and confidence level 95.5%.
Sample size	162 valid responses.
Research technique	Telephone survey combined with face-to-face survey.

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Chapter 6.6

Managing Knowledge Capabilities for Strategy Implementation Effectiveness

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ABSTRACT

The creation and the use of knowledge have increasingly been regarded as important issues for management. A wide range of studies have investigated this topic during the past decade. Notwithstanding these contributions, very little systematic attention has been paid to the linkages between knowledge capabilities and strategy implementation. Drawing from knowledge capabilities theory and strategy implementation literature, two aspects of knowledge capabilities in an organization and their effect on strategy implementation effectiveness are investigated: knowledge process capabilities (KPC) and knowledge infrastructure capabilities (KIC). This study hypothesized that KPC affects strategy implementation effectiveness (SIE) and that KPC affects KIC. The third hypothesis proposed the effect of KIC on SIE by examining the mediating role played by KIC in linking KPC and SIE. 1,321 middle-managers were sent questionnaires via electronic mail and 162 were returned. The findings indicated the presence of a mediation effect of KIC on the relationship between KPC and SIE. This study provides guidelines for middle-managers to better understand how to develop activities of KPC and KIC for SIE. It is hoped that the results of this study will enhance our understanding of the strategic importance of knowledge in an organization, especially in the area of strategy implementation.

INTRODUCTION

Organizations improve their performances by enhancing current capabilities or developing new capabilities. This capability is complicated and believed to coincide closely with organizational knowledge that can be conceptualized in terms of digested information embedded within organizational routines and processes (Davenport & Prusak, 1998; Eisenhardt & Martin, 2000; Myers, 1996). In order to compete effectively, firms must leverage their existing knowledge and create new knowledge in their organizations (Grant, 1996). To achieve these effects, it is imperative for firms to develop and to utilize knowledge capability. Knowledge capability is important because it enables knowledge to flow across organizational routines, thus facilitating knowledge utilization and creation (Allard, 2003; Helfat & Raubitschek, 2003). Nevertheless, there are few empirical studies that investigate the relationship between organizational knowledge and strategy implementation.

A review of the relevant literature suggests a fertile and interesting area between the general strategy process and the knowledge-based view (KBV). Specifically, the area of strategy implementation is open to investigation. The implementation area mainly questions how to effectively manage and translate firm strategy into action. New models and constraints in the knowledge economy pose challenges to implementing strategies. For example, some organizations have to reengineer organizational processes and restructure organizational units by delayering the number of hierarchical levels or shortening the distance between top management and operational management (Keidal, 1994). Some organizations use information technology instead of humans to monitor and control activities directly (Leonard-Barton, 1995). The traditional strategy process has to adapt to the dynamic environment of the knowledge economy.

Since strategy implementation involves all activities in organizations (Beer, 1996; Gadiesh & Gilbert, 2001; Nobel, 1999) and knowledge capability is an important organizational capability, this study argues that these two areas are linked and support each other. Explicitly, from a review of the literature, little systemic attention has been given to the linkage between knowledge capabilities and the effectiveness of strategy implementation. This study examines that linkage. Middle managers were selected as respondents because they are key to the linkage (Floyd & Wooldridge, 2000; Huber & Power, 1985; Nonaka, 1991). At the front-line, middle managers are responsible for effective strategy implementation by mixing and matching organizational capabilities and resources. Furthermore, middle managers play important roles by integrating both vertical and horizontal knowledge flow (Nonaka, 1991). This integration relies on in depth experience and situation-specific knowledge. This study aims to benefit the strategy field by bringing about a better understanding of the relationship between knowledge capability and strategy implementation effectiveness.

In sum, this study addresses the important question: “How do knowledge capabilities affect strategy implementation?” It argues and demonstrates that knowledge capability influences the effectiveness of strategy implementation. Two kinds of knowledge capabilities are explored: knowledge process capabilities (KPC)—that is, the capability of a process to transform knowledge that is stored in the form of standard operating procedures and routines throughout the firm into valuable organizational knowledge, experience, and expertise, and knowledge infrastructure capabilities (KIC)—that is, the capability to manage infrastructures in the organization in order to support and facilitate organizational activities. These two knowledge constructs are believed to contribute to strategy implementation effectiveness (SIE), described as the successful performance of strategy implementation tasks (Ramanujam & Venkatraman, 1987).

This study argues that KPC are an antecedent of KIC. Also, KIC supports, assists, and facilitates SIE. To support the argument, this study employs a mediating model by positioning KIC as mediator between KPC and SIE. The study empirically demonstrates that KIC fully mediate the relationship between KPC and SIE. The demonstration involves two statistical steps. First, the study examines the positive influence of KPC over SIE when KIC is absented. Second, the study attempts to prove that when KIC is present, the positive influence does not hold. Furthermore, the positive influence from KPC to KIC and the positive influence from KIC to SIE are examined.

The contribution of the study is to expand the knowledge of the fields of strategic and knowledge management by providing empirical evidence of the effects of KPC and KIC on SIE. The findings of this study are expected to shed light on linkages between knowledge capabilities and strategy implementation effectiveness in the organization. Furthermore, contributions of this study could potentially go to other fields, such as human resources and management information systems. Not only in the academic field but also in the practical world, the results of this study potentially contribute to the effectiveness of middle managers in strategy implementation. Consequently, when good strategies are more successfully implemented, improvements in business' bottom line are more likely.

THEORETICAL FRAMEWORK AND HYPOTHESES

Organizational capability has its root in the resource-based theory of the firm, whose main argument is that a firm is a bundle of heterogeneous resources and capabilities which support competitive advantage. Organizational capabilities concern an organization's ability to combine different types of resources; especially, firm-specific knowledge enables employees of firms to create new resources. Kogut and Zander (1992) mention that organizational capabilities are a set of specific and identifiable processes that resemble a concept of routines consisting of specific strategic and organizational processes that are complicated and depend on existing knowledge. Nelson and Winter (1982) argue that a great deal of knowledge is stored in the form of standard operating procedure and routines throughout the firm that are embedded in employees. Grant (1996) also suggests that knowledge is integrated in organizational capabilities, embedded in employees. They point out that knowledge is shared across products and is linked to activities within the organization and also depend on social interaction among individuals who share and combine their knowledge to create new resources, bringing effectiveness to an organization.

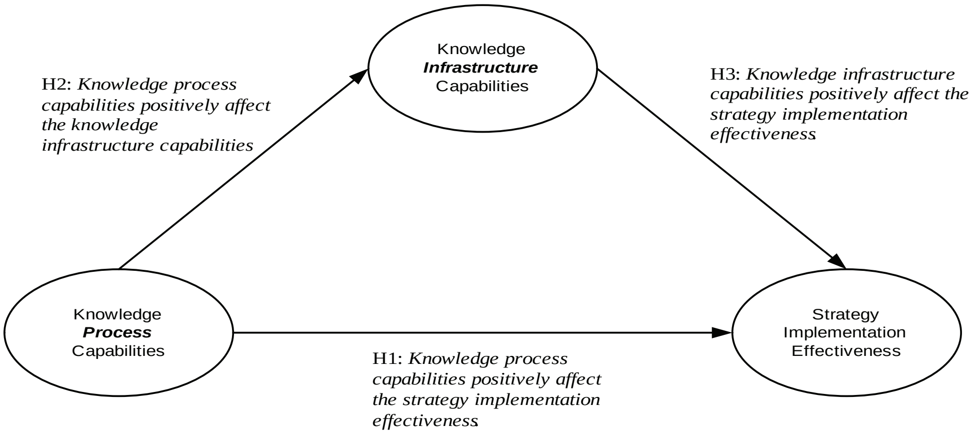
It was mentioned that strategy implementation is an antecedent of organizational effectiveness (Floyd & Wooldridge, 2000) involving all types of activities in the organization (Gadiesh & Gilbert, 2001). Many innovative strategies have failed because they could not be implemented. Leonard-Barton (1995) suggests that strategy implementation involves knowledge embodied in employees and related to communication patterns. The success of strategy implementation depends on leadership and implementation style as well as the communication and interaction process of employees (Argyris, 1991). According to Nobel (1999), strategy implementation is viewed as interpersonal process related to understanding among and commitment among coworkers. Digman (2006) mentions that top managements have to build organizational capability to carry out their strategies. In organizations, strategy usually emerges from top management and is implemented by organizational members. Top managements have to communicate their vision, strategy, and knowledge to organizational members. Also, they have to encourage employees to utilize existing knowledge and to create new knowledge to benefit SIE. Middle managers, who are at the center of the organizational capabilities development and strategy implementation, have to create social interactions by communicating, refining, executing, and interacting among organizational members in order to achieve SIE (Floyd & Wooldridge, 2000; Nonaka, Toyama & Byosiere, 2001).

In order to compete effectively, organizations must leverage their existing knowledge and explore new knowledge by developing knowledge management (KM) processes to create the ability to use knowledge and to develop SIE. The ability of employees to combine, transfer, and create knowledge (including ability to learn) is fundamental to KM and SIE in an organization. It can be implied that KM increases organizational effectiveness and enhances organizational capabilities. Jennex and Olfman (2006) mention that KM enhances decision making effectiveness by improving the ability of decision makers to find and retrieve appropriate knowledge. They propose a KM success model proposed by Delone and Mclean (2003). Three main parts of their KM success model consist of system quality, knowledge quality, and service quality. Jennex and Olfman view the knowledge management system (KMS) as a system that includes information technology (IT) components, users, and processes that use and generate knowledge. They also view knowledge quality in the process of linkage and richness of knowledge and service quality in a view of management support. Gold, Malholtra, and Segras (2001) studied the relationship of KM and organizational effectiveness. They studied the effect of KPC and KIC on organizational effectiveness. They believe that capabilities to manipulate and to manage knowledge that build on the organization's members enable a firm to expand organizational ability and strategy initiatives that benefit organizational effectiveness. Nonaka et al. (2004) state that knowledge creation succession depends on "Ba," or physical and environment factors supporting the process. Even though KM is defined in many different constructs, most of the KM constructs are proposed as KM processes and KM infrastructures. Furthermore, two capabilities of KM that knowledge scholars believe benefit organizational effectiveness capabilities in KM process and capabilities in dealing with infrastructures that support and facilitate the process (Gold et al., 2001; Jennex & Olfman, 2006). Therefore, in order to simplify the area of KM, this study proposes to break the analysis of KM into two main constructs: KPC and KIC.

Causal Model of the Study

Figure 1 shows the causal model of this study. Three hypotheses were proposed to support the

Figure 1. Causal model and hypotheses



research question. Based on the model, the study hypothesized that the impact of KPC on SIE may actually be a result of the mediation of KIC. This study believes that effective execution of KPC promotes organizational growth by allowing the organization to launch strategic initiatives effectively. KPC are believed to enable organizational members in acquiring, creating, sharing, and transferring knowledge in the organization. These KPC activities are believed to influence SIE. Thus, KPC are hypothesized to affect SIE. The study hypothesized that the impact of KPC on SIE may actually be a result of the mediation of KIC. From a review of literature, the mediation effect of KIC is presented by two arguments. First, there is evidence supporting the view that KPC requires and affects KIC. Changes in the capabilities to create knowledge are believed to result in changes in the capabilities to manage the organization's infrastructure. In other words, the KPC are antecedents of KIC. Second, this study argues that the KIC are a basic system in the organization that support and facilitate organizational activities. KIC are believed to inspire organizational members to work with greater effectiveness and efficiency in organizational activities. The capabilities to manage infrastructures in the organization are believed to influence SIE. Therefore, SIE is hypothesized to be effected by KIC.

The Effect of KPC on SIE

KPC are organizational capabilities to manipulate knowledge that are stored in the form of standard operating procedures and routines throughout the organization. KPC are believed to contribute positively to organizational effectiveness by enabling individuals to effectively exploit existing knowledge and explore new knowledge (Prahalad & Hamel, 1990). Effective execution of KPC can promote growth by allowing the organization to launch business initiatives, as well as gain cost and other advantages by improving operations (Trussler, 1998). KPC has been studied by many researchers. The first well-known KPC study is that of Nonaka (1991). He proposed four modes of "Spiral of Knowledge," or a "SECI" model, for the knowledge creation process that consists of knowledge socialization, externalization, combination, and internalization. Edvission (2000) suggests that KPC should consist of four steps: sharing tacit knowledge, creating concepts, justifying concepts, and cross-leveling knowledge. Gold et al (2001) offer another four-stage KPC model: acquisition, conversion, application, and protection, by grouping processes from other empirical studies. Van der Spek and Spijkervet (1997) propose still another four-stage KPC model: creation and sourcing, compilation and transformation, dissemination, and application and value realization. This process is believed to create new knowledge in organization. Alavi and Tiwana (2003) investigate KM process framework that consist of four stages of creation, storage/retrieval, transfer, and application. There is no empirical and systematical investigation to suggest which KPC is the preferred pattern. Holsapple and Joshi (2002) develop knowledge chain through the Delphi study with participant panelists who are knowledge management practitioners and academicians. They introduce five activities of the knowledge chain in order to realize KPC in an organization: knowledge acquisition, generation, selection, assimilation, and emission. Five activities under the knowledge chain are believed to be components of KPC, which is an important driver to transform knowledge in the organization (Holsapple & Singh [2001], whose work systematically studied the visible principle of KM ontology).

In sum, the result of efficiently managed KPC is believed to enhance SIE. Therefore, the components of KPC in organization are believed to assist in the task of translating strategy into action, bringing about the achievement of implementation (Spinello, 1998). This study proposes the first hypothesis below:

Hypothesis 1: Knowledge process capabilities positively affect strategy implementation effectiveness.

Knowledge Infrastructure Capabilities as a Mediator

From the KM success model of Jennex & Olfman (2005), infrastructure is mentioned in terms of system quality and the KMS. Jennex and Olfman determined the KMS as a common network structure focusing on systems hardware and software. They also suggest that the KMS enhances KM decision making skills by improving the ability of decision makers. In strategy field, infrastructure is always mentioned in conjunction with the information system, organizational infrastructure, and management system (Digman, 2006). Infrastructure is a basic system that must function properly. Many researchers suggest that infrastructure mediates organizational activities by supporting and facilitating. Madhok (1997) observes that when companies want to transfer know-how within or across organizational boundaries, managers must rearrange the infrastructures to support the transfer. Gomez-Mejia (1992) reveals that infrastructure is shaped to support organizational process and enhance organizational effectiveness in strategy formulation and implementation. Dyer and Nobeoka (2000) assert that infrastructure supports KPC among suppliers that create coordinating principles between networks. Worren, Moore, and Cardona (2002) mention that infrastructure facilitates knowledge sharing by using electronic networks and databases. In addition, King and Zeithaml (2001) point out that infrastructure is engineered in order to facilitate KPC among and between organizational levels.

Knowledge researchers have described infrastructure as capabilities that are required to support knowledge activities in organizations (Wiig, 1999). KIC are required to build and to maintain generic capabilities that are shared with organizational activities and functions. In this study, KIC includes information technology, management system, and organizational structure. A review of literature shows that KIC mediate organizational activities by supporting and facilitating organizational activities. However, once the organizational process or planning is changed, KIC is shaped and rearranged to match a new process and planning (Powell & Dent-Micallef, 1997).

KPC as an Antecedent of KIC

Infrastructures in the organization were believed by researchers to mediate organizational activities by supporting and facilitating organizational activities (Madhok, 1997; Dyer & Nobeoka, 2000; Worren et al., 2002). However, there are limited empirical investigations on the relationships among KPC, KIC, and organizational effectiveness. A recent study by Gold et al. (2001) shed light on the relationships among KPC, KIC, and organizational effectiveness. The results unveil the positive relationships between KPC and organizational effectiveness, and between KIC and organizational effectiveness. However, the study did not show the relationship between KPC and KIC.

While past studies have examined the role of infrastructure within the organization, it is still not clear how KIC affect KPC. However, there are interesting arguments that imply the effect and relationship of both KPC and KIC. Keidel (1994) suggests that in order to improve competitiveness, an organization redesigns, restructures, or reengineers its configuration to better serve its customer. Keidel mentioned the reengineering process starts with a “blank sheet of paper,” and then determines the pattern that requires the flow charting of the entire work process. The flow charting of the work process is needed before redesigning, reengineering, and restructuring the organization. Keidel also points out that infrastructure may be a mirror image of organizational learning that results from knowledge. It can be thus implied that KPC is an antecedent of KIC. In addition, Keidel suggests that redesigning the way of thinking or the process of knowledge management is needed before the capabilities of restructuring and reengineering infrastructures take place in organization. McDermott (1999) argues that redesigning is associated with a capability to create knowledge that is needed before changes to infrastructures in the organization. Wang and Majchrzak (1999) state when the organization wants to change or extent their organization infrastructures, such as work procedures or physical layout, management should encourage organizational members to share their expertise capabilities by brainstorming ideas and discussion problems. Another piece of literature from El Sawy and Josefek (2003) mentions that the newly created value results from the design of infrastructure capabilities supporting around the process.

These studies show evidence supporting the argument that KPC are an antecedent of KIC. This study argues that KIC support and facilitates organizational activities. However, it does not cause any augmentation of KPC. On the contrary, changes in KPC cause augmentations in the organizational infrastructure to support it. Thus, this study hypothesizes that:

Hypothesis 2: Knowledge process capabilities positively affect knowledge infrastructure capabilities.

The Effect of KIC on SIE

In this section, we describe how KIC evolved in response to strategy implementation needs. In the organization, principally, KIC are changed when they no longer provide the coordination, control, and direction when the organizational process or organizational structure is changed. As a basic system, infrastructure is a fundamental to organizational activities. Also, there were suggestions from strategy implementation scholars that infrastructure is needed as a supportive capability for the implementation activities.

Daft and Mcintosh (1984) studied the role of formal control system in the strategy implementation process. They found that a formal control system helps managers to manage business unit outputs and to control their functional activities. Broadbent, Weill, and St. Clair (1999) suggest that infrastructure capability is fundamental to the architecture of business process and the availability of appropriate infrastructure capability was a key factor preceding the successful implementation of redesigned business process. Shaw, Brown, and Bromiley (2001) comment that strategy implementation is inevitably involved with the decision of organizational infrastructures, such as technological, human resource, finance, or other systems. They mentioned that the congruence of those infrastructures effect relationship of strategy implementation effectiveness. Longman and Mullins (2004) suggest that a proper organization structure is an influence on the success of project implementation.

In organizations, synergies result from combining infrastructure capabilities and other organizational resources (Melville et al., 2004; Powell & Dent-Micallef, 1997). Infrastructure is required to build and maintain organizational capabilities and to share capabilities with other functions within and across organizations. KIC are essential capabilities to support organizational activities by coordinating and controlling strategies among divisions and business units. To increase SIE, the level of KIC is hypothesized to increase as well. The third hypothesis is proposed:

Hypothesis 3: Knowledge infrastructure capabilities positively affect the effectiveness of strategy implementation.

Measurement Model and Variables

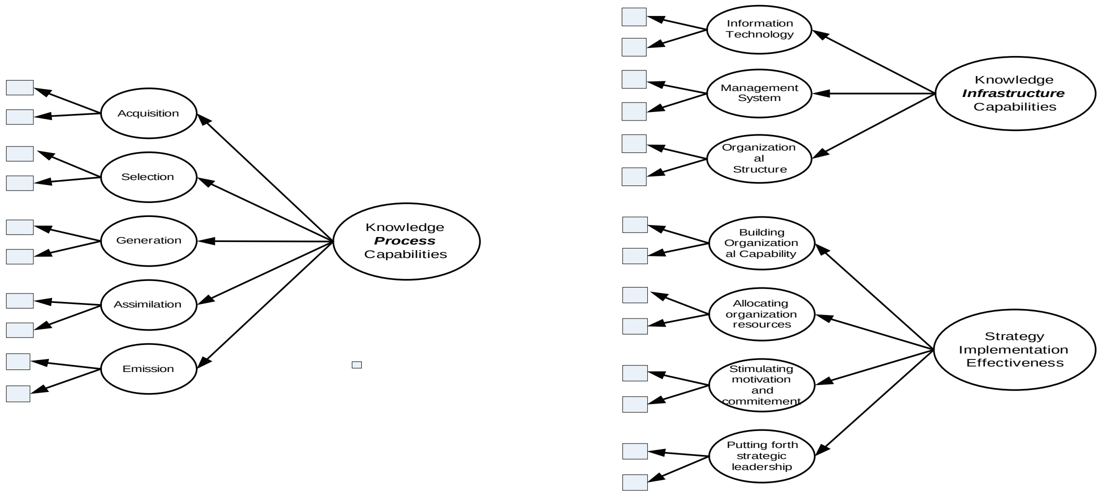
This measurement model consists of three main latent constructs: KPC, KIC, and SIE. In KPC, five subconstructs are knowledge acquisition, knowledge selection, knowledge generation, knowledge assimilation, and knowledge emission, tested as components of KPC. In KIC, three subconstructs are information technology, management system, and organizational structure, tested as components of KIC. In SIE, four subconstructs are building organizational capability, allocating organizational resources, stimulating motivation and commitment, and putting forth strategic leadership that will be tested as components of SIE. Figure 2 presents the measurement model of the study.

METHODS

This study focuses on middle managers as prime respondents. Huber and Power (1985) recognize that these managers are positioned toward the upper echelons of organizations and have important information about their organizations. Relevant to this study, middle managers are deeply and directly involved in strategy implementation (Floyd & Wooldrige, 2000). In addition, middle managers are crucial in developing organizational capabilities, facilitating adaptability, synthesizing information, and championing strategic alternatives (Gadiesh & Gilbert, 2001). They use their knowledge and social interaction to accomplish tasks and innovate and create new capabilities. In this study, middle managers are defined as those positioned below executive officers but above operational managers (such as the functional department managers, regional managers, and district managers) (Floyd & Wooldridge, 2000).

Standard and Poor's COMPUSTAT database was utilized to provide the sample, with sample firms randomly selected from this population. In order to control for industry bias, the study gathered a multi-industry sample to minimize the influence of systematic interindustry difference; the pool of industries from which sample was generated is random. Using the COMPUSTAT database as a sampling frame, the study population includes firms that have a formal organizational structure and clear organizational function because all functions in organizations have already been set and include activities that relate to knowledge activities. Important selection rules are applied to determine the scope of the study's population. In order to enhance the validity of the study, selection criteria are: 1) The firm must have been in business for at least five years, 2) The firm's capital registration must have been more than $50 million in 2003, and 3) The firm's

Figure 2. Measurement model



Note: A square represents observed variable . KPC has four observed variables for each latent variable . KIC has four observed variables for each latent variable . SIE has three observed variable for each latent variable .

profit must have been more than $300 million in 2003. We argue that those criteria are designed to narrow the study scope to firms that have potentially broader profiles of knowledge activities and broad ranges of strategy implementation. Finally, a total of 1,321 middle managers were found from the sampling population**.**

This study used a survey-questionnaire as the measurement instrument. Questionnaires were used to elicit responses related to attitude or preference of constructs (Bartholomew & Knott, 1999). Two main types of scaling techniques—the seven-point Likert scale and descriptive information—have been developed for deriving information. The questionnaire is divided into four main parts (Appendix A). The first part has one question. The objective of this part is to define "how well respondents understand the definition of 'strategy'" by providing the definition of strategy and asking respondents to identify their degree of familiarity with the definition, using the seven-point Likert scale. The scale in the first part is from "not familiar" at 1 to "very familiar" at 7.

The second part addresses knowledge capabilities and has 32 questions. As stated earlier, eight subconstructs (i.e., knowledge acquisition, knowledge selection, knowledge generation, knowledge assimilation, knowledge emission, information technology, organizational structure, and management system) are measured. In this part, seven-point Likert scales are applied to 32 questions. The scale in the second part is from "none" at 1 to "extremely high" at 7.

The third part addresses strategy implementation tasks and aims to answer "how much samplers agree with the key implementation tasks in organizations." There are five measurement constructs and fifteen questions in this part. In this part, seven-point Likert scales are applied to the fifteen questions. The scale is the same as the second part. The last part involves demographic information. In this part, the respondents were asked to provide descriptive information.

The initial draft of the questionnaire was reviewed by three faculty experts to ensure the face validity and readability of the scale items. Data was collected by sending questionnaires via e-mail. This substantially reduced the cost of reaching potential respondents (Schonlau, Fricker & Elliott, 2001).

There were two main stages of the data collection. The first stage included the two pilot projects; the last stage was the full survey. These two stages were implemented to ensure high reliability and validity of data collection.

The pilot study was conducted to determine the clarity and readability of the questionnaire, and to test the internal reliability of the measures. In the first pilot survey, a cover letter and questionnaires were sent via e-mail linked to the questionnaire Web site to 100 target respondents. Seven days following the initial mailing, a follow-up letter and the same Web link were presented to nonrespondents. Seven days after the follow-up mailing, a second follow-up letter and the same Web link were presented to the remaining nonrespondents.

Based on the experience of previous research, these three steps (the initial mailing and two follow-up mailings) could be expected to generate a high response rate. The response rate in the first pilot project was ten percent (10%). Although the returned questionnaires were not enough for a statistical test, "eye-ball" assessments could be made. The questionnaire was modified by adding one question to each construct in part two, and rewording ten questions in part two and one question in part three. These modifications were made to achieve both high internal consistency and high discriminant validity.

For the second pilot survey, modified questionnaires linked to the questionnaire Web-site were sent via e-mail to another 100 target respondents. The response rate in this pilot project was twenty nine percent (29%). The result from the second pilot survey was enough to have a statistical test. The result of the statistical test shows that questions in each construct have high reliability. In order to confirm the face validity and readability of the scale items, the questionnaire was reviewed by experts for the third time. No significant change was required. Therefore, the study used this questionnaire for the full survey.

For the full survey, questionnaires were sent by e-mail linked to the questionnaire Web-site to 1,321 target respondents. Questionnaires were sent to respondents three times, consisting of an initial letter and two follow-up letters. There was a waiting period of seven days before sending a follow-up questionnaire.

RESULTS

The first step in descriptive statistics was to analyze the response rate. The 1,321 questionnaires were sent to middle managers. Following the initial and two follow-up e-mails, the total number of returned questionnaires was 162 middle managers, or a 15.99% response rate. The respondents' positions are 101 division managers (62.3% of total returned questionnaires), and 61 regional managers (37.7% of total returned questionnaires). An average score for "How familiar are you with the concepts and practices of 'Strategy'?" in the first part of the questionnaire is 6.02, with 7.00 being the most familiar. This result shows that respondents feel they are familiar with the given meaning of strategy. In part four, respondents reported an average of 6.08 years in their current position, an average of 11.57 years in their current organization, an average of 17.44 years in knowledge management, and an average of 12.78 years in strategy implementation. The responses to the qualification questions indicated that the survey respondents were well qualified to respond to the questionnaire; the respondents are familiar with strategy implementation and knowledge management.

Structural Equation Modeling Analyses

A majority of the analyses were conducted by SEM framework utilizing MPlus 3 (Muthen & Muthen, 1998-2004) structural equation modeling (SEM) software. The two stage procedures recommended by Kline (2005) are: 1) measurement model analysis; and, 2) causal model analysis and the testing of three hypotheses. The data screening was needed because maximum likelihood estimation, which is the primary estimation method of SEM, relies on the normal distribution. The study's variables were assessed through multiple data screening methods. Distributions were inspected for completeness, normality, and outliers. The examination reveals that data fell within range with no outliers. Normality was assessed for all variables. All questionnaire items were confirmed to be normal. Data screening suggests no critical data-related problems in the study (Appendix B)

There are three goals in examining the measurement model. First is to remove nonrepresentative items. Second is to assess the reliability of constructs. Third is to assess the correlation relationships among constructs. Confirmatory factor analysis (CFA) was utilized in the examination of the measurement model of the constructs in this investigation. The initial CFA models of the three constructs indicate less fit between the theoretical model and empirical data; model respecification was needed. Item removal is recommended (Kline, 2005). Modification indices and factor loading were used to assist item removal. The indicators that failed to have substantial loading on the factors to which they are originally assigned and indicators loaded on a different factor were removed (Kline, 2005). Indicators with good psychometric characteristics and that have relatively high factor loadings were taken into account in the respecification stage (Match & Hau, 1999).

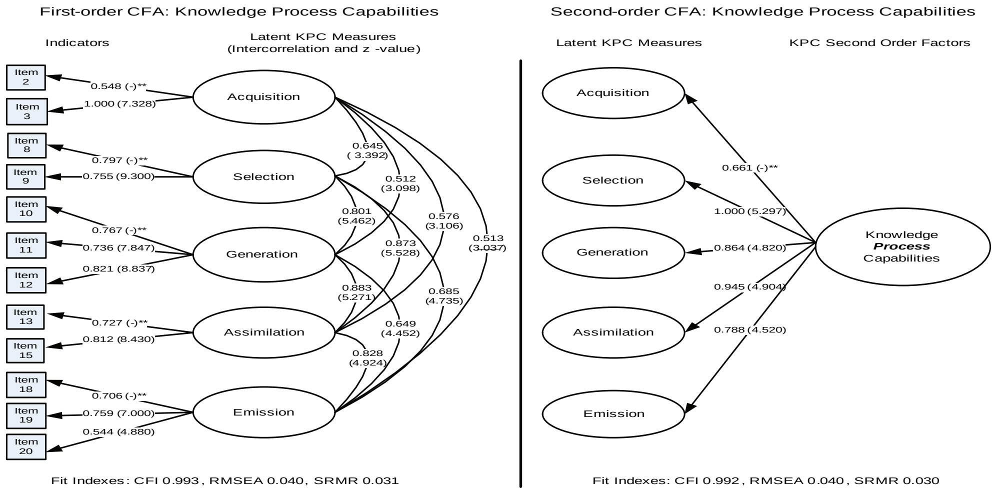
To assess the degree of compatibility between empirical data and study models, this study used three fit indices through our investigations: comparative fit index (CFI) index (Bentler, 1990; Carlson & Mulaik, 1993; Marsh & Hau, 1999); root mean square error of approximation (RMSEA) index (Hu & Bentler, 1999; Klien, 2005); and standardized root mean square residual (SRMR) index (Hu & Bentler, 1999; Kline, 2005). These fit indicators have been shown as the most stable in confirmatory factor analysis and structural equation modeling (Anderson & Gerbling, 1988; Hu & Bentler, 1999).

Hierarchical confirmatory factor analysis was used to examine whether the five activities of KPC, three KIC, and four SIE can be viewed as components of KPC, KIC, and SIE, respectively. We use the following procedures. According to Kline (2005), two analytical steps are part of the hierarchical CFA model. In the first order, we assess the bivariate correlations between the different measures to determine whether they are related. In the second order, in the presence of positive correlation, we estimate a CFA model that permits the identification of the relationship between the indicators, taking measurement error into account. After model respecification, all factor loadings provided acceptable loading on each construct. The results of fit indices of both first-order CFA and second-order CFA are within or better than the cut-off criteria. Especially, SRMR indices of every models show excellent fit. Figures 3, 4, and 5 present the result of the first-order and the second-order CFA. The results of the measurement model indicated that three first-order factor models under CFA showed that all factors are related and observed variables explained each factor well. In the other words, it can be concluded that the empirical data matches the theoretical model.

Evaluating Reliability and Validity

In order to evaluate the validity of the observed variables in a first-order level of measurement, examination of factor loadings of observed variables (items) on latent variables (factors) is recommended (Anderson & Gerbling, 1988; Bollen, 1989; Doll, Xia & Torkzadesh, 1994; Mueller, 1994). In this study, the results of first-order factor models show all items have large and significant loading on their corresponding factors. The result of the second-order factors model showed similar results. Based on the loading results, the measurements of the constructs have high validity.

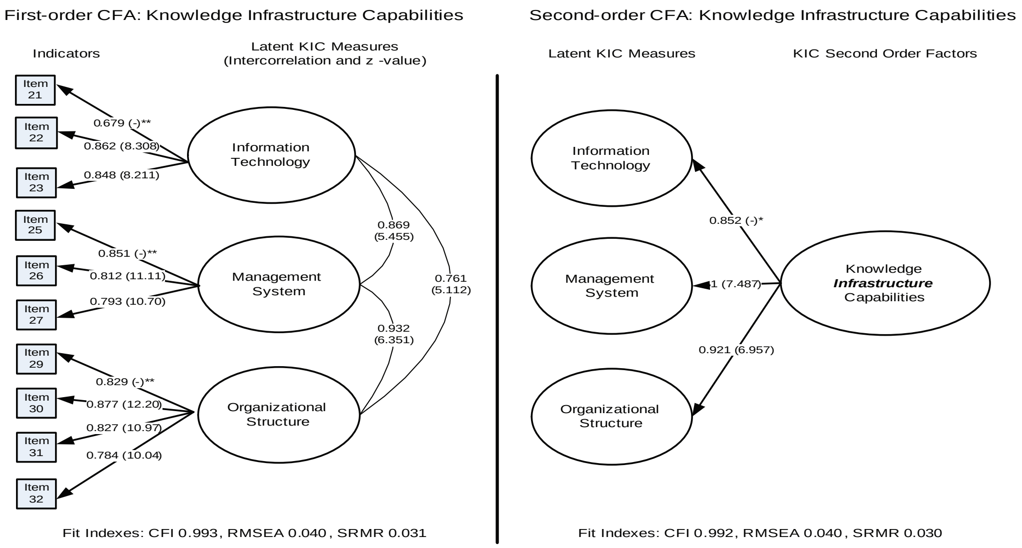
Figure 3. Summarized results CFA of KPC



* The value in the parentheses is z-statistics value. The result of z-statistic > +/-1.96 indicate p-value < 0.05

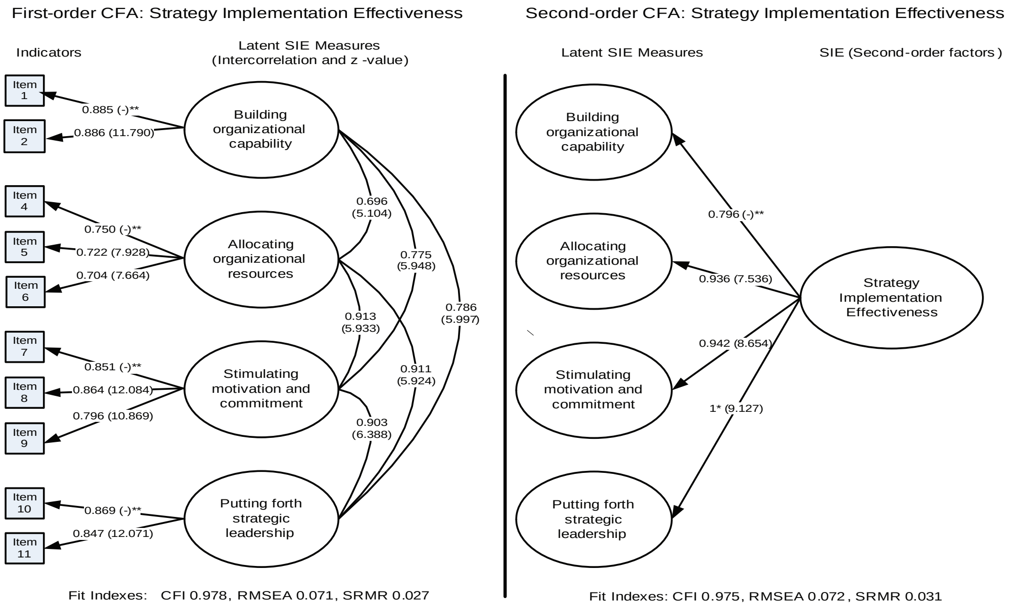
** Absence of a value indicates estimation is not applicable to the variable owing to limitations on simultaneous estimation .

Figure 4. Summarized results CFA of KIC



* The value in the parentheses is z -statistics value. The result of z-statistic > +/-1.96 indicate p-value < 0.05
** Absence of a value indicates estimation is not applicable to the variable owing to limitations on simultaneous estimation .

Figure 5. Summarized results CFA of SIE



* The value in the parentheses is z -statistics value. The result of z-statistic > +/-1.96 indicate p-value < 0.05
** Absence of a value indicates estimation is not applicable to the variable owing to limitations on simultaneous estimation .

Examining reliability, the majority of construct reliabilities exceed the suggested level of 0.70. The reliability in this study ranges from 0.540 to 0.969. Only two components in the KPC showed a result lower than 0.70: 0.540 for knowledge acquisition and 0.675 for knowledge emission. However, in many of the recent empirical investigations in the organizational knowledge area, the results of reliability tests are between 0.54 and 0.85 (e.g., Sabherwal & Becerra-Fernandez, 2003; Szulanski, 1996; Zander & Kogut, 1995). The lower-than-the-suggested level of the two components may suggest that knowledge is an abstraction that has moderate reliability by itself. Taking the observations into account, the reliability results suggest that the indicators are sufficiently reliable to measure latent constructs.

Causal Model

The overall model fit is examined through fit indices and is done to make sure that the empirical observed data actually correspond with the proposed model. For the first measure, the comparative fit index (CFI) index (Bentler, 1990), has a value of 0.923 that is above the commonly accepted rule of thumb at 0.90 to indicate a well-fitting model (Carlson & Mulaik, 1993; Marsh & Hau, 1999). We get the RMSEA of 0.060 for our proposed model. The result of RMSEA is in the range of recently researched results from 0.04-0.09 (Hoskission, Hitt, Johnson & Grossman 2002; Isobe, Makino & Montgomery, 2000). The result of RMSEA showed a good fit model. We get a SRMR of 0.056 for our model, well below the cutoff criteria for SRMR at 0.08 (Hu & Bentler, 1999). Compared with most recent research where the SRMR was used to measure model fit, and the results were in the range of 0.08-0.09 (Isobe et al., 2000; Hoskission et al., 2002). The SRMR index showed an excellent fit of the causal model.

Hypotheses Testing

A main objective of this article is to provide evidence supporting that KIC is a mediator of the causal model. From the literature review, we believe that KPC in organizations is an antecedent to KIC, and that KIC supports SIE. According to the methodology described by Baron and Kenny (1986), in order to demonstrate the mediation effect of KIC, two stages of hypotheses testing are required. The first stage is to demonstrate the positive effect from KPC to SIE, leaving KIC out of the model. This stage confirms Hypothesis 1. As shown in Table 2, the second stage is to integrate KIC and demonstrate a positive path from KPC to KIC and from KIC to SIE. Moreover, there must be no significant path from KPC to SIE. This stage is captured by confirming Hypothesis 2 and Hypothesis 3, and does not confirm Hypothesis 1. Perfect mediation holds if the independent vari-

Table 1. Measurement model: Construct reliability

Construct	Construct Reliability Estimates**
Knowledge process capabilities (KPC)	
Knowledge acquisition	0.540
Knowledge selection	1.000*
Knowledge generation	0.773
Knowledge assimilation	0.898
Knowledge emission	0.675
Knowledge infrastructure capabilities (KIC)	
Information technology	0.755
Organization structure	0.858
Management system	1.000*
Strategy Implementation Effectiveness (SIE)	
Building organizational capability	0.633
Allocating organizational resources	0.876
Stimulating motivation and commitment	0.888
Putting forth strategic leadership	1.000*

Note: * *Use as the reference or an anchor item.*
** *Construct Reliability formula =* $(\Sigma\lambda)^2 / (\Sigma\lambda)^2 + \Sigma\sigma^2$ *(*$\Sigma\lambda$ *represents summation of factor loading in each factor, and* $\Sigma\sigma^2$ *represents summation of measurement error of each factor.*

Table 2. Structural equation modeling results

Construct relationship	Parameter estimates	*z-statistic*	*Result*
The first stage			
H1: KPC → SIE	0.791	4.654	Supported
The second stage			
H1: KPC → SIE	0.260	0.952	Unsupported
H2: KPC → KIC	0.927	4.617	Supported
H3: KIC → SIE	0.571	2.221	Supported

able has no effect on the dependent variable or outcome variable when the mediator is presented in the model (Baron & Kenny, 1986). Therefore, the results of this study show the complete mediation effect of KIC over the path from KPC to SIE.

CONCLUSION

Results Discussion

The purpose of this study is to understand the effects of organizational knowledge capabilities on strategy implementation effectiveness. Two organizational knowledge capabilities (i.e., KPC and KIC) are hypothesized to positively influence SIE. The results demonstrate that the two knowledge capabilities have positive effects on the effectiveness of strategy implementation. However, one of them, KIC, exhibits a mediator property. The result confirms the beliefs of many and sheds deeper light on relationships between the two capabilities and strategy implementation effectiveness.

The discovery of the relationships involved two-step statistical testing, aimed to uncover a mediator. In the first step, the relationship between KPC and SIE was analyzed by disregarding KIC from the model. In this step, the result showed the positive effect of KPC on SIE. In support of prior suggestions (Prahalad & Hamel, 1994; Hertog & Huizenga, 2000; Liebeskind, 1996), the result indicates that the social interaction of KPC affects all functions and resources in the organization, including SIE. Furthermore, the company's capability to combine individual knowledge and skills across boundaries to create knowledge and to launch business initiatives enables firms to enhance SIE. The first-step result indicates that the capability of KPC directly benefits SIE in the organization.

In the second step, all three constructs were presented simultaneously in the model. The result clearly demonstrates the mediator effect of KIC. The positive relationship between KPC and SIE no longer exists. Instead, there are positive effects from KPC to KIC and from KIC to SIE. Our results provide strong support for our second hypothesis that suggests that KPC are an antecedent of KIC. This result supports the prior suggestion (Keidel, 1994; McDermott, 1999; El Sawy & Josefek, 2003) that infrastructures in the organization are changed after the pattern of work process is determined. In other words, the changes in process of knowledge determine any changes in organizational infrastructures (Wang & Majchrzak, 1999). The result supports our argument that KPC causes KIC. KIC do not influence the process as many have believed. Activities inside the five main knowledge-chain activities (such as brainstorming, sharing ideas, recruiting employees from outside, or participating in community practice) may benefit the capability to manage infrastructure in the organization.

Our result also provides strong support for our third hypothesis that KIC affect SIE. This finding suggests that KIC affect SIE as a whole. This result is consistent with position of Shaw et al. (2001) that strategy implementation is inevitably involved with the organizational infrastructure—such as information technology, human resources system, or organizational—and it is also consistent with Longman and Mullins (2004), who argue that a proper infrastructure influences the success of strategy implementation.

In the second step, the no-longer-existing Hypothesis 1 may suggest that the organization may gain advantages by using infrastructure to leverage intangible and complementary human and business resources (Melville et al., 2004). In addition, the results are thus consistent with the suggestions of Madhok (1997) and Dyer and Nobeoka (2000), who assert that KIC support and facilitate organizational members to transfer and to create knowledge within and across organizations. Furthermore, consistent with this explanation, Worren et al. (2002) and King and Zeithaml (2001) suggest that management restructures organizational infrastructures in order to facilitate KPC and to support organizational activities. In short, it may be concluded that the organization needs KIC in order to enhance organizational activities. It is influenced by KPC and it supports and facilitates strategy implementation tasks. In the knowledge economy, the fast-changing environment causes the organization to develop, mix, and match two kinds of knowledge capabilities in order to enhance SIE.

In addition to the contributions of the causal models, the results also demonstrate and confirm components of KPC and KIC. The measurement model of KPC clearly demonstrates that the five components are significantly correlated. Furthermore, all components load significantly under KPC. The statistical results could only suggest that knowledge acquisition, knowledge selection, knowledge generation, knowledge assimilation, and knowledge emission are the components of KPC. Bringing the components under a single construct shows the powerful nature of knowledge activities linked through the social fabric. A picture of social interactions among knowledge process activities can be drawn from the following: using information outside the company; training employees to know how to acquire new knowledge; training employees by using professionals inside organizations, using the company database; brainstorming; ongoing interaction; communicating new information; sharing information among organizational members; producing a market report; and encouraging interorganizational activities. All of these activities create seemingly positive effects on SIE until KIC is brought into the canvas.

In the second measurement model concerning KIC, the model shows and demonstrates information technology, the management system, and organizational structure as the three components of KIC. The interconnection of the three components takes an important place in the relationship between KPC and SIE. They support, assist, and facilitate organizational strategy implementation activities. They are also a function of KPC. In the light of these connections, it becomes important to reorient our understanding that good infrastructure may help strategy implementation. However, good infrastructure is a requirement for a good process. Both scholars and practitioners must balance the importance between KPC and KIC because the two are important in SIE.

In the third measurement model concerning SIE, the model shows and demonstrates four tasks of strategy implementation as the four components of SIE. The measurement model of strategy implementation clearly demonstrates that the four tasks are significantly correlated. Furthermore, all components load significantly under KPC. The statistical results could only suggest building organizational capability, allocating organizational resources, stimulating motivation and commitment, and putting forth strategic leadership as the components of effective strategy implementation. These four tasks of strategy implementation are tasks that top management and middle managers must concern themselves with. If an organization can achieve these four tasks, it can be concluded that the organization has succeeded in the implementation process.

Implications

Overall, this study expands the view of how knowledge capabilities affect the effectiveness of strategy implementation as well as the role of knowledge infrastructure capabilities as a mediator. Through analysis of theories and empirical testing, this research strongly supports the notion that organizations may possess powerful ingredients for successful strategy implementation through the development of key knowledge capabilities.

Implications for Management Practice

Beyond the theoretical contribution, there are some issues in which organizations should develop knowledge capability to ensure effectiveness of strategy implementation.

First, building on the knowledge capabilities, management should promote and develop knowledge process activities in the organization's members. Because knowledge is embedded into organizational routine and activities, promoting knowledge process activities will create social interactions among an organization's members and create knowledge sharing and culture transference. In addition, the top management team should recognize the importance of knowledge by creating a position specifically devoted to knowledge management (e.g., Chief Knowledge Officer [CKO]). This position will play an important role in overseeing knowledge activities and managing organizational knowledge. To enhance knowledge management efficiency, the CKO must establish programs to balance organizational knowledge and capabilities in order to leverage knowledge.

Second, another direct implication for managerial practice regarding key knowledge processes is that management should advocate the development of knowledge capabilities for effectiveness of strategy implementation. Management should pay and balance attention to both knowledge process activities and infrastructure. Davenport and Prusak (1998) caution management that optimizing one aspect of knowledge capabilities can cause detrimental effects in the development of organizational capabilities. Focusing only on process capabilities creates rich knowledge. However, the knowledge is not utilized because no infrastructure exists for it. Organizations must not forget that the observed benefits of knowledge are the result of a well-matched infrastructure. The knowledge process needs the infrastructure to store and to increase the efficiency of knowledge process activities. On the other hand, a study by Hansen, Nohria, and Tierney (1998) reveals that overemphasizing technology to capture and disseminate knowledge does not yield a satisfactory result. The organization does not have sources of knowledge to exploit for competitive advantage.

Third, the findings of this study point to the unique importance of knowledge infrastructure. Organizations should prepare the readiness of the three infrastructures (i.e., IT, management systems, and organizational structures). Ready-for-knowledge infrastructures help organizations to realize benefits of their knowledge in a timely manner when the knowledge becomes available from the knowledge process. If the infrastructure is not ready for knowledge, the knowledge from knowledge activities is less likely to be utilized effectively. The findings of this study also support the fact that strategy implementation tasks need infrastructure to support and to facilitate their activities. The state of technology, management, and organizational structure has to be assessed, as well as their readiness for supporting organizational activities.

Last, another important implementation of the knowledge process lies in the area of incremental innovation. The importance of sharing knowledge for better innovation has been investigated and discussed by many researchers, such as Hinloopen (2003), Carlile (2004), Smith, Collins, and Clark (2005). Therefore, improving KPC not only benefits SIE but also innovations that span within the knowledge process. It should be noted that innovations can happen almost anywhere in an organization (Damanpour, 1996). Furthermore, innovation involves more than product innovation. It includes process innovation, innovative adoption of technology, and innovative problem solving. In fact, innovation can be said to extend to strategy innovation (Hamel, 2002). Thus, organizations can expect the benefit of the KPC to include more than merely SIE.

Implications for Future Research

In the near future, the study model can be improvised to study the interplay among the components of the KPC and KIC. Furthermore, the interplay can be extended to each component of SIE. It is interesting to speculate that the whole is greater than the sum of the parts for each of the three main constructs. The result of the relationships among the three main constructs could be changed in light of the analyses of the interplay among their smaller components.

In the long run, the study presents many opportunities to expand beyond its basic findings. Many questions that require further analysis and investigation have been raised. Both knowledge capabilities, (examined in this study) and process and infrastructure can be explored further. There are several research areas with which this study can be integrated. New research is needed to understand specific strategies and organizational programs that facilitate knowledge capability and lead to an increase in the effectiveness of strategy implementation.

Concerning KPC, we could expand our understanding to explore obstacles in exercising knowledge process activities. Especially, the areas of political and social interaction at each component and across components of the process promise to yield insightful detail. Human resources management can also be linked to knowledge process capability. The area of recruiting and selecting knowledge workers can be linked to knowledge capabilities development.

Concerning the infrastructure capabilities, one direction of future research is to explore how to manage the readiness of infrastructures in organizations, what factors influence the change of infrastructures in organizations, as well as how to design infrastructures that benefit both the efficiency of a bureaucratic organization and the flexibility of knowledge process creation. Furthermore, in strategy implementation areas, we could study middle managers by linking them with strategy innovation and corporate entrepreneurship. Floyd and Wooldridge (2000) believe that middle managers occupy the position that creates organizational capability, knowledge capability, and strategy innovation.

The last interesting direction of future research is to explore how different project characteristics might change the result of this study. This study gathered only general information on strategy implementation effectiveness. However, the spectrum of strategy project characteristics can be explored in contingency with the study model. The spectrum of characteristics could range from evolutionary improvement to revolutionary improvement, from arm's length collaboration to close collaboration, or from intrafirm to interfirm. The end result is to observe how knowledge process and knowledge infrastructure respond to many characteristics of strategic initiatives.

Limitations of the Study

The main limitations of this study relate to the "snapshot nature" of the data; that is, the data represent a picture at only one point in time of organizational life. In reality, the relationships between knowledge capabilities and the effectiveness of strategy implementation are incrementally developed throughout the life of an organization. They could not be developed in a short period, especially the capability of knowledge process which is based on day-by-day social interactions among organization members. Although the snapshot enables us to conduct many analyses and to answer the research question, it limits our ability to analyze beyond current relationships. Therefore, in order to find out the in-depth relationship of knowledge capabilities and strategy implementation, longitudinal action research is recommended.

Conclusion

Knowledge and capabilities have to be built up slowly over time, shaped, and channeled in certain directions by hundreds of daily managerial decisions. The results of this study show that knowledge process capabilities positively affect the effectiveness of strategy implementation when knowledge infrastructure is ignored. However, KPC does not directly affect the effectiveness of strategy implementation when KIC is presented. The infrastructure plays the mediator role. Therefore, organizations should balance both types of knowledge capabilities. Effective execution of knowledge capabilities can promote growth by allowing an organization to launch business initiatives more effectively and successfully. Furthermore, contributions of this study could potentially go beyond the field of strategic management to other fields, such as human resources management and management information systems. The results of this study also benefit the practitioner's world by contributing to the effectiveness of middle managers in the area of knowledge capabilities. Successfully managing the capabilities to transform knowledge will add to the development of organizational members. Organizational members will learn additional knowledge as well as identify knowledge that can enhance the efficiency and effectiveness of strategy implementation. Furthermore, successfully managing the capabilities to manage infrastructures will also increase the ability to facilitate and support organizational activities. Therefore, managing both types of knowledge capabilities activities will contribute to the effective performance of middle managers in strategy implementation. Consequently, when strategies are more successfully implemented, the improvements in business' bottom line are more likely.

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APPENDIX A.

Survey Questionnaire

Knowledge Management and Strategy Implementation

The objective of this questionnaire is to study the effect of knowledge processes and knowledge infrastructure capabilities on strategy implementation. Please respond to this questionnaire through the perspective of strategy implementation.

Part 1: This section focuses on your interpretation of the term "Strategy" Please use the following definition:

Strategy is the means that the organization utilizes or employs to achieve its goals, objectives, and vision as part of the company mission.

From the definition above, how familiar are you with the concepts and practices of "Strategy" Please answer by using the scale below.

(Not very familiar) 1 2 3 4 5 6 7 (Very familiar)

Part 2: This section focuses on the measurement of components of "knowledge capabilities" within your organization. Please use the following scale to rate the extent of your organization's use of the various components.

Rating definitions:
1=none, 2=slight, 3=below average, 4=average, 5=above average, 6=significant, and 7=extremely high

My organization…	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Recruits and hires employees from other firms in order to access knowledge and expertise developed at these firms.	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Uses information from outside the company, by such means as conducting external surveys or purchasing external data sets, in order to get more new information and generate new products and strategies.	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Provides effective training for employees on how to identify and acquire information from external sources.	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Utilize knowledge of customer needs to benefit new product development and organizational strategies.	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Encourages employees to exchange or share their ideas, information, knowledge, and work experiences.	*1*	*2*	*3*	*4*	*5*	*6*	*7*

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Rating definitions:

1=none, 2=slight, 3=below average, 4=average, 5=above average, 6=significant, and 7=extremely high

Uses appropriate procedure for forecasting	1	2	3	4	5	6	7
Routinely extracts and collects information and knowledge from available data bases.	1	2	3	4	5	6	7
Train employees by utilizing experienced colleagues or professionals within the organization	1	2	3	4	5	6	7
Uses company database (such as customer profile) in generating consistent, accurate, and faster decision about customers.	1	2	3	4	5	6	7
Promotes or supports brainstorming among employees to create new insights or to solve problems.	1	2	3	4	5	6	7
Promotes or supports various kinds of new inventions by employees.	1	2	3	4	5	6	7
Enables employees to create new knowledge through ongoing interactions and improvisations while they perform their jobs.	1	2	3	4	5	6	7
Encourages employees to share their information, ideas, or knowledge by using internal information systems (e.g., bulletin board, internal groupware, or internal publications.)	1	2	3	4	5	6	7
Provides on the job training to enable employees to better understand their responsibility/duty of their position.	1	2	3	4	5	6	7
Communicates new innovations, new policies, or new ideas to employees.	1	2	3	4	5	6	7
Promotes employee to participate in community service that related to their profession.	1	2	3	4	5	6	7
Provides information systems tools in order to enable its employees awareness utilize such information sources as the Internet	1	2	3	4	5	6	7
Gives lecture and presentations about product development and company situations to employees	1	2	3	4	5	6	7
Produce or publish market research reports and other status reports.	1	2	3	4	5	6	7
Participates in inter-organizational activities, such as trade groups, professional societies, and so forth.	1	2	3	4	5	6	7
Has effective information technology (IT) to provide information for business units planning (e.g., data mining for marketing forecasts)	1	2	3	4	5	6	7
Utilizes information technology (IT) to facilitate collaboration and communication among employees and business partners.	1	2	3	4	5	6	7
Encourages employees to find new information, innovations, ideas, knowledge, or skills using information technology (e.g., searching the Internet).	1	2	3	4	5	6	7
Identifies and tests new technologies for business purposes by developing applications specific to business-unit.	1	2	3	4	5	6	7
Enables employees to cooperate or to interact with the organization's planning system.	1	2	3	4	5	6	7
Encourages employees to develop work standards in day-to-day operations in order to stabilize organizational processes and quality.	1	2	3	4	5	6	7

continued on following page

Rating definitions:

1=none, 2=slight, 3=below average, 4=average, 5=above average, 6=significant, and 7=extremely high

Enhances development of employees' ideas, knowledge, or skills by job rotation, job redesign, or extensive training.	1	2	3	4	5	6	7
Encourage employees to build social relationships within the organization.	1	2	3	4	5	6	7
The organizational structure (divisions, departments, units) enhances effectiveness of interactions and sharing of knowledge.	1	2	3	4	5	6	7
Facilitates the transfer of new knowledge, ideas, skills, and innovations across the organizational hierarchy and functional boundaries.	1	2	3	4	5	6	7
Encourage employees to go where they need for knowledge regardless of the organizational structure.	1	2	3	4	5	6	7
Fosters an interdependent work community in which employees are able to exchange/transfer their information.	1	2	3	4	5	6	7

Part 4: Demographic information: Please provide the following descriptive information about your position with your organization. Your responses will remain anonymous and will not be associated with your name.

- What is your job title? …………………
- How many years have you been in this job? …………….years
- How many years have you been with this organization? …………….years
- How many years' experience do you have in knowledge management in this or other organizations? …………….years
- How many years' experience do you have in strategy implementation in this or other organizations? …………….years

APPENDIX B.

Table 4.5. Descriptive statistics: Assessment of the data normality (N=162)

Items	Mean	Std. Statistic	Variance	Skewness		Kurtosis	
			Statistic	Statistic	Std. Error	Statistic	Std. Error
p2_1	4.261	1.462	2.137	-0.304	0.217	-0.335	0.430
p2_2	3.679	1.421	2.020	-0.245	0.217	-0.214	0.430
p2_3	5.221	1.398	1.954	0.358	0.217	-0.150	0.430
p2_4	4.897	1.388	1.925	-0.611	0.217	-0.229	0.430
p2_5	4.847	1.301	1.691	-0.268	0.217	-0.158	0.430
p2_6	4.483	1.360	1.849	-0.616	0.217	0.387	0.430
p2_7	4.696	1.462	2.138	-0.426	0.217	0.187	0.430

continued on following page

Table 4.5. continued

p2_8	4.528	1.442	2.079	-0.344	0.217	-0.162	0.430
p2_9	4.698	1.438	2.068	0.003	0.217	-0.564	0.430
p2_10	4.509	1.530	2.341	-0.589	0.217	0.355	0.430
p2_11	4.623	1.483	2.200	-0.443	0.217	-0.134	0.430
p2_12	4.569	1.224	1.499	0.054	0.217	-0.525	0.430
p2_13	4.759	1.418	2.011	-0.256	0.217	0.198	0.430
p2_14	4.695	1.267	1.606	-0.188	0.217	-0.395	0.430
p2_15	4.077	1.204	1.450	0.001	0.217	-0.188	0.430
p2_16	4.987	1.570	2.465	-0.060	0.217	-0.267	0.430
p2_17	4.469	1.329	1.766	-0.602	0.217	0.492	0.430
p2_18	3.992	1.435	2.058	-0.491	0.217	0.511	0.430
p2_19	4.811	1.376	1.894	-0.111	0.217	-0.018	0.430
p2_20	4.513	1.386	1.920	-0.610	0.217	0.488	0.430
p2_21	4.810	1.434	2.056	-0.356	0.217	-0.065	0.430
p2_22	4.644	1.281	1.641	-0.054	0.217	-0.442	0.430
p2_23	4.478	1.302	1.694	0.010	0.217	-0.582	0.430
p2_24	4.073	1.330	1.768	-0.113	0.217	-0.414	0.430
p2_25	4.727	1.250	1.562	0.052	0.217	-0.043	0.430
p2_26	4.003	1.293	1.672	-0.435	0.217	0.487	0.430
p2_27	4.223	1.425	2.030	-0.154	0.217	-0.419	0.430
p2_28	4.083	1.315	1.728	-0.242	0.217	-0.184	0.430
p2_29	4.162	1.330	1.768	-0.077	0.217	-0.385	0.430
p2_30	4.419	1.340	1.795	-0.041	0.217	-0.111	0.430
p2_31	4.368	1.428	2.040	-0.273	0.217	0.219	0.430
Items	Mean	Std. Statistic	Variance	Skewness	Kurtosis		
			Statistic	Statistic	Std. Error	Statistic	Std. Error
p3_1	4.853	1.238	1.533	-0.648	0.213	0.188	0.423
p3_2	4.932	1.265	1.600	-0.525	0.213	-0.284	0.423
p3_3	5.116	1.322	1.748	-0.635	0.213	0.098	0.423
p3_4	4.445	1.327	1.762	-0.594	0.213	0.151	0.423
p3_5	4.581	1.404	1.970	-0.587	0.213	0.118	0.423
p3_6	4.852	1.271	1.616	-0.518	0.213	0.135	0.423
p3_7	4.834	1.337	1.787	-0.652	0.213	0.362	0.423
p3_8	4.834	1.470	2.162	-0.512	0.213	0.234	0.423
p3_9	4.500	1.681	2.824	-0.579	0.213	-0.525	0.423
p3_10	4.716	1.442	2.078	-0.629	0.213	0.309	0.423

Table 4.5. continued

p3_11	4.545	1.352	1.829	-0.635	0.213	0.324	0.423
p3_12	4.662	1.447	2.093	-0.277	0.213	-0.220	0.423

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Chapter 6.7

Empirical Investigation of Critical Success Factors for Implementing Business Intelligence Systems in Multiple Engineering Asset Management Organisations

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ABSTRACT

Engineering asset management organisations (EAMOs) are increasingly motivated to implement business intelligence (BI) systems in response to dispersed information environments and compliance requirements. However, the implementation of a business intelligence (BI) system is a complex undertaking requiring considerable resources. Yet, so far, there are few defined critical success factors (CSFs) to which management can refer. Drawing on the CSFs framework derived from a previous Delphi study, a multiple-case design was used to examine how these CSFs could be implemented by five EAMOs. The case studies substantiate the construct and applicability of the CSFs framework. These CSFs are: committed management support and sponsorship, a clear vision and well-established business case, business-centric championship and balanced

team composition, a business-driven and iterative development approach, user-oriented change management, a business-driven, scalable and flexible technical framework, and sustainable data quality and integrity. More significantly, the study further reveals that those organisations which address the CSFs from a business orientation approach will be more likely to achieve better results.

INTRODUCTION

Background

Engineering asset management organisations (EAMOs), such as utilities and transportation enterprises, store vast amounts of asset-orientated data (Lin, Gao, Koronios, & Chanana, 2007). However, the data and information environments in these organisations are typically fragmented and characterised by disparate operational, transactional, and legacy systems spread across multiple platforms, diverse structures, and different data formats (Haider, 2007; Haider & Koronios, 2003). The plethora of different systems makes it very difficult, even impossible, for a system in one functional unit to communicate with systems in other units. This lack of integration of information systems, together with the large volumes of transactional data which might be spread in different pools across the enterprise, can lead to increased difficulties in analysing, summarising, and extracting actionable information resulting in suboptimal management performance (Ponniah, 2001). Moreover, heightened competition resulting from market deregulation as well as increased regulatory compliance and governance requirements, such as the Sarbanes-Oxley ordinance in the U.S. and the CLERP 9 Acts in Australia, have demanded greater accountability for decision making within such organisations (Logan & Buytendijk, 2003; Mathew, 2003).

On the other hand, existing management information systems are no longer adequate for EAMO's modern business needs and not always meeting the expectations of decision makers at all hierarchical levels (Olszak & Ziemba, 2007). These systems were unable to handle the integration of different, dispersed, and heterogenic data within such enterprises. Nor could they effectively interpret such data in any broader contexts or discover new data interdependencies (Bui, 2000, cited in Olszak & Ziemba, 2007; Gray & Watson, 1998), due to improper techniques of data acquisition, analysis, discovery, and visualisation (Olszak & Ziemba, 2007). Therefore, in response to these pressing challenges of information dispersion and compliance requirements, EAMOs are compelled to improve their business execution and management decision support through the implementation of a contemporary BI system (Olszak & Ziemba, 2007).

According to Negash (2004), "BI systems combine data gathering, data storage, and knowledge management with analytical tools to present complex internal and competitive information to planners and decision makers." Whilst Moss and Atre (2003) state that "it is an architecture and a collection of integrated operational as well as decision-support applications and databases that provide the business community easy access to business data." Stated simply, the main tasks of a business intelligence (BI) system include "intelligent exploration, integration, aggregation and a multidimensional analysis of data originating from various information resources" (Olszak & Ziemba, 2007). Implicit in this definition, data is treated as a highly valuable corporate resource, and transformed from *quantity* to *quality* (Gangadharan & Swami, 2004). As a result, critical information from many different sources of an asset management enterprise can be integrated into a coherent body for strategic planning and effective allocation of assets and resources. Hence, meaningful information could be delivered at the right time, at the right location, and in the right form (Negash, 2004) to assist individuals, departments, divisions, or even larger units for improved decision-making (Jagielska, Darke, & Zagari, 2003).

From an architectural standpoint, a BI system is composed of a set of three complementary data management technologies, namely data warehousing, OLAP, and knowledge discovery (which is aided predominantly by data mining techniques). To be specific, Olszak and Ziemba (2007, p. 138) posit that a BI system is composed of the following components:

- Extraction-Transformation-Load (ETL) tools that are responsible for data transfer from operational or transaction systems to data warehouses;
- Data warehouses to provide some rooms for thematic storing of aggregated and analysed data;
- OLAP analytic tools to let users access, analyse and model business problems and share information that is stored in data warehouses;
- Data mining tools for determining patterns, generalisations, regularities, and rules in data resources;
- Reporting and ad hoc inquiry tools for creating and utilising different synthetic reports; and
- Presentation layers that include customised graphical and multimedia interfaces to provide users with information in a comfortable and accessible form.

In the past few years, the BI market has experienced extremely high growth as vendors continue to report substantial profits (Gartner, 2006a; IDC, 2007). Forrester's recent survey indicated that for most CIOs, BI was the most important application to be purchased (Brunelli, 2006). The results of the latest Merrill Lynch survey into CIO spending similarly found that the area with the top spending priority was BI (White, 2006). These findings are echoed by Gartner's CIOs priorities surveys in 2006 which revealed that BI ranked highest in technology priority (Gartner, 2006b). In the most recent survey of 1,400 CIOs, Gartner likewise found that BI leads the list of the top ten technology priorities (Gartner, 2007).

While the BI market appears vibrant and the importance of BI systems is becoming more widely recognised, particularly in EAMOs, nevertheless few studies have investigated the implementation of BI systems in general and critical success factors in particular. Although there have been a plethora of guidelines from the IT industry, most rely on anecdotal reports or quotations based on hearsay (Jagielska et al., 2003). This is because the study of BI systems is a relatively new area that has primarily been driven by the IT industry and vendors (Jagielska et al., 2003). Therefore, empirical research to shed more light on those critical factors influencing the implementation of BI systems is desirable because the understanding of critical success factors (CSFs) enables BI stakeholders to optimise their scarce resources and efforts on those significant factors that are most likely to have an impact on the system implementation, and thus increase the chances of implementation success.

Research Motivation

CSFs have been one of the earliest and most prominent topics in the area of IS research (Lu, Huang, & Heng, 2006). Rockart (1979) defines CSFs as "the limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organisation." Whilst Greene and Loughridge (1996) assert that the identification of CSFs can help to clarify the nature and amount of resources that must be gathered to permit the project team to concentrate their efforts on meeting priority issues rather than what the available technologies will allow. Thus, the emphasis here is on "few" and "must go right" (Khandelwal, 2000). For obvious reasons, CSFs are high-level management considerations as distinct from a detailed set of project deliverable specifications.

The IS literature contains many studies that investigate the factors that impact the implementation of an information system. As a result of such research efforts, a number of critical factors have been investigated and identified; for instance, top management commitment and adequate sponsorship (Lu et al., 2006). However, while these studies are helpful, the complexity involved in the implementation of BI systems is arguably different from traditional systems development efforts (Bischoff & Alexander, 1997; Fuchs, 2006; Han & Kamber, 2001; Ponniah, 2001; Power, 2002). The implementation of a BI system is not a conventional application-based IT project (such as an operational or transactional system), which has been the focus of many CSF studies (Wixom & Watson, 2001). Instead, it shares similar characteristics with other enterprise-wide infrastructure projects such as enterprise resource planning (ERP) systems implementation.

That is, a BI system implementation is regarded as a complicated infrastructure project and is defined as a set of shared, tangible IT resources that provide a foundation to enable present and future business applications (Duncan, 1995). It is not a simple activity to purchase a combination of software and hardware, but rather it is a complex undertaking requiring requisite infrastructure and resources; initially it involves various stakeholders several months to develop, and it may possibly take several years to become adopted fully across the enterprise (Moss & Atre, 2003; Moss & Hoberman, 2004; Olszak & Ziemba, 2007; Reinschmidt & Francoise, 2000; Watson & Haley, 1997). Typical expenditure on these systems includes all BI infrastructure, software programs, licenses, training, consulting, and implementation costs, and may demand seven-digit expenditure (Watson & Haley, 1997). Furthermore, BI stakeholders need to address issues foreign to the conventional systems, and these might include cross-functional data quality and integrity issues, technical complexities such as multidimensional data modelling, cross-organisational needs and socio-politics, and broader enterprise integration and consistency challenges (Shin, 2003).

Specifically, the key infrastructural component—a data warehouse—is a subject-oriented, integrated, time-variant, and nonvolatile collection of data that differ from conventional online transactional processing (OLTP) databases (Inmon, 1994). A complex data structure must be maintained in order to provide an integrated view of the organisation's data so users can query across departmental boundaries for dynamic retrieval of rich decision-support information. Furthermore, the BI system's architecture is highly complex owing to the back-end systems originating from multiple data sources and to the vast volume of data to be processed (Sen & Jacob, 1998). Moss and Atre (2003) reported that a surprisingly high rate of 60% of BI projects end in abandonment or failure due to an assortment of issues. The complexity of BI systems is further exemplified by Gartner's recent study which predicted that more than half of the systems that had been implemented would achieve only limited acceptance (Friedman, 2005). In brief, the implementation of a BI system is associated with many challenges as summarised below (Fuchs, 2006; Moss & Atre, 2003; Watson, Gerard, Gonzalez, Haywood, & Fenton, 1999):

- Lack of recognition of BI projects as cross-organisational business initiatives which differ from typical stand-alone solutions.
- Unengaged or weak business sponsors.
- Inadequate formal involvement from the business side of the enterprise.
- Inappropriate project team structure and dynamics.
- No software release concept (no iterative development method).
- No work breakdown structure (no methodology).
- Ineffective project management (only project administration).

- No business analysis and no standardisation activities (with too much reliance on disparate methods and tools)
- Underlying back-end systems and processes which originally were not adapted for BI applications because the normalised database structures in operational systems are suited to updating data, but not for exporting data to other systems.
- Poor data quality derived from source systems that can often go unnoticed until cross-systems analysis is conducted.
- Inadequate resources needed to keep the system alive and constantly adapted to the needs of users.
- The maintenance process for BI systems that tends to be vague and ill-defined because it is quite difficult to determine how the business users will work with the BI system if they are given such analytical and reporting freedom.

Despite the daunting complexities in implementing BI systems, there has been little empirical research about the CSFs impacting the implementation of BI systems. The gap in the literature is reflected in the low level of contributions to international conferences and journals (Yeoh, Gao, & Koronios, 2006). More importantly, the value of previous CSF studies will obviously decline with age (Little, 1998). As pointed out by Dickson, Leithesier, Wetherbe, and Nechis (1984), “New technologies, economic and legal conditions, and other developments will cause the relative importance of these issues to change and cause new ones to come into existence.” Thus the rapid advancement of technology innovation in general, and the pace at which new technologies are being adopted in particular, will apparently influence the state of criticality for such types of CSFs research (Little, 1998). Furthermore, CSFs applicable to other types of information systems may not necessarily apply to a contemporary BI system.

Therefore, the increased rate of adoption of BI systems, the complexities of implementing a contemporary BI system, the scarcity of academic research, and the far-reaching business implications justify a more focused examination of CSFs as well as the associated contextual issues required for implementing BI systems.

BI System vs. Operational System

As the focus of this study is on BI systems, it is critical to understand how they differ from other systems, and especially those for operational and transactional purposes. In general, there are two fundamental types of information systems within the IS literature, namely online transactional processing (OLTP) systems (also known as operational or transactional systems) and online analytical processing (OLAP) systems such as BI systems (Datta & Thomas, 1999; Ponniah, 2001; Power, 2002). There have been numerous successful cases associated with OLTP-based operational systems, but the knowledge required for building these systems is not adequate for successful implementation of OLAP-based BI systems (Fuchs, 2006; Power, 2002). In fact, BI systems differ in many ways from operational systems that process business transactions (Power, 2002), and there is a need for a more sophisticated technical and philosophical understanding of BI systems. A number of researchers have described the differences between BI systems and operational systems (see Datta & Thomas, 1999; Fuchs, 2006; Han & Kamber, 2001; Ponniah, 2001; Power, 2002) and these are summarised in Table 1 below, followed by detailed discussion.

The major difference between operational systems and BI systems is in the general purpose of each. Operational systems are online transactional processing (OLTP) systems designed to expedite and automate transaction processing, record keeping, and simple reporting of transactions (Datta & Thomas, 1999; Power, 2002). These so-called “bread-and-butter” systems,

Table 1. Comparison of BI system with operational system (Adapted from Fuchs, 2006; Han & Kamber, 2001; Ponniah, 2002; Power, 2002)

Attributes	Operational system	BI system
Business purpose	Support the operational business activities in an efficient manner.	Support strategic and tactical activities by giving the right information and new insights to the business.
Characteristic	Operational processing	Informational processing
Orientation	Transaction	Analysis
Function	Day-to-day operations	Long-term informational requirements, decision support
Business	The users often have no choice whether or not to use the system; he or she is not obligated to use the system in order to conduct business.	"Voluntarily," in the sense that users can perform analysis and reporting with other tools (such as spreadsheets), even though it may be less efficient.
Education	Easy to plan, because an operational system often consists of fixed business process that need to be taught.	Difficult to foresee, as most BI systems allow for many nonprocesses based ways to create reports and analyses.
User type	Frontline worker, operational staff	Knowledge worker, managerial staff
IT support	Relatively easy to plan, unless the system suffers from quality problems.	Demands flexibility
Focus	Data in	Information out
Unit of work	Short, simple transaction	Complex query
View	Detailed, flat relational	Summarised, multidimensional
Operations	Index/hash on primary key	Lots of scans
Data content	Current values	Archived, derived, summarised
Data structure	Optimised for transactions	Optimised for complex queries
Database design	Entity relational based, application oriented	Star/snowflake schema, subject oriented
Access frequency	High	Medium to low
Access type	Read/write, update, delete	Mostly read
Usage	Predictable, repetitive	Ad-Hoc, random, heuristic
Number of records accessed	Tens	millions
Priority	High performance, high availability	High flexibility, end-user autonomy
Metric	Transaction throughput	Query throughput, response time
Response time	Sub-seconds	Several seconds to minutes
Number of users	Large number	Relatively small number
Development	Most operational processes are known and taken into account when implementing the system	The BI system develops over time, because it is often difficult to foresee the usage of a new and mostly non-process based system
User reaction in case of system failure	Immediate when the system is not working, because the day-to-day business stops	The user "can wait" in the sense that the business will go on, even though the BI system stops

such as sales order processing, procurement, inventory control, claims processing, billing, and so on, are not designed to provide business intelligence. They are used to run the repetitive, day-to-day core business of an organisation and to support its daily business processing by capturing information about the economic activities of the company (Ponniah, 2001). For example, information processed for each transaction may include a single invoice, a single order, or a single purchase. Hence, an OLTP system records current information and maintains a database of transaction information which is a predictable usage (Corey, Abbey, Abramson, & Taub, 2001) whereas a BI system uses those transaction data for analysis (Power, 2002). In brief, the purpose of operational systems is to record data in the database of computers (Ponniah, 2001).

In contrast, specially designed BI systems are not intended to run the core business processes, but aim to retrieve information from existing computer's databases (Ponniah, 2001). It is an online analytical processing (OLAP) system that is used to support decision-making and thus facilitate better managerial work. In this information environment, summarised and aggregated data are much more critical than detailed records (Datta & Thomas, 1999). As a result, business users are able to scour data for information about the business to provide tactical or even operational decision support (Turban, Sharda, Aronson, & King, 2007). Therefore, a BI system is intended to provide competitive advantages that make an impact on the bottom line of the organisation (Kulkarni & King, 1997). The typical output information consists of summarised reports and consolidated statements that provide a picture of the overall performance of the enterprise, and in so doing they enable insights, new thinking, and new understanding of the business to knowledge workers. The database typically contains long periods of historical data comprising hundreds of gigabytes and terabytes (Chauduri & Dayal, 1997).

An analytical processing using OLAP system is performed through comparisons or by analysing patterns. For instance, sales trends are analysed along with specific marketing strategies to determine the relative success of those initiatives. However, such analysis is difficult to perform with OLTP systems because the data are sourced from different information systems across multiple departmental units (Poe, Klauer, Brobst, 1997). In other words, a BI system can be viewed as market-centric with a shrinking information time window as opposed to an operational system that is customer-centric and time specified (Han & Kamber, 2001).

The differing requirements of OLTP and OLAP systems demand different data models for each type of system (Datta & Thomas, 1999). The relational data model commonly used in OLTP systems is not meant for effective querying and so is unlike the dimensional data model used in OLAP systems (Datta & Thomas, 1999; Goede, 2001). However, the dimensional design of an OLAP system is not suitable for OLTP systems because of redundancy and the loss of referential integrity of the data (Datta & Thomas, 1999; Goede, 2001). Although these two qualities are crucial in every information system, an OLAP system primarily emphasises flexibility in the retrieval of decision-relevant information in conducting analysis (Power, 2002). Also, Eckerson (2003) asserts that the relational design (of an OLTP system) enforces a business process structure which should not be changed regularly, but dimensional design (of an OLAP system) needs to be changed dynamically to meet the ever-changing needs of the business. Thus, an OLAP-based BI system aims to enhance effectiveness of business decision-making rather than increasing efficiency in processing transactional data (Power, 2002).

Moreover, the maintenance process for BI systems differs significantly from operational systems (Fuchs, 2006). Typically, an operational system implementation has a standard project management plan. Usually, the system maintenance and support are not considered as part of the project, but a future process for which a system maintenance team will be held responsible. Unlike BI systems, the maintenance part can be relatively small once the system is put in place. In contrast to operational systems, the overall project management of a BI system implementation takes into account the maintenance process during the outset (Fuchs, 2006). The BI project evolves into a process that turns some of the usual IT project phases into a well-defined repetitive process. In order to optimise the investment, the existing BI application would be measured against certain predefined metrics and overall benefits. Based on this, together with the evolving business and user demands, the system is further modified and improved. This adaptive process model acknowledges that the user's needs change over time and that their way of working with BI applications is often difficult to predict at one single stage. Thus the maintenance process optimises the current BI solution in corresponding to the changing needs leading to a perception of positive benefits (Fuchs, 2006).

Therefore, given the above substantial differences, organisations are compelled to implement two separate types of information systems, one being an OLTP-based operational system and the other an OLAP-based BI system. Whilst there have been a number of studies on CSFs for operational systems, their applicability to contemporary BI systems cannot be taken for granted. The subtle differences warrant rigorous research to specifically address the CSFs affecting the implementation of BI systems.

Research Aim

Given the motivation for this research and drawing on the CSFs framework developed in a previous Delphi study, the authors used multiple case studies to:

- Examine the CSFs and their associated contextual issues that impact the implementation of BI systems in EAMOs

The remainder of this chapter has been structured as follows. The following section describes the research framework and discusses the definition of success criteria in this study before elaborating on the research methodology. The later section then presents the research findings. In the subsequent section the authors discuss the findings of the study and then state their conclusions.

RESEARCH FRAMEWORK

Implementation Success Criteria

A rigorous review of the literature has indicated that it is very difficult to quantify the benefits of a BI system implementation using standard economic evaluation methods. While the cost and timeframe of a BI system implementation can be estimated, assigning monetary value to the benefits is difficult since the benefits can be intangible and transient (Rockart & DeLong, 1988). Instead, the return on investment in a BI should be included in those of the business process as a whole (Liautaud & Hammond, 2001). Therefore, the benefits perceived by business stakeholders in this study should be considered to be qualitative, and dependent upon the particular features of each individual case. Nevertheless, Delone and McLean (1992, 2003) have suggested that the success of an information system could be evaluated against a number of criteria, and other researchers, such as Wixom and Watson (2001) and Ariyachandra and Watson (2006), have proposed additional criteria that can be used to determine the level of success of a data warehouse-based information system.

Based on their combined suggestions, especially Ariyachandra and Watson's proposition (2006), the implementation success criteria of this research takes into account two key dimensions: *infrastructure performance*, and *process performance*. The infrastructure performance has parallels with the three major IS success variables described by Delone and McLean (1992, 2003), namely system quality, information quality, and system use, whereas process performance can be assessed in terms of time-schedule and budgetary considerations. Specifically, system quality is concerned with the performance characteristics of the information processing system itself, in which the system should be flexible, scalable, and able to integrate data (Ariyachandra & Watson, 2006; Delone & McLean, 1992, 2003). Information quality refers to accuracy, completeness, timeliness, relevance, consistency, and usefulness of information generated by the system (Ariyachandra & Watson, 2006; Delone & McLean, 1992, 2003; Fisher, Lauria, Chengalur-Smith, & Wang, 2006). System use is defined as "recipient consumption of the output of an information system" (Delone & McLean, 1992, 2003). Given that many theoretical and empirical studies have used and tested DeLone and McLean's IS success criteria (albeit with a number of multiple dimensions), it is considered that the success criteria provide a solid foundation for measuring implementation success, and thus are suitable for this study into the related CSFs.

CSF Reviewed

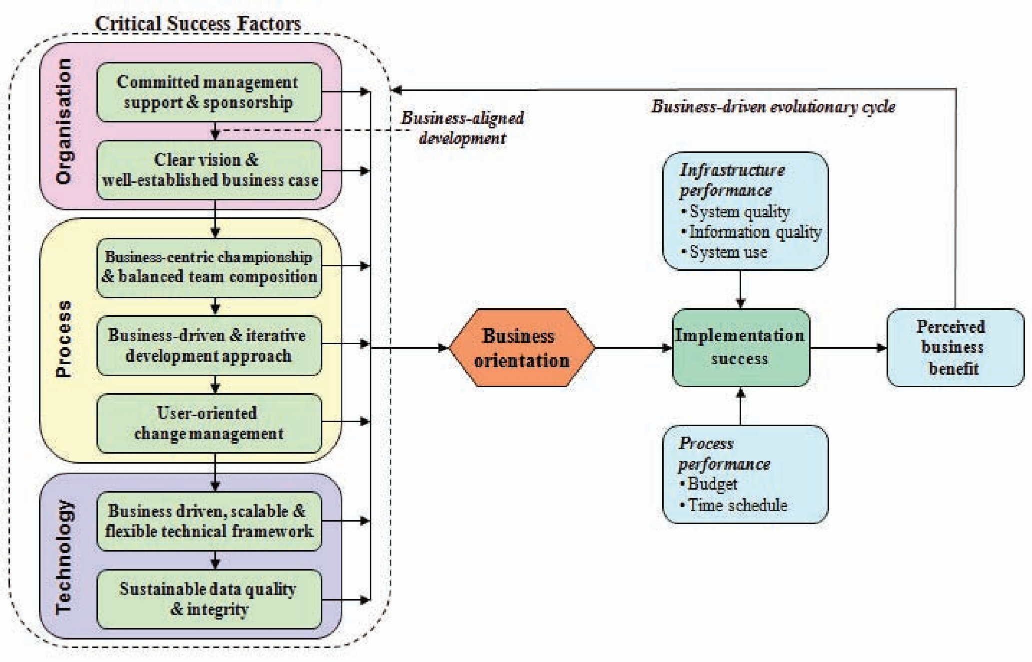
In the previous section, the measure for implementation success was introduced and defined. Those success criteria serve as the operationalisations of this study's dependent variables. The focus will now move on to the dependent variables, the so-called critical success factors.

There is relatively little academic literature on the subject of CSFs for successful BI system implementation. The field of BI systems is driven by industry, and it takes time for a tradition of academic scrutiny and evaluation to develop into a comprehensive literature. Nonetheless, there have been a number of studies which have sought to identify CSFs for the implementation of a data warehouse. Since a data warehouse is a core component of a BI system, their CSF studies are believed to be applicable to BI systems. Specifically, the synthesis of the literature (conducted in an earlier phase of this research, see Yeoh et al., 2006) provides a theoretical platform for this study about CSFs affecting the success of a BI system implementation. Following the literature review, a Delphi study was carried out with a panel of 15 BI system experts in order to identify the relevant CSFs (see Yeoh, Gao, & Koronios, 2007). Based on the Delphi findings, a CSF framework was developed to incorporate those CSFs which were endorsed by the panel.

This research framework outlines how a set of factors contribute to the success of a BI system implementation. It postulates that there is a set of CSFs which determine the quality of the BI system and its information output which, in turn, have a positive effect on the users' attitudes towards the use of the system. In other words, this framework treats the proposed factors as necessary factors for implementation success, whereas the absence of the CSFs would lead to failure of the system. Subsequently, individual users and their respective organisations would assess the benefits of the BI system implementation. This perception of the benefits would then become part of an interactive, business-driven evolutionary continuum to further support evolving business needs for improved BI systems (Arnott, 2004; Arnott & Pervan, 2005). This framework, and its related research issues, are the foci for the data collection and analysis of this research. The framework's components are illustrated in Figure 1. Within the framework, description of each CSFs identified by the Delphi study (Yeoh et al., 2007) is as follows.

Business orientation (BO) emphasises the business-aligned approach relating to the current and future needs of business intelligence in order to successfully address the CSFs influencing BI systems.

Figure 1. CSFs framework for implementation of BI systems



CSF#1: Committed management support and sponsorship*.* This refers to the commitment and sponsorship of top management to the BI initiative. This commitment is particularly required to overcome organisational challenges, including issues such as: flow of information, data ownership and technical framework development that is cross-functional, people issues, and consistent sponsorship of the initiative from the business side.

CSF#2: Clear vision and well-established business case. This refers to the existence of a strategic business vision with a clear outline of business objectives. In implementing BI systems, a detailed business case is required to describe the BI initiative in qualitative terms, and more importantly it must be aligned with the business vision. The case should clearly outline the business needs, processes and inadequacies of the existing information infrastructure to address the core decision-support problems of the business.

CSF#3: Business-centric championship and balanced team composition. This refers to a business-centric champion who views the BI system in strategic and organisational terms rather than in technical terms. Ideally the champion possesses strong business acumen, is technically knowledgeable, and committed to the leadership of the BI competency team. The team comprises cross-functional representatives from IT and business. They provide a central location to drive consistent BI deployments, and this ensures ease in coordinating and supporting BI and performance management initiatives that span multiple departments.

CSF#4: Business-driven and iterative development approach. The scope of the BI system implementation is clearly defined at the outset, and an incremental delivery (“iterative”) approach is adopted. The project commences in those areas which can readily be impacted in order to get buy-in and where programs can be scheduled to deliver quick wins.

CSF#5: User-oriented change management. Key users and relevant functional managers are involved throughout the entire implementation process, and during the business-driven, iterative maintenance process to develop further improvements. Training, education, and consistent support from the BI competency team are in place to induce individuals to embrace new practices, procedures, and technology throughout the period of the system implementation.

CSF#6: Business-driven, scalable, and flexible technical framework. This refers to the establishment of a strategic, scalable, and flexible technical framework covering both architecture design and data modelling in alignment with short and long-term business requirements, and including additional internal and external data sources. At the initial phase, a pilot prototype is used as proof-of-concept and stable source systems are in place.

CSF#7: Sustainable data quality and integrity. This refers to business-led establishment of common definitions, measures, and classifications that are used across the organisation, and the foundation of high-quality data at source systems, and a data governance framework is in place to monitor the data collection process.

RESEARCH METHODOLOGY

Methodology

This study applied a qualitative case study methodology with multiple-case design and content analysis techniques. The use of this approach is valid for the following reasons.

- As opposed to sampling logic, case study research is an empirical investigation following *replication* logic that leads to analytic generalisation (Eisenhardt, 1989; Yin, 2003); by
- Investigating a relatively new research area within a real-life context (Eisenhardt, 1989; Yin, 2003); to
- Provide in-depth and rich contextual information which describes an actual situation (Robson, 1993); from
- Rigorous observation and systematic examination using multiple sources (Miles & Huberman, 1994; Yin, 2003).

It should be noted that, unlike sampling logic, replication logic is a purposive selection—it does not aim to generalise the findings to an entire population (Firestone, 1993). Thus multiple case studies in this study should be regarded as multiple experiments and not multiple respondents in a survey (Yin, 2003). That is, relevance rather than representativeness is prioritised in case selection. Within each case, and guided by the research questions, the need for in-depth investigation and richer understanding of critical factors within the organisation's real-life context was the subject of this study. Given the research objectives, case study research with multiple-case design was the appropriate methodology.

Research Site

In order to maintain homogeneity and thus lessening the potential for confounding effects of different industries and IT environments, it was decided that all case organisations should come from the same industry. The engineering asset management organisations (EAMOs), such as electric, gas, water utilities, and railway companies, were selected for three reasons. First, the types of information systems in these asset-intensive organisations are identical. Typically, they are composed of asset operational systems, maintenance systems, condition monitoring, work management, and contract management. Secondly, due to fierce competition resulting from deregulation, increased regulatory compliance, and governance requirements, many EAMOs are on the verge of implementing large-scale BI systems, yet there is very limited literature to guide such organisations. For instance, a recent BI project introduced by an Australian water utility cost several millions dollars (LeMay, 2006). Third, the experiences of such EAMOs (that are traditionally characterised by its silo information environment) could provide better insights and richer contexts for comprehensive understanding.

Furthermore, fear of a shortage of cases was eliminated because this research was supported and sponsored by the Cooperative Research Centre for Integrated Engineering Asset Management (CIEAM). Hence, the BI system usage in this study focuses on the asset management business rather than the conventional market-centric applications. To assess the importance of the seven previously-identified CSFs, the authors studied five Australian EAMOs that had implemented BI systems. The backgrounds of these case companies are illustrated in Table 2.

Data Collection

Data collection for this study entailed semistructured interviews with key stakeholders of BI projects, and those interviewed included project managers, end users, key project stakeholders (who have been involved directly in either business or IT functions), and in two instances, external consultants/contractors. To facilitate data triangulation, data were also gathered from a number of sources including relevant documents (such as business cases), training documents, presentation slides, and publicly available reports (such as annual reports and financial statements).

In order to maintain consistency of questioning, the authors used the CSF research framework as a basis for the interviews, inviting participants to comment on the proposed CSF framework. After the interview, further clarifications (if any) were made by follow-up phone calls. The authors also observed the BI system in operation and gathered data about the CSFs for BI system implementation. However, the authors were cautious about being over-reliant on key informants, and attempted to seek contrary evidence when possible in order to corroborate findings and issues from other interviewees.

A cross case analysis approach was used in this study to gain better understandings and increase the generalisability of the findings (Miles & Huberman, 1994). In searching for patterns, the authors examined similarities and differences about relationships within the data (Eisenhardt, 1989). Hence, varying the order in which case data are arrayed enables patterns to become more obvious (Stuart et al., 2002). Moreover, this research did not produce quantitative data. In all cases, the authors were examining the pres-

Table 2. Background of case organisations

Case	Types of EAM Industry	Annual revenue *	No. of staff **	Total assets #
C1	Rail transport and network access	M	M	L
C2	Rail transport and network access	L	L	L
C3	Builder and maintainer of large engineering asset	M	M	S
C4	Electric and gas utilities	L	M	L
C5	Water, sewage, recycled water utilities	L	M	L

Note: Case descriptions have been disguised slightly to preserve the anonymity of participants.
**Small=<AUD $100 million, Medium=AUD $100 to $1000 million, Large= >AUD$1000 million*
*** Small = <1000 staff, Medium = 1000-5000 staff, Large = over 5000 staff*
#Small=<AUD $1000 million, Medium=AUD $1000 to $5000 million, Large= >AUD$5000 million

ence or absence of a particular CSF (e.g., were adequate resources provided?), while at the same time ascertaining whether that characteristic was fulfilled in a meaningful way.

RESULTS

Implementation Success

After analysis of the triangulated results for all five organisations, three instances of notable success emerged, together with one moderately successful case and one failure. The three successful cases of BI system implementation described their respective BI systems as stable, easy to use, fully functional, flexible, and responsive within anticipated times. Furthermore, the information generated was considered accurate, timely, complete, consistent, and relevant to most participants. In addition to the encouraging trend of system use among end-users, the project leaders of these organisations confirmed that their implementation projects were completed on time and within budget. However, the moderately successful case was experiencing uncontrollable external factors in its BI system implementation. The key application of its BI system was not identical to those of conventional commercial enterprises. Due to its unique form of business and the peculiar bonus system with its major client, it was more concerned with ensuring on-time delivery of assets and meeting quality and safety standards rather than reducing costs or staffing. The BI system thus enables them to analyse and investigate underlying business activities with ease. Also, auditable reporting can be generated from the system to assist the business meet its strict regulatory requirements.

On the other hand, the firm that experienced BI failure did so because it encountered business issues at the early phase of its implementation process. The business needs and requirements for BI system had not been clearly defined, yet there existed silo information systems with multiple versions of the truth. In that firm the BI initiative was driven mainly by the IT department alone and was viewed as a technological issue, and as a result the management had to suspend the BI initiative. This instance of failure served as a useful contrast case for comparative analysis in this research. Table 3 summarises the findings of implementation success for all cases.

Table 3. Implementation success measure for the five cases (source: developed from field data)

Success measures / Case code		**C1**	**C2**	**C3**	**C4**	**C5**
Infrastructure performance						
1	System quality	✓	✓	✓	✓	N/A
2	Information quality	✓	✓	✓	✓	X
3	System use	✓	✓	*N*	✓	N/A
Process performance						
4	Budget	✓	*N*	✓	✓	X
5	Time schedule	✓	✓	✓	✓	X
	Overall	S	S	*N*	S	*U*

Note: ✓=Good; N =Acceptable; X=Poor; S=Successful; N =Partially successful; U =Unsuccessful

CSFs Observed

To demonstrate how the implementation success compared against the management of the CSFs of the five case organisations, an analysis of the CSFs 1 to 7 was conducted through a cross-case analysis. Table 4 summaries the relevant CSFs performance in matrices recommended by Miles and Huberman (1994), and these were used as an initial step in analysing patterns in the data. For each case, management of each CSF is rated through a summary rating of ✓ (for a CSF that was fully-addressed), *N* (for a CSF that was partially addressed), or X (for a CSF that was ignored). Moreover, the summary ratings are supported through factual data from field research with each organisation.

OVERALL ANALYSIS AND DISCUSSION

The CSFs identified from a previous Delphi study were examined empirically in five engineering asset management organisations. This section discusses the qualitative results of the case studies. Essentially, the evidence from these studies clearly substantiated the construct and applicability of the multidimensional CSFs framework proposed in the previous Delphi study. More importantly, the studies further reveal the significance of addressing those CSFs through the *business orientation* approach. That is, without a specific business purpose, the BI initiatives rarely produce a substantial impact on business. As a result, the implementation of a BI system has a much greater likelihood for success when business needs are identified at the outset and used as the driver behind the implementation effort. Thus, the entire system implementation must be business-driven and organisation-focussed. It should also have interactive business-side involvement, and be adapted to meet evolving business requirements throughout the lifecycle. Invariably, a "build it and they will come" approach which overlooks business-focused strategies in system implementation proves to be unsatisfactory and very expensive (Bates, 2000). In other words, this particular metafactor (i.e., a business orientation approach) dictates the commandment of the proposed CSFs, particularly within the following important aspects: business case formation, management commitment, championship, team composition, scoping and development methodology, organisational change management, technical framework development, data model, and data quality issues.

In essence, the three successful cases (C1, C2, and C4) seemed to emphasise the business-oriented approach when addressing the CSFs, while the partially successful case (C3) appeared to comprise a mixture of business and customer-centric approaches. The instance of failure (C5) was not totally business-driven but instead was technology oriented. The three successful cases shifted their focus from the technological view and instead adopted an approach that put their respective business needs first. On the basis of these case studies, it is apparent that the manner in which an organisation addresses those CSFs, whether through a business-oriented, technology-oriented, or customer-oriented approach, will have a substantial impact on the implementation outcome. Having a clearly-defined set of CSFs is important, but it is even more critical to address the CSFs from the right approach. In the case of BI systems implementation, the triangulated data of case studies clearly demonstrates that by placing business needs ahead of other issues an enterprise has a higher likelihood of achieving a useful business information system.

In order to meet the need for systems which provide management with dynamic analytics and business reporting, the findings of these case studies indicate that business stakeholders should involve interactively throughout the implementation process. One explanation is that a BI initiative "provides the users with access to information that

Table 4. Evaluation of critical success factors in multiple EAMOs

CSF	C1 (Rail company)	C2 (Rail company)	C3 (Large engineering asset builder and maintainer	C4 (Electric utility)	C5 (Water utility)
Background *Note:* *BIS = BI system*	*Due to new arrangement, the company has acquired a competitor company and is now overseeing a much wider area of rail network. *The BIS success story of the acquired company has inspired the executives to expand the BIS initiative to an enterprise-wide scale. *In order to facilitate "one-stop" planning, reporting and business analysis, the company adopted BIS with great enthusiasm.	*The company has been using BIS for more than a decade initially for its various silo functional needs, such as safety reporting, network access, maintenance and operation. *To better facilitate overall business performance, the organisation has recently been restructured accordingly, and the silos BIS are undergoing amalgamation.	*BIS was implemented as part of its ERP package. The key use of the system is for business reporting, analysis of asset lifecycle performance and supply chain management. *Due to its unique business nature, the BI tool was not meant to cut down the operating cost or for competitive advantage, but rather to meet the strict compliance requirements and bonus system.	*BIS was implemented for advanced analysis, planning and risk management of the vast electricity network. *Due to market deregulation, legislative compliance and auditing requirement, BIS was adopted and widely supported by all stakeholders. * For the BIS, conformance and compliance is more critical than cost saving.	*The BI initiative was mainly driven by its manager of business information system, who is a technology enthusiast. *He has been promoting the advantages of BIS, and organised a number of interactive sessions with BI vendors. *However, the BI effort was not supported by business stakeholder, as they clearly failed to identify their BI needs and requirement.
1. Committed management support and sponsorship	✓ *There was consistent support from the executives, and direct endorsement from the CEO. *Their endorsement of the BIS commanded respect and interest among others. *Budget described as generous.	✓ *The initial BIS development was strongly supported by functional managers. *Now the silos BIS have gained the attention of top executives. *As a result, it involved some degree of organisational restructuring (i.e., an amalgamated BIS is in progress for its major network access and maintenance divisions). *Budget described as adequate.	*N* *Initially the executives focused more on the benefits of ERP than the BIS. * However, the BIS was gaining momentum as in supporting auditable business reporting and complying with the needs of its key client and strict regulation. *Budget described as adequate.	✓ * Top management support was strong, MD is crucially aware. *Budget described as generous. * Top-down commitment was shown in defining process of business needs and report requirement.	X *Top management was not convinced about the usefulness of a BIS to their business. *The executives rather supported its ERP modules expansion projects.

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Table 4. continued

2: Clear vision and well-established business case	✓ * There is clear business vision for the BI system adoption. * A link from the BI system to business objectives is defined. * The current BI initiative spans all functional boundaries of asset management. * The business case was highly endorsed by top management and supported by all relevant stakeholders.	✓ * Initially the business vision was more functionally oriented, but recently an enterprise-wide business vision has been in place. * The recent amalgamated BI initiative was a vision of top management. The actual business case is still in the preparation stage.	*N* * There was some degree of business vision in place, but the business case was mainly driven by its key customer who is still very influential. * The company was initially seen as a purpose-built contractor of the customer (who actually still maintains a large share of ownership with the company).	✓ * The current BI initiative spans all functional boundaries of asset management. * The business case was highly endorsed by top management and supported by all relevant stakeholders, and particularly welcomed by business analysts and general users.	X *There is no clear business vision from the senior management. *Business case was driven by technology and thus received little support from the business side.
3. Business-centric championship and balanced team composition	✓ *The team consists of IT manager (champion) and several IS staff in partnership with external consultants. *Particularly, the champion played a successful role as "coordinator" among executives, business stakeholders and key users. *However, the actual construction of the system was developed by external consultants and contractors with the assistance of some internal IS staff. *On-going incremental development was carried out by the internal team.	✓ *Owing to legacy, the two main silo BIS are championed respectively by two individual project managers. However, a "middleman" was recently appointed to coordinate silo BI systems integration issues from business perspective. *All systems were developed in-house and maintained by a large team and contractors. *The team comprises both BIS experts and business personnel. *Though the IT department alone comprises more than 50 competent IS employees, the challenges of silo BIS integration was due to the business issues.	*N* *Initially, the manager of business information system acted as the champion, but the actual implementation was contracted to external consultants and IT vendor. *After the system was in operation, a business analyst was assigned to the role of system owner to oversee the maintenance task. Nonetheless, his role is more like a coordinator between users and service provider.	✓ *The BI initiative was championed by a designated system manager, who was also a senior electrical engineer with strong business acumen. *The system was mainly developed by external contractors and assisted a team of internal IS staff. *For on-going development, a team of internal IS staff in partnership with external contractors acted upon the request of key users during regular review and, occasionally, upon ad-hoc request.	X *The BI initiative was championed by manager of business information system, a technology enthusiast. *The BI team comprises IT personnel only with minimal participation from business side.

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Table 4. continued

4: Business-driven and iterative development approach	✓ *Project scope was clearly defined, covering almost the whole enterprise. *Top-down approach for setting report requirements. *Incremental delivery approach was adopted over a number of phases to deliver quick wins. *The project started on area most easily impacted. *The team learnt from the BIS experience of acquired company, and practiced it in parent company.	✓ *Project scope is clearly defined by functional area, but not meant to be enterprise-wide. *For second phase integrated BIS, incremental delivery approach was adopted with the initial focus on business integration issues. *Technical solutions will be introduced later according to the identified business problems.	*N* *Project scope was limited to those involved in asset management and integrated lifecycle support area. *Top-down approach was adopted as the company had little choice over the system vendor.	✓ *Project scope was clearly defined for engineering side of the business. *Incremental delivery approach was adopted to deliver quick wins. *Reporting requirement was set via top-down approach, but bottom-up implementation was widely practised.	X *Project scope is clearly defined. *The project started on several areas at once, "big-bang" approach. *The team faced communication issues with the business stakeholders.
5: User-oriented change management	✓ *The project manager consulted the CEO and top management individually before making final case. *Key business stakeholders and users were involved with project throughout the implementation process. *Consistent support was in place.	✓ *The users were familiar with and dependent on the BIS, and generally welcomed the integrated BIS effort. *Education was not an issue. *When any new requirement arose from respective functional units, unit manager called-in as local champion. *Consistent support is in place.	X *Users were not consulted but rather asked to use the system, especially in meeting the compliance requirement set by its key customer. *Consistent support is in place.	✓ *Key business analysts/users were involved from outset. *Regular workshops were conducted with user group. *Consistent support was in place.	X *Business stakeholders and key users were not involved in the early phase. *Business side were asked to suggest their BI needs rather than based on genuine, evolving business requirement.

*Note: * denotes emerging finding from multiple case studies*

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Table 4. continued

6: Business-driven, scalable and flexible technical framework	✓ *The ERP implementation laid a solid infrastructure foundation for the BIS. *The data model was flexible, scalable and extensible cross all functional areas. *The technical framework was standardised centrally and driven by business needs. *The compatibility of various analytical, reporting and mining tools with the ERP was validated at outset.	*N* *The silo BIS and ERP implementation had provided adequate infrastructure foundation for the integrated BIS. *Though the data model of silo BIS was adequate and extensible, it was not meant for integrated BIS. *Integrating those silo BIS posed compatibility issues due to different IT vendors. *The team was working on the broader data model and technical framework in order to integrate the silo BIS.	✓ *The ERP implementation laid a good infrastructure foundation for the BIS. *Although the data model was flexible, scalable and extensible, it was limited to certain functional areas only. *There was a standardised technical framework, but with limited extensibility. *There was no compatibility issue for the various analytical and reporting tools as those tools are strategic partners of its ERP system.	✓ *The implementation of integrated asset management system provides a good infrastructure foundation for the BIS. * The data model is flexible, scalable and extensible across all asset management domains. *There was a standardised, scalable and extensible technical framework to accommodate both advanced analytics and mining requirements.	*N* *The ERP implementation and various silo systems provide somewhat stable foundation for BIS infrastructure. * The data model is flexible and extensible but meant for functional needs. *The technical framework is extensible to accommodate BI requirement. *There is compatibility issues with various IS application.
7: Sustainable data quality and integrity	✓ *Master data management approach was adopted. *A data dictionary framework was in place. It included a data governance committee, corporate coding policy, corporate glossary, and data dictionary. *A corporate data model has been developed, which includes candidate information entities and subject areas and baselines. *In doing so, workshops, interviews and questionnaires were done; corporate systems were reverse engineered. *Transaction systems were aligned to facilitate common hierarchy for management reporting and communication.	*N* *A functionally-based data dictionary framework was in place, and includes corporate glossary and data dictionary. *To address multiple versions of truth, the newly appointed Integrated BIS champion and the business decision support personnel were preparing a core asset information oriented framework. *These silo BIS are reverse-engineered, high-level steering committee and workshops were in place.	✓ *The quality of data was adequate as most of the glossary and measures had been fully supplied by its key customer. *The role of the data steward was well defined as being the functional steward. *Within the system, there was an automated data quality "watchdog" mechanism to track operational data quality issues. *Data provider will be alerted and asked to solve the issues.	✓ *A data dictionary framework was in place. *Data quality working group, corporate glossary and data dictionary were in place. *There were regular workshops with the key users. *Users were pro-active to report any data quality issues, and actions were taken promptly. *Data cleansing tool was applied.	*N* *A functional-based data dictionary framework is in place. * Visualisation tool and pictures of assets were incorporated as part of data quality and validation effort. *The data inconsistency was usually validated by long-time experienced personnel.
***Overall business orientation approach**	✓	✓	*N*	✓	X

*Note: * denotes emerging finding from multiple case studies* they did not already know that can actually be used to change their actions and decisions" (Hancock & Toren, 2006). In other words, it necessitates the participation of business stakeholders in the development of a process of business analysis and reporting that usually demands practical business experience (Hancock & Toren, 2006). Moreover, due to evolving business needs and ever-changing information requirements, it was found that the respective BI teams had to provide continual high-level maintenance and support not only on tools application, but also at broader data modelling and system scalability issues. The designing of data models and system architecture frameworks needs consistent input from those most familiar with the business needs of the enterprise.

In summary, the three successful cases clearly demonstrated that addressing the CSFs from a business perspective was the cornerstone on which they successfully based the implementation of their BI systems. Conversely, the unsuccessful case failed because it focused primarily on the technology and neglected the core requirements of its business. In order to better address the CSFs, it is essential for an organisation to emphasise the business orientation approach, and in so doing it will gain an advantage over competitors. Indeed, this view was supported by Gartner Research, which stated that, "best in class organisations focus on business objectives and use a business-driven approach to define and scope their people, process, application, technology and/or services strategy" (Burton, Geishecker, & Hostmann, 2006).

Also, it is relevant to note that in implementing a BI system neither data nor technical factors appeared to be as critical as other organisational and process factors. According to most research participants, technological difficulties can be solved by technical solutions. However, it was found that achieving management and organisational commitment for a BI initiative poses the greatest challenge because the BI teams considered them to be outside their direct control. The level of organisational support is reflected in the attitudes of the business stakeholders; that is, their attitudes to change, time, cost, technology, and project scope. Based on a large-scale survey result, Watson and Haley (1997) similarly pointed out that the most critical factors for successful data warehousing implementations (the antecedent of BI systems) were organisational in nature. Thus, committed management support and adequate resources were found to determine the implementation success because these factors worked to overcome sociopolitical resistance, address change-management issues, and increase organisational buy-in. This finding was also congruent with Gartner's recent observation that "overcoming complex organisational dynamics will become the most significant challenge to the success of BI initiatives" (Burton et al., 2006). Therefore, organisational and process-related factors must not be taken for granted in the implementation of BI systems.

CONCLUDING REMARK

Implementing a BI system is a costly, resourceful, and complex undertaking. This study examined the CSFs impacting BI systems implementation in EAMOs. Based on a previous Delphi study, it developed a multidimensional CSF framework for understanding those CSF issues. These CSFs are: committed management support and sponsorship, a clear vision and well-established business case, a business-centric championship and balanced team composition, a business-driven and iterative development approach, user-oriented change management, a business-driven, scalable and flexible technical framework, and sustainable data quality and integrity.

Subsequently, the proposed CSFs were then examined empirically in case studies of five engineering asset management organisations. The evidence from these studies clearly confirmed and substantiated the construct and applicability of the CSFs framework. Within the set of CSFs, an analysis of the findings indicated that non-technical factors, including organisational and process-related factors, were more influential and important than technological and data-related factors. More importantly, the research suggests that organisations are in a better position to successfully address those CSFs through the *business orientation* approach. Thus this business orientation meta-CSF should be regarded as the most critical factor in determining the implementation success of BI systems.

This research has made a contribution to our understanding of the CSFs that impact on BI systems implementation. The literature review reveals that there is a lack of research on CSFs for successful implementation of BI systems. This study, therefore, fills in the research gap. This research provides thought-provoking insights into multidimensional CSFs that influence the implementation of BI systems. The CSFs which have been identified allow a clear understanding of the pivotal factors that must be addressed. Hence, it focuses attention on those important areas that might otherwise be neglected or taken for granted but are significant for the implementation success. Moreover, the consolidated CSFs framework provides a significant contribution to theoretical understanding of how implementation of BI systems can be improved. More specifically, the findings suggest that in investigating the critical success factors researchers should not only consider the technical context but also focus on organisational and process dimensions to provide a more comprehensive research approach.

Not only does this research contribute to the academic literature on this topic but it also benefits organisations in several ways. The identification of CSFs enables BI stakeholders to gain a comprehensive understanding of those CSFs through a business orientation approach, especially in the planning and management of BI initiatives. Such outcomes will help them to determine those factors to which they should give priority. It also helps to ensure that those CSFs will receive deliberate and continuous management scrutiny. For senior management, this research finding can certainly assist them by optimising their scarce resources on those key areas that are most likely to have an impact on the implementation of the BI systems. Moreover, the management can concentrate their commitment to monitor, control and support those critical areas of implementation. In short, the CSFs findings represent the best practices of firms that have successfully implemented BI systems. The empirical evidence that was revealed provides insights for BI stakeholders and will significantly increase the chances of implementation success. Those that address the CSFs from a business orientation approach and translate the business needs into a well-managed BI system implementation will likely succeed.

IMPLICATION FOR FUTURE RESEARCH

The results of this study suggest several areas for future research. They include replication of current study, theory testing research, and longitudinal study. First, this research focused on engineering asset management industries that implement BI systems for better managing their asset-intensive business. Thus, further empirical research in other industries or in other countries may shed light on where and how the research findings can impact the success of a BI system implementation. Research on cross-industry or across-country comparisons of CSFs will enrich and complement this research with additional insights, and possibly new understanding of factors.

As it stands, this study was exploratory in nature and hence quantitative research can be conducted using a structured questionnaire with adequate samples. It could provide insight into the correlation between factors identified in the CSFs framework and determine the generalisablity of this study. In addition, a longitudinal study may be useful to further test the theory built in this research. It would be ideal if a researcher could observe a case organisation prior to commencing a BI system implementation project, and then follow the progress of implementation to completion. Nonetheless, a longitudinal research would require a long-term commitment by both the researcher and the participating organisation.

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Chapter 6.8

Exploring Relationship Between Information Systems Strategic Orientation and Small Business Performance

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ABSTRACT

Businesses invest in developing information systems resources to gain competitive advantages. Literature has demonstrated the requirement of strategic alignment in converting these competitive advantages into sustained superior business performance. The knowledge of information systems strategic orientation and its relationship with business performance will enable these businesses to fine tune their strategic information systems applications portfolio in achieving required strategic alignment. This study focuses on the information systems strategic orientation of small businesses and investigates its relationship with their perceived business performance. The organizational impact of adoption of the initial stages of electronic business development is also examined. The data were collected from small businesses on nine strategy areas, through mail survey. The result reveals three multifaceted dimensions of information systems strategic orientation. These dimensions of strategic orientation have significantly influenced their business performance. For the adopters of Web presence, all these three dimensions remain significant in explaining their business performance.

INTRODUCTION

Small businesses are an important and integral part of every nation's economy and their contributions are significant in the present business environment of globalisation and digitization. In response to changes in their environment, these small businesses are investing in information technologies at an increased rate to develop information systems to support their business strategy. The small businesses use the Internet and establish Web presence as a complement to traditional way of competing. Weill (1990) found that investment in strategic information systems, rather operational information systems, was risky but with a potential for high payoff in the long term. The Internet architecture has turned information systems into a far more powerful tool for strategy (Porter, 2001).

The translation of information systems investment into the attainment of competitive advantage and increased business performance are the focus of the attention of these small businesses. The knowledge about the extent to and manner in which information systems complement company strategy will help small firms to prioritize relative information systems investments. This enables small businesses to adjust portfolios of strategic information systems so that they could provide more business support that leads to superior business performance.

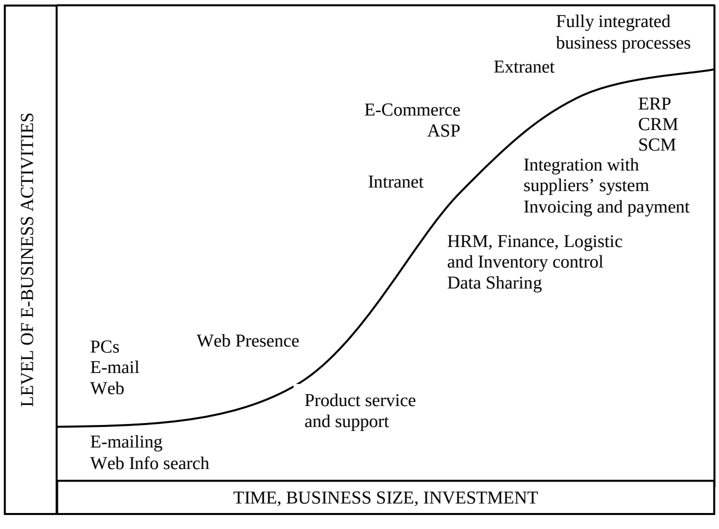
The present study examines the information systems strategic orientation in small businesses and explores its relationship with business performance. To study further the consequences of adoption of Web presence, one of the earlier stages of electronic business development (Figure 1), the impact of Web site ownership on the degree and the direction of this relationship is investigated.

The subsequent sections present the review of literature on strategic management of information systems in small businesses and describe the methodology used by the present study and it is followed by the presentation of results. Then the research findings and their implications are discussed. The article concludes with the summary of the study and its contributions.

Literature Review

Businesses allocate resources to develop information systems because it is believed that these investments provide them with competitive advantages and economic returns. While small businesses have been traditionally seen reluctant to develop information systems strategy (Hagmann & McCahon, 1993; Mehrtens, Cragg, & Mills,

Figure 1. E-business development (Source: E-Commerce and Development Report 2004, United Nations, Geneva, 2004, p 53)



2001), evidence over the past decade shows an increase in strategic use of information systems in small businesses (Naylor & Williams, 1994; Poon, 2000).

The information systems have evolved from its traditional orientation administrative support toward a more strategic role within an organization (Henderson & Venketraman, 1993). Blili and Raymond (1993) emphasize that small businesses must adopt some kind of framework for strategic planning information systems, if they wish to create information systems-based strategic advantage. Levy and Powell (2000) propose an approach (Figure 2) to information systems strategy development for small businesses.

For small businesses, the strategy execution perspective (Figure 3) proposed by Henderson and Venkatraman (1993) is more appropriate. This perspective is anchored on the notion that a business strategy is the driver of both organizational design choice and the design of information systems infrastructure. They argue that the

Figure 2. Information systems strategy approach for SMEs (Levy and Powell, 2000)

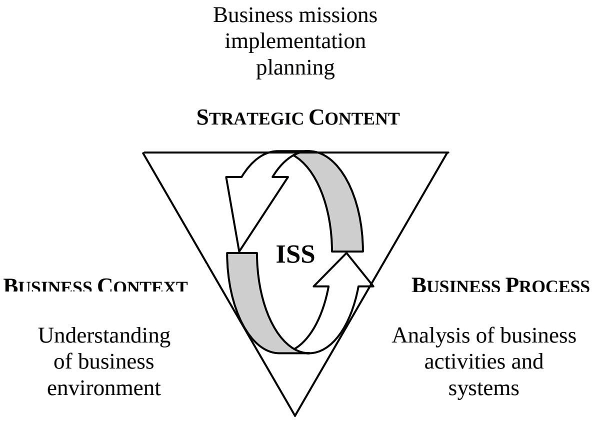
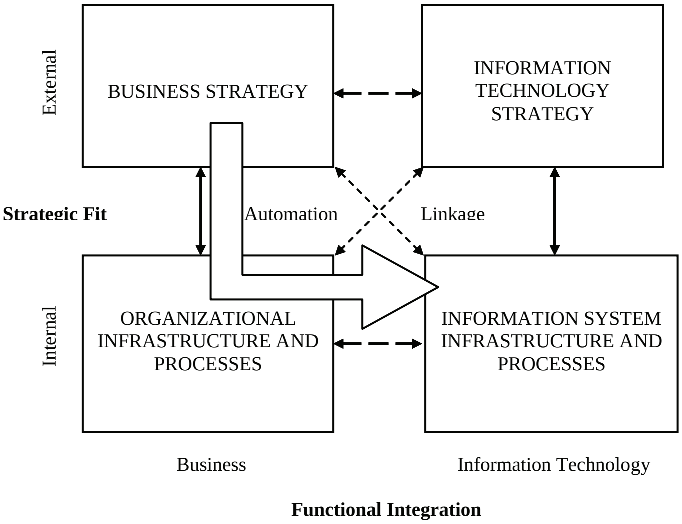


Figure 3. Strategy alignment model with strategy execution alignment perspective (Henderson and Venkatraman, 1993)



top management should play the role of strategy formulator to articulate the logic and choices pertaining to business strategy, whereas the role of the information systems manager should be that of a strategy implementer, who efficiently and effectively designs and implements the required information infrastructure and processes that support the chosen business strategy.

The resulted information systems strategy with implemented information systems infrastructure and processes, constitute the information systems resource for small business. The organizational performance impact of the information systems resource is commonly referred to as IT Business Value (Melville, Kraemer, & Gurbaxani, 2004). The process of IT business value generation is shown in Figure 4.

Wade and Hulland (2004) describe information systems resources using six resource attributes viz., value, rarity, appropriability, imitability, substitutability, and mobility based on the finding of prior information systems research. In resource-based view (Figure 5), these information systems resource attributes will enable a firm to achieve competitive advantages over others and lead to superior long-term performance.

However, resources rarely act alone in creating and sustaining competitive advantage. The information systems resources normally act in conjunction with other firm resources to provide strategic

Figure 4. IS business value model (Melville et al., 2004)

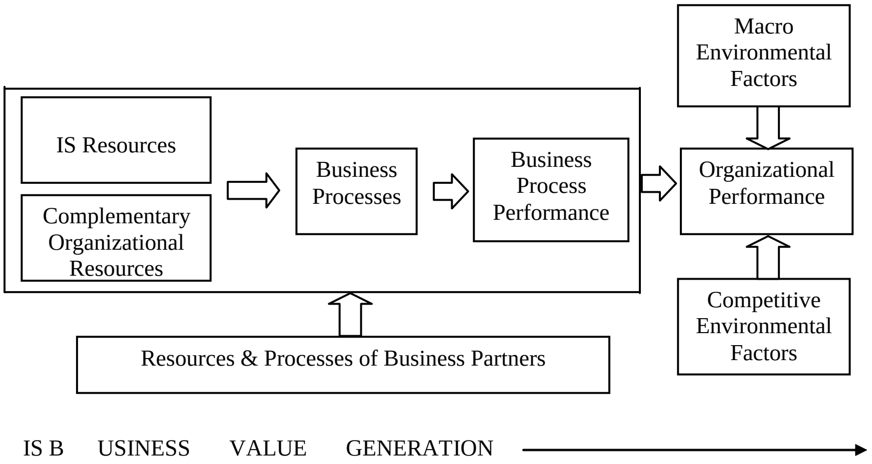
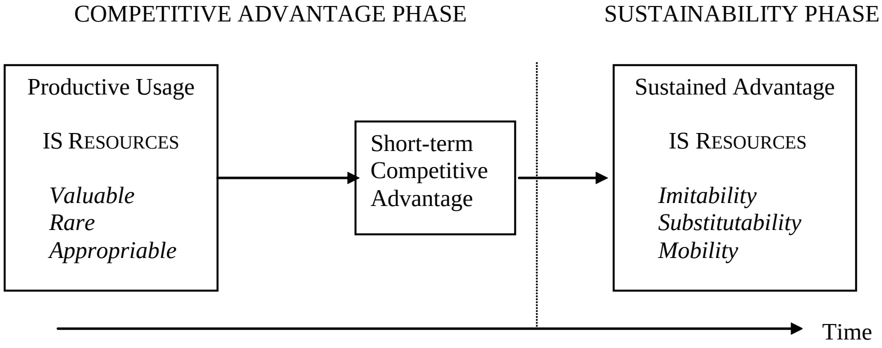


Figure 5. Resource-based view of IS (Wade and Hulland, 2004)

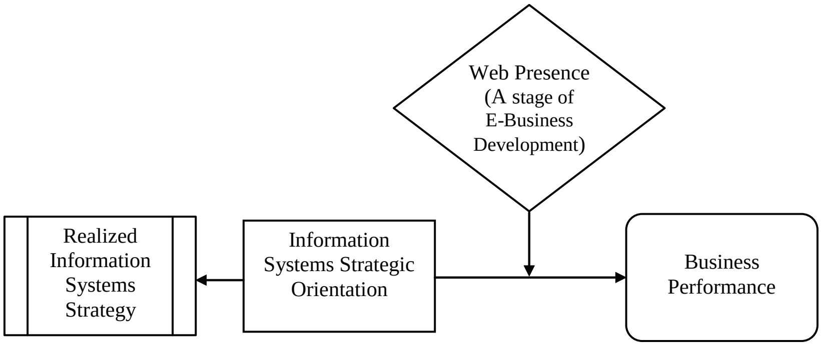


benefits (Ravichandran & Lertwongsatien, 2002). Benjamin and Levinson (1993) conclude that performance depends on how information systems resource is integrated with organizational, technical, and business resources. Chan, Huff, Barclay, and Copeland (1997) argue that the impact of information systems on performance may not be a direct one, but intermediated by other factors such as the alignment between information systems strategy and business strategy.

Luftman, Lewis, and Oldach (1993) recognize that for companies to succeed in an increasingly competitive, information intensive, dynamic environment, the alignment of business strategy and the information systems strategy is a necessity. Alignment expresses an idea that the objective of design, for example, an organizational structure or its information systems must match its context in order to be effective (Iivari, 1992). Strategic orientation expresses this context and its relationship with business performance, will set the direction to the measurement of strategic alignment. The moderation model of strategic alignment suggests that the strategic orientation of a business determines the relative importance of the alignment dimensions. Strategic orientation of information systems indicates the degree of information systems support for each strategic alignment dimension.

The strategic orientation of the existing portfolio of information systems applications, representing the general pattern of realized information systems strategy provides valuable predictive information regarding perceived business performance. Venkatraman (1989) identifies key traits of business strategic orientation based on the theoretical perspective and specifies the following six characteristics as dimensions a priori in developing valid measurement for strategic orientation of business enterprises (STROBE): Aggressiveness, Analysis, Defensiveness, Futurity, Proactiveness and Riskiness. Chan, Huff, Barclay, and Copeland (1997) use these dimensions to hypothesize the structure of information systems strategic orientation. But the empirical findings of their study suggest a parsimonious taxonomy of three generic realized information systems strategies. The three core dimensions of information systems strategic orientation that emerged are information systems support for anticipation, information systems support for analysis and information systems support for action. But the emergence of these dimensions is ignored in the further analyses of their study. However, they conclude that the concept of information systems strategic orientation is somewhat novel and is an area ripe for future information systems strategy research. Thus, a relevant question for small business information systems strategy research study could be to derive information systems strategic orientation and examine the efficacy of the dimensions of orientation to generate business value within the conditions set by the information systems resources (Figure 6). The approach

Figure 6. Research model



represented in the research model (Figure 6) is to empirically derive dimensions of information systems strategic orientation, a posteriori.

The recent streams of studies on net-enhanced large business organizations suggest that e-business initiatives tend to make information systems resources more valuable. Zhu and Kraemer (2002) emphasize that Web presence promotes the business value generation capability of information systems resources. To validate this finding in the small business context, the role of the Web presence in determining the relationship between information systems strategic orientation and their business performance could be investigated (Figure 6).

RESEARCH METHODOLOGY

Research Instrument

The studies of business strategy in small businesses provide evidence that small businesses have to adopt numerous strategies. Storey (1994) identifies strategy as one of the three main components that contribute toward growth among small businesses. Sougata (2004) argues that the environment played a significant role in shaping business strategy during reforms. These studies have drawn on typologies based on large firms viz. Ansoff (1965)'s matrix of strategies (Barkham, Gudgin, Hart, & Harvey, 1996; Hewitt-Dundas & Roper, 1999) and Porter (1980)'s generic strategies (Namiki, 1988; Reid, 1993; Kakati & Dhar, 2002). Julien, Joyal, Deshaies, and Ramangalahy (1997) have found out that exporters compete on price, technical superiority, product quality, and customer service. Gunasekaran, Okko, Martikainen, and Yli-Olli (1996) identify productivity and quality improvement strategies based on cost control, improving quality, new product, lower price, fast delivery, and increased market share, for small and medium enterprises in the manufacturing sector.

These studies have produced different typologies and have failed to provide a consensus model of strategy for small businesses (Southern & Tilley, 2000). As the approach to strategy formation in small business is informal, inexplicit, intuitive, and incremental (Mintzberg, 1988), the explicit identification of strategy is found to be more difficult (Lefebvre et al., 1992). Cragg, King, and Hussin (2002) extracted key factors that contributed toward small business competitiveness from these studies. Pretesting with practicing owner/managers of small businesses, they refined this list of business strategy items. For the present study, these nine strategies (Table 1) are considered as business strategies of small businesses.

As explained in the earlier paragraphs, the planning and development of strategy in small businesses are embryonic and informal. To capture the actual and realized deployment of information systems applications, the instrument for information systems strategies was designed around the same nine business strategies shown in Table 1 (Chan et al., 1997; Cragg et al., 2002). For each business strategy item (question), a parallel information systems strategy item was created to assess the extent to which the information systems support that particular aspect of business strategy. A five point Likert scale was used for measurement.

From a business perspective, performance is

Table 1. Business strategies of small businesses

Sl. No.	Business Strategy
1	Pricing Strategy
2	New Market Strategy
3	New Product Strategy
4	Quality Service Strategy
5	Quality Product Strategy
6	Intensive Marketing Strategy
7	Process Efficiency Strategy
8	Product Differentiation Strategy
9	Product Diversification Strategy

a complex and multifaceted concept (Venkatraman & Ramanujam, 1986). Strategic management research literature proposes a subjective approach to measure business performance and it is appropriate in a small business context where financial data are often unavailable or unreliable (Dess & Robinson, 1984; Sapienza, Smith, & Gannon, 1988). Khandwalla (1977) developed a four items (long term profitability, sales growth, availability of financial resources, and image and client loyalty) instrument to measure business performance based on the owner/manager's subjective assessment of the company's performance relative to its competitors. This business performance instrument was validated in the small business context (Raymond, Pane, & Bergeron, 1995; Cragg et al., 2002) and deemed appropriate for the present study. The suitability and face validity of the instrument along with business and information systems strategies were confirmed during the pretesting stage of the questionnaire development.

The status and the usage of information systems infrastructure of small manufacturing knitwear exporters with a Web site differ significantly from that of exporters not having a Web site (Vivekanandan & Rajendran, 2005). To examine the contingency effect of Web presence on the linkage between information systems strategic orientation and business performance, the necessary provisions were made in the questionnaire to collect details about their Web presence.

Research Method

A mail questionnaire survey was conducted among the small businesses of Tirupur, India. This cluster of small manufacturing businesses is well known for its excellent export performance and its participation in the global apparel supply chain as a quality supplier (Vivekanandan & Rajendran, 2006). The total number of knitwear apparel exporters identified was 1100. The manufacturing sector was selected as they could provide a range of levels of information systems sophistication (Cragg & King, 1993; Rajendran, 1999). Each questionnaire was sent with a prepaid business reply envelope and a letter explaining the purpose of the study. The questionnaire was pretested with two professionals associated with small businesses and then with the owner/managers of five leading exporting organizations and was suitably modified. Further, a pilot test was conducted among a randomly selected 150 exporters and it resulted in minor modifications in the questionnaire. Thus, the questionnaire was refined at three stages (Dillman, 1978).

The refined questionnaires were sent to other 950 exporters and in total 129 useable questionnaires were returned. To assess the nonresponse bias, the first 30 and last 30 responses were compared on the nine information systems strategy items (Armstrong & Overton, 1982). The Mann Whitney test revealed that the differences are not significant except for the new product strategy and so concluded that the nonresponse bias is not a significant factor that could affect the results of the data analysis.

Results

The results of preliminary analysis of the data are shown in Table 2.

The mean score and standard deviation of business performance and information systems strategies are shown in Table 3 and Table 4.

Factor analysis is a multivariate interdependency technique used for data reduction and structure simplification (Hair, Anderson, Tatham, & Black, 1998). To assess the appropriateness of factor analysis, the Bartlett test of sphericity was conducted and it was found satisfactory (Sig. 0.000). As the increasing the sample size causes the Bartlett test to become more sensitive, the measure of sampling adequacy (MSA) was used to reassess the appropriateness of factor analysis. The MSA index of 0.845 revealed the meritorious nature of the data for factor analysis. Under fac-

Table 2. Profile of the respondents

Description	Range	Frequency	Percent
Company Age	Up to 10 yrs	34	26.4
	10 to 20 yrs	70	54.3
	Above 20 yrs	25	19.4
Ownership Status	Proprietorship	38	29.5
	Partnership	73	56.6
	Private limited	17	13.2
	Public limited	1	00.8
Growth Stage	Conceptual	2	01.6
	Survival	15	11.6
	Stabilization	30	23.3
	Growth Orientation	48	37.2
	Rapid Growth	20	15.5
	Resource Maturity	14	10.9
Internet Experience	More than 3 yrs	107	82.9
	2 – 3 years	12	09.3
	1 – 2 years	7	05.4
	Less than one year	2	01.6
	Not applicable	1	00.8
Web Presence	Ownership	79	61.2

Table 3. Business performance score

Performance Criteria	Mean	Std Deviation
Public image and client loyalty	4.15	0.77
Sales Growth	3.87	0.72
Financial Resources	3.69	0.75
Long term profitability	3.68	0.84

Scale: 1- Strongly Disagree, 5 – Strongly Agree

Table 4. Information systems strategy score

Information Systems Strategy	Mean	Std Deviation
Quality Service	3.93	0.97
Process Efficiency Improvement	3.84	0.95
Cost reduction	3.83	0.95
New Market Expansion	3.71	0.85
Quality Product	3.67	0.90
Intensive Marketing	3.47	0.80
Product Differentiation	3.29	0.84
New Product	3.22	0.93
Wide Product Range	3.19	0.85

Scale: 1- Strongly Disagree, 5 – Strongly Agree tor analysis procedure, the principal component analysis was used to extract minimum number of factors that explain maximum percentage of variation. The Varimax rotation with Kaiser normalization was used to simplify the revealed structure (Table 5).

The three factors extracted explained 76% of variation and were considered as the dimensions of information systems strategic orientation. These dimensions of information systems strategic orientation were labeled as 1. Cost-Quality Leadership, 2. Product Development and 3. Market Development. The rotated component matrix of the simplified structure (Table 5) reveals the convergent and discriminant validity of the above three constructs. The reliability coefficient, Cronbach's alpha being the most widely used measure (Peter, 1981) was used to assess the internal consistency of these constructs. The values of Cronbach's alpha were 0.83, 0.88 and 0.78 and these are well above the lower limit of 0.70 (Nunnally, 1978; Robinson, Shaver, & Wrightsman, 1991). The factor scores were computed based on the factor loadings of all variables on each factor, to replace the original scores of nine information systems strategies.

The Business performance was the dependent variable in this study. The factor analysis was conducted to convert the multiple measure of business performance into a single composite measure. However, the Principal Component Analysis resulted in a single factor that explained 56% variance with construct validity of 0.73 (Cronbach's alpha). The factor score was generated as a composite measure of business performance.

As the primary object of this study was to explore and explain the relationship between the dimensions of information systems strategic orientation and business performance, the multiple regression analysis was used. The multiple regression analysis is a multivariate dependency technique used to analyze the relationship between a single dependent (criterion) variable and several independent (predictor) variables.

The regression equation generated is a linear combination of the independent variables that best explains and predicts the dependent variable. It is the regression variate that is formed by a set of weighted independent variables. The weights (regression coefficient) represent the relative contribution of the independent variables to the overall prediction and facilitate interpretation on the influence of each variable in making the prediction. The correlations among the independent variables are also referred to as multicollinearity.

Table 5. Simplified structure of information systems strategic orientation (rotated component matrix)

Information Systems Strategy	Component		
	Factor 1	Factor 2	Factor 3
Process efficiency improvement	**.79**	.26	.22
Cost reduction	**.79**	.20	.02
Quality service	**.78**	.17	.34
Quality product	**.66**	.35	.18
Wider product range	.21	**.89**	.08
New products	.27	**.84**	.24
Product differentiation	.31	**.78**	.20
New market expansion	.14	.12	**.90**
Intensive marketing	.29	.27	**.80**

Extraction method: Principal component analysis.
Rotation method: Varimax with Kaiser Normalization.

Multicollinearity reduces the variables' predictive power and complicates the interpretation process (Hair et al., 1998).

The multiple regression analysis was conducted with the business performance as dependent variable and the dimensions of information systems strategic orientation as independent variables. To ensure the minimization of impact of multicollinearity, the factor scores generated in the factor analysis with Varimax as an orthogonal rotation method, were used in the regression procedure.

The coefficient of determination (R^2) for the regression model generated was 0.252 with adjusted R^2 equal to 0.234. The model was statistically significant (ANOVA – Sig. 0.000). All the three dimensions of information systems strategic orientation significantly influenced the business performance. The details of regression coefficient and their significance are shown in Table 6. To assess the influence of Web presence, the regression analyses were conducted independently for exporters having Web site and for others. The results are shown in Table 7.

DISCUSSION

The results of the preliminary analysis of the data show that 74% of the respondent businesses are more than 10 years old and 89% have reached the business growth stage of stabilization and beyond. As expected, the proprietorship and partnership are predominant (86%). All the exporters have Internet connectivity and two thirds of them have Web presence. Eighty three percent of the respondents have more than 3 years of experience in using Internet. This indicates their high receptivity to the adoption of initial stages of electronic business practices.

The quality service strategy receives the highest mean score and it is followed by process efficiency improvement and cost reduction strategies. The mean score of all the other strategies are also above 3.00 and the overall mean score is 3.57. The exporters perceive that the information systems in general support their business strategies. Thus, these small businesses are upgrading their ways of competing that can lead to successful national economic development (Porter, 2004). These small businesses assess their competitive positions in all four criteria of business performance as strong.

The factor analysis reveals the three dimensions of information systems strategic orientation. The strategies of process efficiency improvement, cost reduction, quality service, and quality product emerge as indicators of the information systems strategic orientation dimension, Cost-Quality Leadership. The other two dimensions of information systems strategic orientation are Product Development (wider product range, new product, and product differentiation strategies) and Market Development (new market expansion and intensive marketing strategies). These are in line with Ansoff's matrix of strategy and Porter's generic strategies.

Table 6. Results of regression analysis – Coefficients and its significance

Predictors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
	B	Std. Error	Beta			VIF
(Constant)	.000	.077		.000	1.000	
Cost-Quality Leadership	.355	.077	.355	4.586	**.000**	1.000
Product Development	.261	.077	.261	3.374	**.001**	1.000
Market Development	.242	.077	.242	3.124	**.002**	1.000

Dependent variable: Overall business performance

Table 7. Results of regression analysis—Web-site owners and non-owners

Model Component Independent Variables	Exporters with Web site	Exporters without Web site
Cost-Quality Leadership		
Regression Coefficient	0.404	0.179
Beta Coefficient	0.403	0.176
t value	4.022	1.244
Sig.	**0.000**	0.220
Product Development		
Regression Coefficient	0.332	0.117
Beta Coefficient	0.351	0.111
t value	3.593	0.845
Sig.	**0.001**	0.402
Market Development		
Regression Coefficient	0.233	0.333
Beta Coefficient	0.237	0.341
t value	2.368	2.418
Sig.	**0.020**	**0.020**
Model Fit		
R^2	0.285	0.206
Adjusted R^2	0.257	0.154
ANOVA Sig.	**0.000**	**0.013**

The defensiveness (Venketraman, 1989) is the predominant characteristic of the Cost-Quality Leadership dimension. The Proactiveness (Venketraman, 1989) is the predominant characteristic of the Product Development dimension and Aggressiveness (Venketraman, 1989) is the predominant characteristic of Market Development dimension. The result presented in Table 5 was scrutinized to analyze the percentage of variance in each information systems strategy score, explained by these common factors and specific factors (Table 8). This analysis reveals that these three characteristics (common factors) mainly constitute the means (dimensions of strategic orientation) to achieve the formulated goals within the conditions set by the information systems resource in the external and internal domains. These characteristics are held together by unique factors that are specific to the concerned strategic goals. A few of these specific factors are jointly significant and may include the characteristics of Analysis, Futurity, Riskiness (Venketraman, 1989), and so forth. As they are not common to other strategies, these characteristics are not explicitly brought out by the factor analysis. All these characteristics collectively describe the information systems strategic orientation.

The extraction of a single factor from multiple measures of business performance indicates that the four different criteria reflect the overall business performance. The factor score is an indicator of their business performance and is used as dependent variable in the regression analyses. Multiple regression analysis provides insight into the relative importance of each dimension of information systems strategic orientation in the prediction of business performance. The order of importance is cost-quality leadership, product development and then market development. The strategic orientation, like strategic alignment, is a process and not an event. The information systems strategic orientation is strategy specific and industry oriented, whereas the strategy alignment is strategy independent and applicable to all industries. However, the strategic orientation analysis has set the direction to the measurement of alignment and its linkage with business performance.

The knowledge about the predictive value of the information systems strategic orientation is highly useful in understanding the business value generating process of information systems resource deployment in a given business setting. This facilitates the fine-tuning of the information systems investment and adjusting the portfolio of information systems applications by knowing the efficacy of a particular information systems strategy to attain certain ends within a particular setting. And strategic orientation as a process does not normally lead to competitive convergence (Porter, 2001).

Implication for Strategy Research

The major contribution of the present study is the revelation of three core multifaceted dimensions of information systems strategic orientation in small business context. This emphasizes that small businesses explicitly indulge in information systems strategic planning for business performance management (Frolick & Ariyachandra, 2006). Future research could focus on small business information systems strategic planning and investigate their strategy making process (Miller, 1987).

As the newer strategic management research paradigm explicitly separate goals from strategy, the information systems strategy could also be viewed as means to attain certain ends within a particular setting. Empirically deriving dimensions of strategic orientation a posteriori has certain limitations (Venkatraman, 1989). A valid operational measure could be developed specifying the identified dimensions a priori.

In net-enabled organizations (Straub, Hoffman, Weber, & Steinfield, 2002), strategy is fast becoming a dynamic process of recreating and executing innovative options to gain and sustain competitive advantages (Teece, Pisano, Shuen, 1997). The insight gained through the present study into the relationship among core dimensions of information systems strategic orientation in their prediction of business performance could be used in assessing and choosing emerging and enabling information technologies (ET). Selecting ET is the first stage in the Net-enabled Business Innovation Cycle (Wheeler, 2002) that asserts that choosing IT proceeds rather than aligns with business strategy in developing dynamic capabilities (Eisenhardt & Martin, 2000) to turn timely net-enabled business innovations into customer value (Chen, Chen, & Wu, 2005).

Future research studies could investigate whether the contingent effect of the Web presence on the relationship between information systems strategic orientation and business performance is a direct one or intermediated by any other factor. The capabilities of the Web site could also be examined in detail to ascertain its role (Whinston & Geng, 2004) in determining the degree and character of association between information systems strategic orientation and business performance.

Implications for E-Business Development

The Web presence strengthens the relationship between information systems strategic orientation and business performance as a “promoting” variable. This emphasizes the strategic benefits of adoption of Web presence, one of the initial stages of electronic business development. The market development dimension of information systems strategic orientation is equally significant for exporters who have not yet adopted Web presence (Table 7). Even though their regression model explains only 15% of the variation in their business performance, the model remains significant.

It seems that their participation in the global production networks, and the extent of trade liberalization forced these exporters to adopt the first stage of electronic business development viz. e-mailing and Web information search as a means of expanding their market. The near universal desire of business to gain advantages over their competitors, in addition to extend their markets, reach new markets, and protect existing markets, is perhaps the most significant force (Gibbs, Kraemer, & Dedrick, 2003), driving these exporters to move to the next stage of electronic business development viz. Web presence. It appears that Web presence creates information visibility (Straub et al., 2002) forcing the small businesses to improve their internal processes and strategic positioning that in turn lead to superior business performance.

As the strategic planning in small businesses is incremental in nature (Mintzberg, 1988), the demonstration of the beneficial results for adopters will enable the small businesses to move forward in the electronic business development. Rogers (1983) argues that change agents should recognize their responsibility for the consequences of the innovation they advocate. Thus, the results of the present study have practical implications to government and nongovernmental organizations that promote the diffusion of electronic business adoption in small businesses.

CONCLUSION

The small businesses are investing in information and communication technologies to develop information systems applications to support their business strategy and thereby establish a competitive advantage based on the distinctive capability created in their markets. However, these small businesses struggle to achieve business benefits from their information systems investments and in particular to obtain a sustained competitive advantage and superior business performance. To explore the relationship between the strategic orientation of these information systems and business performance, a study was designed. The mail survey was conducted among 950 small businesses manufacturing and exporting knitwear apparels.

The results reveal the three general patterns of their realized information systems strategies viz. cost-quality leadership, product development, and market development. These dimensions of information systems strategic orientation have strong positive relationship with their business performance. The consequences of their adoption of Web presence promote the degree of the linkage between information systems orientation and their business performance. The study demonstrates the business value of information systems investment and adoption of initial stages of electronic business development.

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Chapter 6.9

Computational Intelligence in the Financial Functions of Industrial Firms

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ABSTRACT

Information technology has been proved to be a strategic weapon in the business armory for the creation and sustention of competitive advantage, especially, when it is aligned with the needs of the internal and external environment. Solutions are provided from the operational level up to strategic planning and are capable to support every choice in the strategy portfolio, from cost to quality and flexibility. IT systems in the manufacturing and operational level were analyzed extensively in literature: ERP systems, computer aided design/computer aided manufacturing (CAD/CAM), and so forth. According to Wong, Bo, Bodnovich, and Selvi (1997), 53.5% of the reviewed literature in artificial intelligence refers to applications in production and operations management. Nevertheless, the second most important area for advanced IT applications is that of finance (25.4%). This research will be focused on the common set of the two previously mentioned areas: production management and the necessary financial tools. Production and operation management requires specific financial tools in order to accomplish the functions of production planning, costing, investment appraisal, and so forth. Computational intelligence in those financial functions is mostly needed for the production operation department and for the production operation strategy. Specifically, the weight will be put on information technology automation of financial functions adopted by production departments: forecasting production needs, production planning and control, profit volume analysis, cost analysis, investment appraisal analysis, and so forth. An attempt will be made to classify the various quantitative and qualitative techniques in relation to various

financial aspects. Specifically, advances of neural networks, expert systems, advanced statistical analysis and operational research methods, and various hybrid techniques will be presented in relation to financial models applied in production. Financial applications will be analyzed according to their modules and their outputs in a strategic alignment concept. Finally, a strategic alignment model will be derived for the adoption of financial applications in businesses.

INTRODUCTION

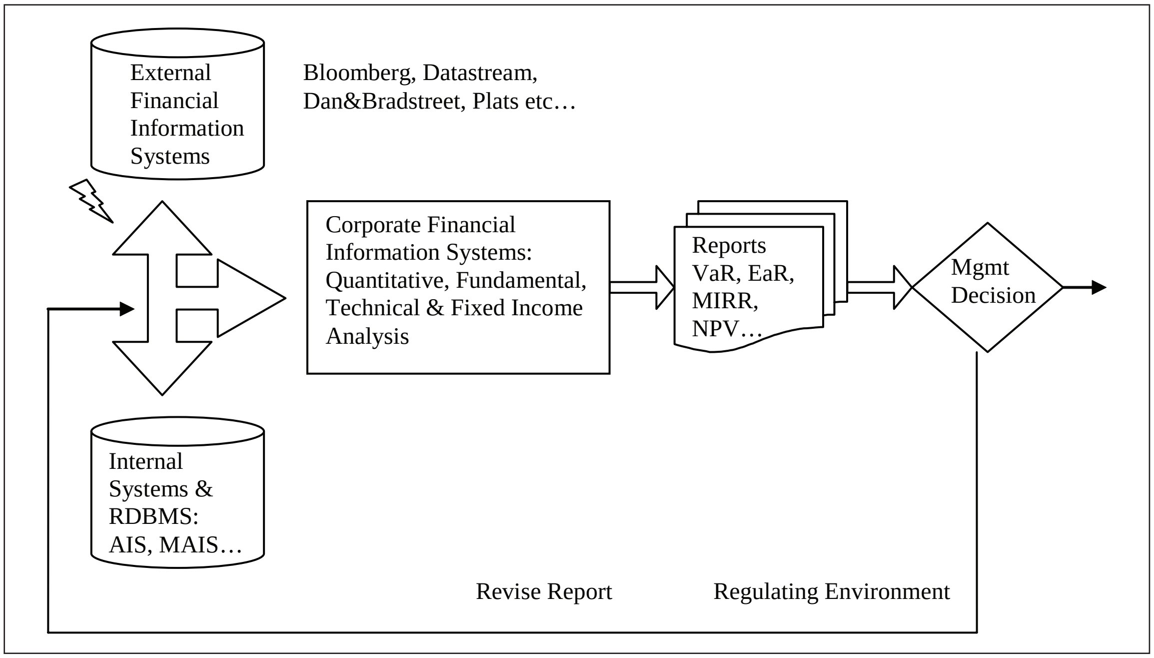
A tremendous progress in production methods happened in the last decade. The new production models customer and financially oriented incorporate new quantitative and qualitative techniques integrated with the known production and operations management models. The "black processing box" of this new financially oriented model incorporates advanced computational intelligence techniques. Production is not restricted on the shop floor management; instead a market oriented approach along with financial functions for the increase of financial performance is a prerequisite for the strategic survival. Computational intelligence employed in those financial models includes techniques of advanced statistics (mainly time series with exceptions, like discriminant analysis for the credit risk evaluation), simulation of stochastic processes, and artificial and neural network models. Logit-Probit models, multivariate discriminant analysis, simulation techniques (Monte-Carlo), weighted moving average (WMA), autoregressive conditional heteroskedasticity-generalized autoregressive conditional heteroskedasticity (ARCH-GARCH), and so forth are some of the techniques included in the statistics toolbox. Moreover, techniques of artificial intelligence and neural networks include case base reasoning, genetic algorithms, genetic programming, heuristic methods of linear programming and neural optimization, and so forth. Machine learning techniques are applied in portfolio optimization and derivatives pricing. Furthermore, those systems try to estimate risks in order to predict bankruptcy and rate credibility. The financial oriented production model targets to optimum allocation of funds among production activities, and to further hedge operational risks with financial impact. The diversification in demand and the variability in the external environment increased the need for rapid response with diversification in product and production. Therefore, computational intelligence must be incorporated in order to facilitate flexibility (Theodorou, 1996).

Manufacturing companies organize their systems in order to manage their operations on the spot and hedge the risks in the secondary markets. The operation in those markets requires extensive computational intelligence. The integration of financial information systems (FIS) with the production management systems is increased in order to gain competitive advantage. The performance of the advanced FIS should be measured in relation to the strategic factors of quality, flexibility, dependability, and valuate the benefits of scope economies and lead-time shortenings under the strategic alignment perspective. In the following paragraphs the generic FIS will be presented along with the literature review concerning its components. Specific attention will be given on the basic quantitative processing techniques which are based on statistics, artificial intelligence and neural networks. Finally, an attempt will be made to integrate the generic FIS within the strategic alignment model for future research.

LITERATURE REVIEW

Financial information systems (FIS) are usually found as a subtopic of the accounting information systems, but they must be separated due to differences in principles and practices. Especially, the quantitative character of finance demands a

Figure 1. Generic FIS



completely different approach than that of the accounting information systems, even though forecasting financial statements and budgeting analysis uses inputs from accounting information systems (AIS) and management accounting information systems (MAIS) (Covaleski & Dirsmith, 1986). AIS feed the systems with data and information for financial statements forecasting, and MAIS with information regarding the cost categories (Abernethy & Brownell, 1997; Abernethy & Stoelwinder, 1996; Bruggeman & Slagmulder, 1995; Chenhall & Langfield-Smith, 1998; Chenhall & Morris, 1986; Choe, 2004; Cooper, Hayes, & Wolf, 1981; Cooper & Kaplan, 1992, 1991; Cooper & Suver, 1994; Feltham & Xie, 1994; Flamholtz & Das, 1985; Foster & Swenson, 1997; Govindarajan, 1984; Ittner, Lanen, & Larcker, 2002; Johnson, 1992; Kaplan & Norton, 1992; Karmarkar, Lederer, & Zimmerman, 1990; Krumwiede, 1998; Lawrence, 1990; McNair, 1990; Miller, 1992; Preston, 1992; Shank & Govindarajan, 1993; Simons, 1987). Those systems must work close but each is separate from the other in scope and practice. The black box of FIS includes quantitative analysis, fundamental analysis, and technical and fixed income analysis. Stochastic processes and portfolio analysis make extensive use of artificial intelligence and neural networks where extensive literature can be found. Financial information systems use various quantitative techniques that are employed to model credit ratings and sovereign ratings, to evaluate credit risk, to forecast failure, bankruptcy and financial risk, to model stock selection, and so forth. All of these models are employing statistical and artificial intelligence techniques. Some of the statistical techniques employed are linear and nonlinear regression, probit regression, logit analysis, linear or quadratic multivariate discriminant analysis, multidimensional scaling, simulation techniques, logistic regression and linear programming, WMA, ARCH-GARCH, and various transformations (Altman, 1968; Baker & Wurgler, 2004; Belkaoi, 1980; Black, Jensen, & Scholes, 1972; Cambell & Shiller, 1988; Ederington, 1985; Fama & French, 1998, 2001; Hodrick, 1992; Horrigan, 1996; Jobson, 1982; Keim & Stambaugh, 1986; Kothari & Shanken, 1997; Kothari & Warner, 2001; Lewellen, 2004; Mar, Apellaniz, & Cinca, 1996; Mcinish & Wood, 1992; Taffler, 1983; Trevino & Thomas, 2000a, 200b). Artificial intelligence techniques consists of neural networks, case base reasoning, genetic algorithms, genetic programming ,and so forth (Ahn, Cho, & Kim, 2000; Bennell, Crabbe, Thomas, & Gwilym, 2006; Bennell & Sutcliffe, 2004; Bentz & Merunka, 2000; Brown, Coakley, & Phillips, 1995; Chen & Leung, 2005; De Freitas, Niranjan, Gee, & Doucet, 2000; Geigle & Aronson, 1999; Gemela, 2001; Healey, Dixon, Read, & Cai, 2002; Kelly, 1994; Kim, 2006; Mahfoud & Mani, 1996, 2002; Malliaris & Salchenberger, 1993a, 1993b; Odom & Sharda, 1990; Qi & Maddala, 1996; Tsakonas, Dounias, Doumpos, & Zopounidis, 2006). Risk management and financial forecasting make use of neural networks and expert systems advances as well as advanced statistics and operational research (Zhang, Patuwo, & Hu, 1998). In the coming sections a more detailed analysis will be presented. Fundamental analysis is basically based on financial statements and ratio analysis. From the basic outputs of accounting information systems, expost budgeting analysis forecast financial statements for the coming years (proforma). Technical analysis is trying to describe and forecast the movement of the prices on the markets using techniques such as trendlines, channels, candlesticks, point and figure, indicators and oscillators, various moving average methods (simple, linear, exponential), ARCH, GARCH, and so forth. Moreover, the state of efficiency according to efficient market hypotheses determines the type of analysis as well as the random walk hypotheses. A more detailed presentation will follow in the coming sections regarding the quantitative methods and its use in financial modeling. All these models should be examined in relation to the level of detail, frequency of reporting, and so forth under the alignment perspective (Figure 3). In the following paragraphs a generic FIS presentation will be made and its components will be discussed in detail along with relevant literature and their application field.

THE GENERIC MODEL

The generic model in an abstracting mode can be presented in the following diagram.

In this model a low level of detail is kept for the sake of discussion upon the generic topics. Further detail can be provided in future research for specific applications in specific industrial environment. This model should be adapted in the strategic alignment perspective (Figure 3) and should be discussed by taking in account relevant contingencies (Theodorou, 2003, 2004, 2005). The components of the generic FIS will be discussed in the following paragraphs.

The Internal RDBMS Systems

The internal relational database management system (RDBMS) include all available information and data generated and monitored within the firm by the firm's operations. Those systems comprise the internal pool of information separated conceptually (based on different economic principles) but interdependent and sometimes integrated from the software point of view. Those systems are the accounting information systems (AIS) and the costing or management accounting information systems (MAIS).

The accounting information systems generally include modules of accounts receivable-payable, generally ledger, payroll (sometimes separated module), order entry, billing, fixed assets accounting, and income tax preparation. The basic outputs of AIS used as inputs to the financial information systems are the income statements, the balance sheets, the cash flow statement, and the statement of changes in equity (based on the international financial reporting standards (IFRS)). Accounts receivable and payable record invoice and billing and helps schedule payments and issuing checks. Produce aging reports for cash collection that is also found in order entry applications. Payroll systems include pay rate, vacations hours tax, and other deductions and tax reports. Fixed asserts systems monitor and report the purchase of buildings, vehicles, and equipment for depreciation calculations and tax treatment, the gain or loss on assets sale, and so forth. Some systems are integrated with customer relationship management, e-commerce, project management, sales force automation, and work order management (*http://www.findaccounting-software.com/software/search/form.aspx?submittedfor=1&industry=Utilities&x=62&y=7* and *http://en.wikipedia.org/wiki/Comparison_of_accounting_software*).

The management accounting Information system (MAIS) is mainly dedicated in cost and inventory control and planning. The system collects, classify, and reports information that assists in financial planning and control of production activities (Bruggeman & Slagmulder, 1995; Flamholtz & Das, 1985). The system provides expost data for performance evaluation against predetermined goals and standards by the financial system. The financial part of MAIS can be grouped into traditional cost control information systems (TCCI) and advanced cost control information systems (ACCI) (Abernethy & Brownell, 1997; Chenhall et al., 1998; Govindarajan, 1984). One form of the advanced cost control information system is the design of activity based costing (ABC) (Foster & Swenson, 1997; Ittner et al., 2002; Krumwiede, 1998). TCCI systems are managing cost by means of standards, variances, and other metrics based at the individual level (Miller, 1992). In TCCI organizational performance is increased by maximizing individual efficiency (McNair, 1990) in relation to ACCI systems where interrelationships among function and group cooperation is of higher importance for performance (Choe, 2004). The critical attributes of those systems are the level of detail, the ability to disaggregate costs according to behavior, the frequency with which information is recorded, and the extent of calculation of variances. The more functional the type of MAIS the greater detail it provides, the better behavior classification it provides, as well as frequent reporting, and calculation of variances. The level of detail is analyzed by Chenhall and Morris (1986), Felthan (1977), Kaplan and Norton (1992), and Karmarkar et al. (1990). The system, in order to supply detail, must separate and classify cost according to behavior in fixed and variable, direct and indirect, controllable and noncontrollable (Feltham & Xie, 1994), and so forth.The greater the detail of MAIS, the greater the flexibility that it generates to analyze the cost for different purposes (Shank & Govindarajan, 1993). Feltham (1977) as well as Chenhall and Morris (1986) point out that decisions that are based on more detailed information are capable for performance increase in relation to decisions which are based on more aggregated information due to accuracy. Aggregations can be made in relation to the procedures, where direct costs are traced to the procedure and indirect, fixed, and variable costs allocated to the procedures. This requires a meaningful classification of cost according to behavior and activities (activity based costing system) (Cooper & Kaplan, 1992). The correct identification of cost behavior ensures the accurate information at all levels of detail (Cooper & Kaplan, 1991; McGown, 1998).

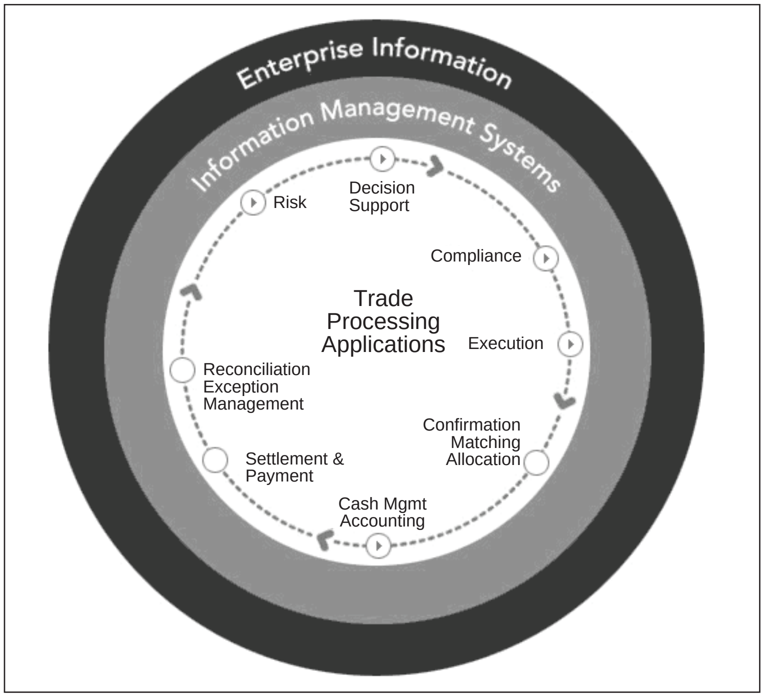
Cost reporting frequency enables the early recognition of problems in order for management to take corrective actions and accomplish fit with the environmental changes (i.e., takes advantage of opportunities and avoids threats). Chenhall and Morris (1986) found that frequency has a positive impact on performance for firms that operate in uncertain environment. Frequent reporting of the MAIS to the financial modeling system has found to have positive impact on financial performance. Hilton (1979) modeled the value of an MAIS in a cost volume profit decision setting where higher frequency of reporting increased the performance of the system.

The cost system trait, through variance analysis, determines the gap among expost and exante financial proforma estimations in order to resolve the causes of difference (Cooper & Suver, 1994; Feltham & Xie, 1994; Hilton, 1979; Johnson, 1992; Karmarkar et al., 1990; Khandwalla,1972; Simons, 1987). Variance analysis feed the financial information system with appropriate data in order to achieve budgetary control and help the administrative monitoring. Furthermore, inelastic pricing and contracts increase the need for variance analysis as they force firms to adopt risk of unexpected cost and utilization. Finally, variance analysis is extremely useful for the appropriate allocation of resources through measuring performance in relation to predetermined targets (Abernethy & Stoelwinder, 1996; Cooper et al., 1981; Covaleski et al., 1993; Lawrence, 1990; Ouchi, 1979; Preston, 1992).

The External Financial Information Systems

Market data that will feed the financial information system are obtained through external database management system (DBMS). Those external financial information systems keep track of market data, like prices, indices, interest rates, and other macroeconomic data as well as published information of financial accounts of other firms. Some of those databases need registration while others are free of charge. Examples are Bloomberg, Datastream, Hoovers, Yahoofinance, Plats, Edgar, Ibbotson, Reuters, and so forth. In this category we can refer interbank systems like Society for Worldwide Interbank Financial Telecommunication (SWIFT) as well as stock exchange information systems provided from various brokers. Those systems monitor and report the results of the stock exchange markets. The Electronic Data Gathering Analysis and Retrieval System (EDGAR) automates the collection, validation, indexing, and forwarding of data for companies required by the law with Securities and Exchange Commission (SEC). EDGAR, among others, delivers fundamental data, global annual reports, aggregated information, SEC fillings plus comparison, and searching and screening tools. Moreover, EDGAR with I-Metrix Professional offers analytical tools for fundamental, market data, and earnings forecasting, peer analysis, benchmarking, valuation, and so forth. Ibbotson, founded in 1977, offers tools and information for asset allocation, investment management, forecasting, education, and National Association of Securities Dealers (NASD)-reviewed presentation material. Presentation material is used to explain and demonstrate asset allocation strategies and investment concepts. Ibbotson offers software and data for investment planning, analysis, and asset allocation. EnCorr Analyzer accesses a central database to perform historical capital market data analysis, while EnCorr Input Generator refines and generates the necessary forecasting and optimization analysis. EnCorr also has an optimizer to test and analyze portfolios on frontiers, created using resampling methodology. EnCorr Attribution is used to analyze management style and attribute performance to investor decisions. EnCorr Allocator is used to implement asset allocation policy and Ibbotson Scenario builder is used toanalyze what-if scenarios. These database offers access to 3500 domestic and international macroeconomic indices and performance data series with monthly and quarterly Internet updates since 1926. Investment Planning Software and Data includes the Portfolio Strategist and Analyst, the Security Classifier, and the Investment Planning Data module. The software determines the optimal asset mix with the higher return and minimum risk. Find portfolios with the highest chance to obtain desired returns. Account the impact of taxes and create comparisons of multiple portfolio allocations on the efficient frontier. Moreover, examine the effect of changing assumptions (like taxes, interest rates, inflation, etc.). Classify security holdings to recommend an asset allocation to implement the plant with mutual funds and look at historical be-

Figure 2. The Reuters enterprise financial information systems



havior. With historical analysis, rank performance and examine risk/return trade offs. The Security Classifier defines the allocation of the portfolio and maintains a database of over 21,000 mutual funds, annuity subaccounts, and stocks. In the Ibbotson database, more than 5,800 mutual funds, 7,200 annuity subaccounts and 8,350 individual securities have been classified. Finally, service extends to security classifier, risk assessment, mean variance optimizer, historical calculations, wealth forecasting using straightforward analytical model and Monte Carlo simulation, and fund optimizer that determines the portfolio of mutual funds and subaccounts that most closely matches a target asset allocation.

The Reuter systems deliver financial information generated by exchanges, over-the-counter markets, price contributors, research services, and news. Also included are real-time prices, price histories and news, statistics, broker research and company fundamental data, and estimates. The financial information system of Reuter enables the market analysis and trading and investing opportunities identification, risk assessment of different strategies, ability to communicate with other market participants, direct trading, and access to executable prices and trading tools. Reuter premium financial information system incorporates trading functionality of the equity, fixed income, foreign exchange, and commodities from the desktop system of the company. Regarding the front office, Reuter offers pretrade analysis, limits checking, real time positioning, pricing analytics, tactical risk management, and profit and loss reporting. Regarding the middle office, it offers limits management, market risk and credit risk management, back testing, enterprise wide risk management, regulatory reporting, double validation, and market conformity check. In the back office, prevalidation is offered along with back validation, settlement, cash management, accounting, reporting, and messaging.

Bloomberg provides real-time and archived financial, market data, pricing, trading news, and communications tools. Platts is a division of McGraw-Hill Companies dedicated to energy financial information for oil, electricity, gas, coal, nuclear, petrochemicals, and metals. Platts offers energy benchmark pricing, forward curves, oilgrams, and real-time market news and industry analysis.

All the data and information collected from internal and external FIS are processed further in the processing box in order to advise and support decision making. In the following paragraph we will present the processing box operations along with the quantitative methods used to solve specific problems.

CORPORATE FINANCIAL INFORMATION SYSTEM: PROCESSING BOX AND QUANTITATIVE METHODS OF ANALYSIS

External databases provide the financial information system with inputs such as: YTM of the long-term bond (risk free rate), level of inflation, GDP growth, exchange rates, interbank rates and spreads (cost of debt), prices of commodities (metals, fuels, electricity, etc.) that determine the manufacturing cost, and so forth. The internal database and mainly the MAIS will provide FIS with the inputs relative to the unit cost classified according to behavior and activities. AIS will provide the relevant inputs for the financial statement forecasting and for the estimation of pro-forma financial statements. Sales and marketing information systems will provide the relevant forecasts for the sales budget. In the processing box, budgeting analysis will determine future needs for sales and capacity additions as well as investment needs. Future capacity investments will be selected according to the required returns (internal rate of return (IRR), net present value (NPV), return on invested capital (ROIC)). Material needs and their costs will be determined in conjunction with material requirements planning I (MRPI) systems. Sales budget, production budget, and inventory budget along with former financial statements (provided by AIS) will determine the forecasted pro-forma financial statements upon which further analysis will be contacted (i.e., ratio analysis, determination of additional required funds, etc.).

Portfolio management, financial, and specifically credit risk analysis will also be used for working capital and current assets management. Trading department will bargain and insure the price of both materials and end products on the spot and secondary markets wherever are organized otherwise in over-the-counter. FIS will determine metrics like earnings-at-risk (EaR), value-at-risk (VaR), and so forth to impose trading limits and define trading and hedging strategies. The operations will be accomplished by the coordinative effort of two functions: the front/middle office and the back office. Fundamental, technical (trends, support and resistance levels, reversal and continuation patterns, head and shoulders, triangles, pennants, flags, candlesticks, point and figure charts, etc.) and quantitative analysis (statistical, artificial intelligence and simulation techniques like Monte Carlo, and relevant software like @ Risk and Crystal Ball, EaR, PaR, CaR, etc.) will be accomplished by the front/middle office functions, while the operation of back office will be only supportive and mainly focused on matters of accounting. In the front and middle office the operations of market analysis, risk hedging, and trading monitoring will be accomplished while back office operations will include, risk measurement and reporting, accounting handling, and credit risk control. Various quantitative techniques are employed to model credit ratings using artificial neural networks (ANN) and sovereign credit ratings to model credit risk evaluation, to forecast financial risk, to model sock selection, to model failure and bankruptcy prediction, and so forth. All of these models employ statistical and artificial intelligence techniques to solve different financial problems. In the first case techniques such as linear and nonlinear regression, probit regression, logit analysis, linear or quadratic multivariate discriminant analysis, multidimensional scaling, simulation techniques, logistic regression and linear programming, WMA, ARCH-GARCH, and so forth can be seen. The category of artificial intelligence consists of artificial neural networks, case base reasoning, genetic algorithms, and genetic programming. Each of the above techniques has been used so as to provide solutions in different financial topics and will be presented in the following paragraphs along with their usage in financial modeling.

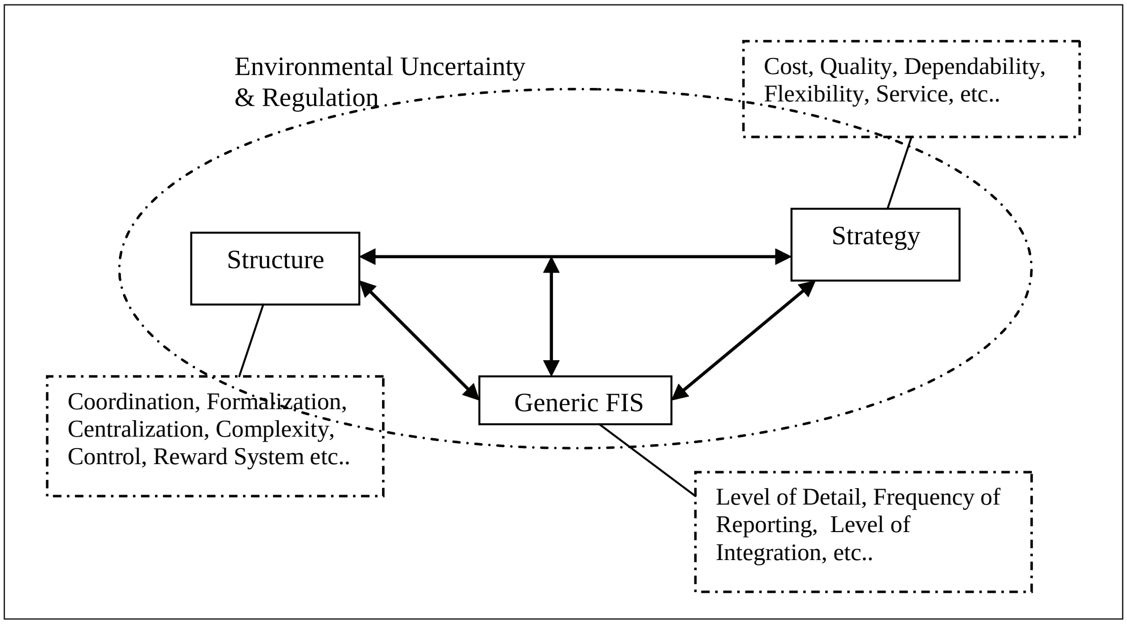
The linear regression technique, although trivial, can efficiently solve many forecasting problems. Multivariate linear regression was used by J.D. Jobson (1982) to test the arbitrage pricing theory and by Horrigan (1996) to find a link between the utility of the accounting data and the long-term credit administration. Schwartz (1988) identified four determinants of bid-ask spread (activity, risk information, and competition) and McInish and Wood (1992) used multivariate linear regression to demonstrate the relation among spreads and those factors. Prediction regressions and autoregression models have been applied by Keim and Stambaugh (1986) to predict the excess returns by some lagged variables: (a) the difference between the yield on long-term BAA underrated corporate bonds and the short-term Treasury bill rate; (b) the level of the S&P 500 index; and (c) the level of the small firm stock index. Using the same technique, Fama and French (1998) estimated the effect of the lagged dividend-price ratio on the stock returns. Additionally, Campell and Shiller (1988) found that the lagged dividend-price ratio and lagged dividend growth rate have a significant relation with stock returns. The same technique was applied by Hodrick (1992) to predict stock returns by the dividend-price ratio. Lewellen (2004) used the book-to-market ratio as a predictor while Kothari and Shanken (1997) have used the lagged book-to-market ratio. Predictive regression also was used by French, Schwert, and Stambaugh (1987) (predictor was the return variance obtained from an autoregressive integrated moving average (ARIMA) model). Linear regression finally could be found in popular studies of the capital asset pricing model (CAPM). Black et al. (1972) and Fama and McBeth (1973) have used the two-stage cross-sectional regression method. Finally, we can refer the work of Cantor and Packer (1996) and Trevino and Thomas (2000a, 2000b). Another type of regression which is also used in FIS is that of probit and logit. This technique has been used to examine the decreasing trend of firms to pay dividends (Baker & Wurgler, 2004; Ederington, 1985; Fama & French, 2001; Trevino & Tomas, 2000-2001). Linear multivariate discriminant analysis was used by Altman (1968), Belkaoi (1980), and Taffler(1983), and quadratic multivariate discriminant analysis was applied by Prinches & Mingo (1975). Mar et al. (1996) applied multidimensional scaling for bond ratings. Logistic regression was used by Wiginton (1980) to compare logit and discriminant models of consumer credit behavior. Linear programming techniques have been used by Mangasarian(1965), Freed & Glover (1981), and Hand (1981). Finally, simulation techniques have been used in economic analysis, decision making, and operational research. Simulation techniques have been applied in financial based computer systems, management games, for decision making, and operational research. Simulation procedures have been used by Kothari and Warner (2001) for the study of empirical properties of performance measures for mutual funds.

Genetic algorithm as a search algorithm is used to find solutions in complex optimization problems. Genetic algorithm offer advantages over the usual optimization techniques. Mahfoud and Mani (1996) say that the traditional optimization techniques “are of no use” if the problem that we want to solve is nondifferentiable. Genetic algorithms do not require gradient information, so there will be no problem in such optimization. Moreover, genetic algorithms are more likely to find a global optimum, as they search many points at once. The global optimum is more difficult to be found by other optimization techniques which do not search as genetic algorithms. Finally, genetic programming is a methodology that executes a procedure which guide automatically to the solution of the defined problem. Neural network applications can be found in financial topics such as financial and economic forecasting, data mining and target marketing, bankruptcy prediction, credit evaluation, portfolio selection/diversification, simulation of market behaviour, corporate loan portfolio risk evaluation, risk assessment, and pricing financial derivatives. Brown et al. (1995) talk about FALCON, a financial information systems that use ANNs by large credit card companies to screen transactions for potential fraud and credit advisor that accord credit for automobile loans. Furthermore, extensive literature can be found concerning the topic of pricing options using artificial neural networks. Malliaris and Salchenberger (1993a, 1993b) compare the performance of the Black-Scholes model and an ANN showing that the ANN model was superior for out-of-the-money options and the Black-Scholes model better for in-the-money options. Hutchinson, Lo, and Poggio (1994) compare three ANNs with Black-Scholes formula in pricing American call options on S&P100 futures. All three networks were better than the Black-Scholes model. Qi and Maddala (1996) compare the performance of an ANN in pricing European call options and found that the ANN produces better results. Alike to Qi and Maddala, Geigle and Aronson (1999) examine the performance of ANNs in pricing options. They have indicated that ANNs were better than Black-Scholes formula. The superiority of ANNs is shown also by De Freitas et al. (2000) who applied ANNs and Black-Scholes model to price Financial Times Stock Exchange (FTSE) 100 (United Kingdom) call and put options. Kelly (1994) shows that the ANN was superior than the binomial model in a study to price American-style put options on four U.S. firms. Healey et al. (2002) show that ANNs are well enough in pricing options. Bennell and Sutcliffe (2004) compare the performance of Black-Scholes model with an ANN in pricing European-style call options on the FTSE100 index. They provide an extensive study on the performance of ANNs in pricing UK options. The results have shown that ANNs were superior and they mentioned that this superiority "suggests that ANNs may have an important role to play in pricing other options." Another application of such networks is the use of Bayesian networks in financial analysis. Gemela (2001) studied the use of probabilistic Bayesian networks in fundamental financial analysis. They present the construction of a Bayesian network for the financial analysis of specific firms and sectors of the Czech economy. A survey of ANN applications in forecasting mentions that extensive literature can be found in financial applications of ANNs. ANNs have been used for forecasting bankruptcy and business failure (Tsakonas et al. 2006). Zhang, Hu, Patuwo, and Indro (1999) use neural networks for modelling bankruptcy and they linked to the Bayesian classification theory. Ahn, Cho & Kim (2000) presented a combination of rough sets and neural networks. Parag & Pendharkar (2004) proposed a threshold-varying artificial neural network for binary classification. Comparisons of results with other techniques such as inductive machine learning and genetic algorithms are also performed. In bankruptcy prediction the work of Odom and Sharda (1990) Tam and Kiang (1992), and Fletcher and Goss (1993) can be referred to. ANNs have also been used as a prediction and forecasting tool for exchange rates, stock prices, and volatility. The work of Casdagli and Eubank (1992), Hlupic, Walker, and Irani (1998), Refenes (1993) and Wu (1995) explores exchange rate forecasting. White (1998), Schoneburg (1990), Bergerson and Wunsch (1991) apply ANNs for stock price prediction. Kaastra and Boyd (1994) provide a procedure to design a neural network forecasting model for financial and economic time series. Kim (2006) proposes a genetic algorithm approach in ANNs for financial data mining. Hamid and Iqbal (2004) use ANNs to forecast the volatility of Standard & Poor's (S&P) 500 index futures prices. They present that the volatility forecasts from neural networks with realized volatility are about the same. Finally, Chen and Leung (2005) suggest that "neural networks are a better tool to forecast the exchange rate correlation." They compared the forecasting performance of neural networks with that of implied volatility and random walk models. Applications of ANNs could be found on predicting sovereign credit ratings. Bennell et al. (2006) believe that neural networks are superior to ordered probit models which have been used for credit rating. They found that ANNs, which are used by major rating agencies (e.g., Standard & Poor's and Moody's), can be used to predict sovereign credit rating. ANNs have also been applied in marketing problems. Bentz and Merunka (2000) showed that the neural network can be used as a generalization of the multinomial logit model which is used for brand choice modelling. Techniques such as genetic algorithm have also been used for financial forecasting. Mahfoud and Mani (2002) presented a genetic algorithm system to predict future performances of stocks. They tested the genetic algorithm system and a neural network system on 5,000 stocks where genetic algorithm systems produced better final results. Adaptive genetic algorithms have been used for construction finance decisions. Lam, Hu, NG, Yuen, Lo, and Wong (2001) propose adaptive genetic algorithms as an alternative method for modelling financial decisions. In this field, many optimization techniques have been used, such as heuristic method, linear programming, and neural optimization networks. The technique of genetic programming has been used in financial topics, such as option pricing. Chen, Lee, and Yeh (1999) use data from S&P 500 index options and distinguish them in in-the-money and out-of-the-money categories. They compare the genetic programming tree with the Black-Scholes model in its capability to hedge. Finally, we could find applications of machine learning techniques in financial topics, such as portfolio optimization problems. Ince and Trafalis (2006) developed a short-term management model based on the volatility around the earning announcements.

CONCLUSION AND FUTURE TRENDS: MANAGERIAL DECISION

The performance of a FIS as any other advanced IT system should be examined under the strategic alignment perspective (Theodorou, 2005, 2003, 1996; Theodorou & Giannoula, 2008). Otherwise performance comparisons and benchmarking practices will lead to wrong conclusions. Specifically, FIS should be aligned with the organizations' structure and strategy which is determined by the environment's uncertainty and volatility where the business operates under certain regulations (Chenhall, 2003; Theodorou, 2003). Performance achievements should be judged in relation to an alignment model in control of contingencies such as firm size, age, and so forth. Theodorou (2004) presents in detail the alignment model and its' variables with the relevant literature. The frequency of FIS reporting, the level of FIS detail, the level of integration among internal, and external financial information systems should be decided in relation to the strategic alignment mechanism (Figure 3) in control of contingencies such as size and age of the firm. The more volatile the environment where the firm operates the greater the need for the FIS to generate frequent reporting and higher level of detail in order for management to take corrective actions (Theodorou, 1996). Thus, decision making needs to do frequent corrective actions in a volatile environment. Rigid structure for firms working in a stable environment directs competitive strategy toward cost. Level of detail and frequency of FIS were kept at low level along with low level of integration among FIS and internal and external financial information systems.

Figure 3. Alignment of FIS



The FIS model previously presented should be examined on the previous characteristics but this must be done under the “umbrella” of strategic alignment theory. Decision making in a more detailed FIS model is also another topic that has to be examined using the criterion of performance. Sometimes potential benefits of frequent reporting, greater detail, and integration do not exceed the cost of the system. Implementing a sophisticated FIS system entails costs of consulting, training, and maintenance, but not the cost of investing. For example, if the firm has no significant number of counterparts than the cost of a credit risk system may exceed the benefits realized. Finally, further research can be conducted regarding the commonly adopted quantitative methods by successor firms.

FUTURE RESEARCH DIRECTIONS

Future research for the design of a financial information system must make use of the alignment framework (Theodorou, 2005, 2003, 1996) and the contingency approach (Figure 3), especially for the processing box and the quantitative methods. The components of the financial information system (described in the previous sections) should be chosen according to the environment where the firm operates and its existing structure. Increased performance and competitive advantage by the system will be expected only if modifications of business structure and the systems design are aligned with the environment. For example, a business with a flexible structure designed around risk management can better operate in a volatile environment. The financial information system of this business should incorporate modules of risk management (calculations of VaR, EaR, etc.) and hedging techniques, to help management eliminate the variability. In such an environment where nonstationarity of the mean exist, the computational averaging techniques (simple/centered/doubled/weighted moving averages, exponential smoothing, ARIMA, etc.) may be obsolete. More advanced computational methods must be applied, such as random walk models (RWM), stochastic volatility (SV) models, models that use stochastic processes, and computational intelligence of nonlinear artificial neural networks (S-E-TAR ANNs). Moreover, the computational techniques of autoregressive and generalized autoregressive conditional heteroscedasticity (ARCH-integrated-GARCH, fractionally integrated-GARCH, etc.) should also be used in these FIS in order to better describe volatility clustering, excess kurtosis, and fat tailedness. Finally, there is no need to incorporate this computational intelligence and the structural processes of risk management in the financial information systems which operate in a stable and predictable environment. If we do so, than the return on the additional not needed invested capital will be decreased as well as the overall performance.

That is why future research must take into account the alignment framework (Theodorou, 2005, 2003, 1996) in order to decide about the design of an FIS as well as the computational intelligent which has to be employed by taking into account behavioral characteristics.

Finally, until now there is no research indicating which parts of the previously mentioned generic FIS model are adopted by the firms. Also there is nothing indicating how the effect of frequency of reporting, level of detail, and integration of the FIS model with enterprise resource planning systems (ERP) impacts business performance.

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Chapter 6.10

The Impact of E-Commerce Customer Relationship Management in Business-to-Consumer E-Commerce

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ABSTRACT

The growth of business-to-consumer (B2C) e-commerce has gained a lot of attention among SMEs. Most B2C firms are turning their attention on how to retain new customers and are left in a situation to compete with larger firms. This paper aims to examine the impact of E-Commerce Customer Relationship Management (ECCRM) in a small business firm that engages in B2C e-commerce. Drawing upon the theories of customer relationship management, e-commerce, trust and loyalty, we develop an integrated framework of ECCRM model to illustrate the impact of the hard and soft factors that reflect the level of transactional and relational components of communication thereby impacting the customers shopping time lifecycle experiences. We develop a number of hypotheses to facilitate testing of the framework via an exploratory case study. We then discuss the findings of the integrated framework leading to theoretical and practical implications of this study and directions for future research.

INTRODUCTION

The Internet has become the foundation for electronic commerce customer relationship management (ECCRM). ECCRM refers to the application of e-commerce using the Internet and Web applications to manage customers. Information Data Center predicts that e-commerce spending will reach $496.7 billion in the United States and $1.3 trillion globally by the year 2009. In recent years we have witnessed an increased growth of small businesses turning towards the Internet to market their products. Business to consumer

(B2C) e-commerce, a significant subset of total Internet business, can provide significant benefits to customers and small-medium enterprises (SMEs), including the ability to market their products and services online thereby achieving global connectivity, high accessibility, scalability, interoperability, interactivity, and greater information richness (Turban, Lee, King, & Chung, 2006).

SMEs are an important and integral part of every country's economy and have been long recognized as different from larger businesses (Street & Meister, 2004). The Internet helps SMEs to manage customer relationships effectively, as it provides an easy and inexpensive way to advertise, lowering the barriers to entry for SMEs. Despite that customers are now even more demanding than ever before and B2C e-commerce firms are challenged to keep pace with the changing customers needs in maintaining a competitive edge. Unlike traditional means of communication such as newspapers or television, the Web gives the customers control in choosing and processing informing about the firm. Web tools such as online feedback forms, 1-800 telephone numbers, help-desk operators assist customers in obtaining information and clarifying questions quickly. Products such as LikeMinds from Macromedia uses complex algorithms to create affinity groups for each customer, so that B2C firms can better understand their customers engaged in buying from their Web site. The Web overturns the traditional hierarchical system of distribution channels by allowing integration of systems and information between the marketing, sales and servicing activities thereby forcing SMEs to view CRM seriously. Beyond blogs, podcasts, and wikis, social media comprises social networks of all strips, social tagging that provides organized customer generated content for small businesses and customers to share views. The breadth of the medium allows wider availability, accessibility and selection of hard-to-find products and services. Web tools thus serve two purposes namely; to provide Web content and to manage customers' interactions.

Customer relationship management (CRM) is the ability of a firm to capture and integrate customer data from all over the organization and then consolidate, analyze and distribute the data to various touch points within the organization. In most cases CRM uses groupware software to enable these processes to occur. Alternatively, ECCRM uses the e-commerce system and the CRM system of the firm to integrate and consolidate both the firm's and customer's data in order to facilitate access to any type of information, anytime and anywhere using the Web. These Web-based applications enable firms to generate, aggregate, and analyze customer data, thereby employing the results to improve service and marketing activities. ECCRM relies on the Web interactions between the firm and its customers while supporting e-commerce that entails shopping online, thereby contributing to profitability. Thus, it is more than simply a sales or marketing automation tool. It is an end-to-end, company wide solution that integrates the marketing, sales, and service activities.

Despite the hype and growth of the Internet for e-commerce, the application of ECCRM in the context of SMEs is limited. In fact, previous research suggests that only 20% of the SMEs are deploying CRM applications (Markowitz, 2005). This study aims to examine the impact of ECCRM in the context of B2C e-commerce among SMEs. Drawing upon the theories of customer relationship management, e-commerce, and trust and loyalty, we develop an ECCRM model to illustrate the impact of the hard and soft factors that reflect the extent of transactional and relational components of communication thereby impacting the customers shopping time life-cycle experiences leading to four modes namely; learning, monitoring, collaborating and distancing modes. The rest of the article is organized as follows. The next section discusses the ECCRM and its impact on the hard and soft factors. While hard factors reflect the transactional component of communication including Web site's performance, user friendliness, quality of Web content, customer acquisition/search costs and perceived security. Soft factors reflect on the relational component of communication including the quality of products/services, satisfaction, trust, loyalty and reputation of the firm. We develop a number of hypotheses to facilitate testing of the ECCRM model via an exploratory case study with a small B2C e-commerce firm in the retail-marketing industry. We then report and discuss the findings of the study leading to theoretical and practical implications of the study and directions for future research. This study contributes to theory as we provide a holistic ECCRM model that incorporates both hard and soft factors and its impact on customers shopping time life cycle experiences. The study also contributes to practice as B2C e-commerce practitioners will be aware of the mechanisms used to achieve timely, cost-effective, scalable, manageable and reliable feedback on their customer relationship performance.

E-COMMERCE CUSTOMER RELATIONSHIP MANAGEMENT (ECCRM)

The term ECCRM refers to the application of e-commerce to manage customers using Web applications. ECCRM when incorporated properly into the daily business processes can:

- reduce the cost of communicating with customers;
- provide Web-based opportunities for self-service activities, thereby reducing administrative overhead;
- integrate delivery of services, production, and derive value chain cost savings;
- boost sales through Internet marketing; and
- improve customers, interaction with the firm, leading to service improvements (Burr, Patterson, Rolland, & Ward, 2007).

ECCRM allows firms not only to keep in contact with their customers but also to extend their relationships with customers (Tsikriktsis, Lanzolla, & Frohlich, 2004). In fact ECCRM is a revolving process as B2C e-commerce firms need to interact with their customers, thereby generating, aggregating and analyzing customer data from the results of their sales, marketing, and servicing activities (Romano & Fjermestad, 2001; Seybold, 2001). The certainty in ECCRM requires that both the technology and the firm's positive relationships with their customers' lead to successful CRM as in attracting new customers and retaining existing customers thereby increasing profitability. Yet, little attempt has been made to understand how firms that engage in B2C e-commerce attempt to manage their ECCRM. In the next section we discuss the hard and soft factors that impact ECCRM.

Hard Factors

B2C e-commerce is a socio-technical system used to advertise, sell and share business information and products by conducting business transactions over the Internet. We argue that it is critical to consider the role of the Internet and other Web applications that facilitate the *transactional component* of communication thereby contributing to the hard factors such as; Web site's performance as in increased sales, reduced complaints, user friendliness, quality of Web content, customer acquisition/search costs and perceived security. The transactional components include both the transactions of information and money pertaining to the purchasing process. The transactional component of communication is reflected in the more formal and precise reporting of outcomes and quantitative results such as sales figures. Transactional attributes of communication also refers to the accuracy, timeliness, adequacy, correctness, and credibility of information exchanged between the firm and their customers (Daft & Lengel, 1986; Huber & Daft, 1987; Mohr & Spekman, 1994).

Hard factors thus refer to the technological mechanisms that facilitate customers to use the B2C firm's Web site to engage in online shopping. They form the foundation for B2C e-commerce transactions to occur and are derived from the Technology Acceptance model (TAM), which is one of the most widely accepted models used for predicting e-commerce adoption. Drawing from the TAM, which has its origins in the theory of planned behavior (TPB) (Davis, Bagozzi, & Warshaw, 1981), and theory of reasoned action (TRA) (Ajzen & Fisbein, 1980), we propose that technical solutions and security solutions provide impersonal assurances that contribute to positive expectations, intentions, and behaviors in e-commerce relationships. This is consistent with Zucker (1986), who claims that trust is created in impersonal economic environment (without familiarity) and similarity (communality). Trust forms not because people know each other personally, but because institutional structures that are akin to policies, auditing, and recourse embedded in the e-commerce technology. McKnight and Chervany (2001, p. 13) advanced this argument in the context of B2C e-commerce, arguing that "beliefs that the Internet has legal or regulatory protection for consumers (institution-based trust) should influence relationship trust of a particular e-vendor (interpersonal trust)."

TAM thus posits that e-commerce adoption is affected by prior use related beliefs. It identifies two beliefs namely; perceived usefulness (as a response to the B2C firm's extrinsic value—accuracy, quality, timeliness of business transactions); and perceived ease of use (as a response from the customers pertaining to the intrinsic characteristics of the e-commerce system (ease of learning, flexibility, security solutions). E-commerce solutions and other third-party application providers inform the B2C firm's expectations of the transactional capabilities of the technology platform. Customers form beliefs regarding the accuracy and efficiencies of the system thereby reducing search costs. The e-commerce system is also used to support a wide range of applications including standing purchase orders, just-in-time sourcing, invoicing and payments, as well as collaborative design and development. The technology also provides a mechanism to monitor the customers' interactions and communications with the firm and ultimately the firm's economic performance. Further, best business practices as in IT solutions and proven problem solving methods are used to attract and retain customers. Best business practices also include enforcing governance mechanisms in the form of contracts, regular audit policies, top management commitment, high-quality standards, adequate and complete training of the employees, and enforcing risk-management procedures that impact and control the quality of the Web content, security and Web-site performance (Marcella, Stone, & Sampias, 1998).

Soft Factors

Soft factors are derived from the *interpersonal or relational component* of communication between the firm and their customers. They include quality of products/services, satisfaction, trust, loyalty, and reputation of the firm. McKnight and Chervany (2001, p. 13) advance this argument in the context of B2C e-commerce, arguing that "beliefs that the Internet has legal or regulatory protection for consumers should influence relationship trust of a particular e-vendor." Trust is frequently defined in the literature as (1) the confidence or predictability in one's expectations (Zucker, 1986), and (2) the confidence in others goodwill (Ring & Van de Ven, 1994). The benefits of trust in e-commerce relationships seem wide ranging, including lowering transaction costs (Gulati, 1995), promoting desirable behaviors, reducing the extent of formal contracts, and facilitating dispute resolutions (Ring & Van de Ven, 1994). The behaviors reflect integrity and dependability as well as the customers' knowledge of the products and satisfaction of the firm increases. Previous research suggests that customer loyalty increases profit and growth in many ways to the extent that increasing the percentage of loyal customers by as much as 30% to 85% depending on the industry (Gefen, 2002). This is evidenced by Keen (2000, p. 1) who noted: “We are moving from an IT economy to a trust economy.” Similarly, a significant number of studies support the underlying importance of trust in e-commerce relationships (Dyer & Chu, 2000; Hoffman, Novak, & Peralta, 1999; Jarvenpaa, Tractinsky, & Vitale, 2000; Keen, 2000; Sako & Helper, 1998).

Based on the hard and soft factors that impact the customers’ interactions and communications using the firm’s Web site, we identify four modes derived from the customers shopping time life-cycle experiences leading to the four modes namely; learning, monitoring, collaborating and distancing modes. A mode refers to the characteristics of a particular e-commerce customer relationship at any given moment in the life of the relationship and it represents a pattern of behavior reflecting the customers’ desire to improve predictability and reduce uncertainty in their relationship with the firm. The firm also monitors behaviors of their customers, assesses performance, identifies ways to improve their ECCRM strategies and adjusts their behaviors in order to retain and attract new customers.

Customers Shopping Time Life-Cycle Experiences and its Impact on ECCRM

The customers shopping time life-cycle experiences and its impact on ECCRM is based on the hard and soft factors reflected on the transactional and relational components of communication leading to the four modes, namely learning, monitoring, collaborating and distancing modes. ECCRM does not involve just the use of technology. It is a continual process and approach a firm takes toward its customers backed up by thoughtful investment in technology and business processes (Morrell & Philonenko, 2001). The firm monitors behaviors of their customers, assesses their shopping behaviors and identifies room for where the firm can improve, and adjusts in order to align it with their future intentions of their customers. The firm also focuses on the operations of their e-commerce system, to potentially reveal additional information about their needs and expectations of their customers (Dwyer, Schurr, & Oh, 1987). The communications the firm has with their customers will reflect their satisfaction and intentions to continue the e-commerce relationship. Previous research suggests that the quality of communication is related to satisfaction of the customers, intentions to continue a relationship, and a willingness to provide referrals (Dwyer et al., 1987; Morgan & Hunt, 1994; Sawhney & Zabin, 2002; Schurr & Ozanne, 1985). MacNeil (1981) acknowledges that honest and open lines of communication encourage continued growth and close ties between trading partners. The customers shopping time life-cycle experiences in ECCRM impacts both the hard and soft factors that are reflected in the transactional and relational components leading to the four modes discussed below.

Learning Mode

The learning mode in ECCRM occurs when the impact of the hard factors is low and the soft factors are high. Novice customers using the B2C firm’s Web-site experience a positive relationship with the firm (Vatanasombut, Stylianou, & Igbaria, 2004). During the initial stages of an e-commerce relationship, the firm encourages their customers to contact them via 1-800 call numbers and e-mail. The emphasis is on the relational component of communication and experiences the customers have with the firm and to what extent the firm will satisfy the customers’ learning curve in using their Web site. Because the B2C firm values the customers they will go out of their way to make additional investment in assuring that their customers are satisfied. The firm is tolerant of the initial mistakes made by their customers. The firm focuses on how to attract new customers and build customer relationships. By properly integrating the ECCRM systems the customers experience reduction in consumers search costs. Typically, the B2C firm will concentrate on negotiating and implementing technical security solutions so that their e-commerce system can provide speed, accuracy, privacy, and accountability, thereby reducing the customer acquisition/search costs. Furthermore, certain Web technologies such as search engines and intelligent agents directly reduce the customers' search costs by providing relevant information for consumer decision making at a much lower cost and time (Lager, 2005). The B2C firm will continue to attract sophisticated customers as the firm provides user friendly technical solutions in the form of security, privacy policy information, functionality of the Web site, warranty details and increase in both the ease and depth of navigation (Vatanasombut et al., 2004). It is essential for firms to offer online attractive promotions on their Web site backed with high-quality products and services in order to convert potential customers to actual sales. Therefore, we propose that *RH-1: The customers in a learning mode of an ECCRM are more likely to experience a positive relationship with the firm.*

Monitoring Mode

The monitoring mode in the ECCRM occurs when the impact of the hard factors is high and the soft factors are low. The situation occurs when the hard factors are not used in a proper manner by the customers in order to create a positive relationship. The emphasis is on the economic returns from the transactional components. Because the firm has confidence in the functionality of their e-commerce system, they increase the monitoring measures to their benefit and assess the performance of their customers. Novice customers who do not have sufficient experience with the Internet may feel comfortable and tend to use the Internet for simple tasks (Lager, 2005). Their concerns relate to the compatibility of the browsers, hardware/software, cookies, user friendliness of the Web site, and sometimes being unable to remember how to log onto the B2C Web site. Sophisticated customers on the other hand have a higher understanding of the Internet technology demand speed and timely information. Their concerns relate to search costs, timeliness and accuracy of information/transaction updates, system and transaction reliability, new features, Web site functionality and accurate, timely product information (Vatanasombut et al., 2004). The sophisticated customers who have become the firm's regular customers' may not purchase the firm's products and services if their concerns were not met. Therefore, we propose that: *RH-2: The customers in a monitoring mode in an EC-CRM are more likely to experience a negative relationship with the firm.*

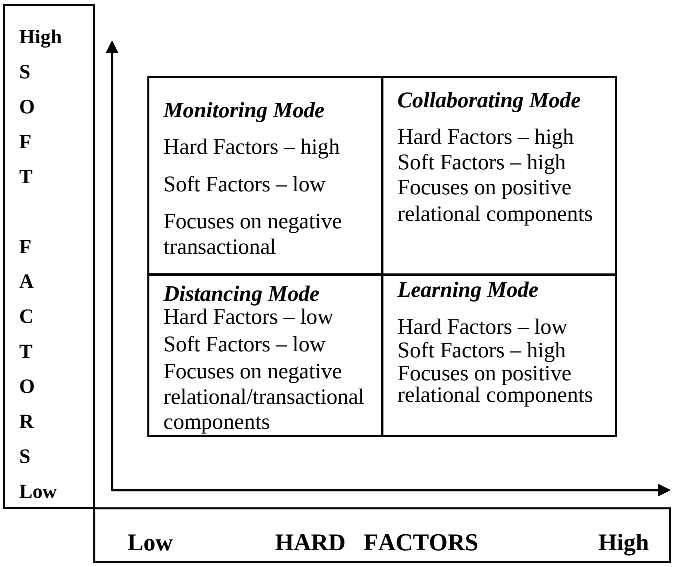
Collaborating Mode

The collaborating mode of the ECCRM occurs when the impact of both the hard and soft factors are high. The emphasis is on the relational component of the relationship between the customers and the firm. The customers experience cooperation, increased positive communications, trust satisfaction, and loyalty when interacting with the firm. Furthermore, the customers' positive experiences with the firm are associated with a willingness to recommend new customers derived from the reputation and image of the firm. Previous research suggests that there is a positive relationship between trust and commitment (Doney & Cannon, 1997; Ganesan, 1994; Lewicki & Bunker, 1996; Parasuraman, Zeithaml & Berry, 1985; Rousseau, Sitkin, Burt & Camerer, 1998). This, if reflected in current research, which suggests that ECCRM significantly impacts the level of trust of B2C e-commerce firms and their customers (Bunduchi, 2005). Trust can be achieved by providing customers with valuable information in a timely manner. According to Ganesan (1994), trust is the extent to which the customer believes that the vendor has intentions and motives that are beneficial to the customer. When customers trust a B2C e-commerce firm, they will share and communicate with the firm. Loyal customers are more tolerant when something goes wrong and are easier to satisfy because the B2C firms are aware of their customers' expectations (Gefen, 2002). Thus, loyal customers are satisfied and are more likely to continue shopping with the B2C firm thereby increasing both the number and/or frequency of purchases. Satisfaction with delivered products and services have been suggested and empirically documented as affecting the customers' intention to continue, thereby increasing the B2C firm's reputation. Therefore, we propose that *RH-3: The customers in a collaborating mode in an ECCRM are more likely to continue purchasing with the firm.*

Distancing Mode

The distancing mode in the ECCRM occurs when both the hard and soft factors are low. The customers perceive that the firm is not meeting their needs and are not keen to shop on their Web site. Because the customers lack confidence in the firm and their e-commerce system, they are more likely to encounter difficulties in trying to resolve issues and spending more time searching for their products and services. The customers lack trust and experience negative interactions with the firm. Most SMEs who conduct business over the Internet do not follow the robust technical, and security standards needed as they are challenged by financial resources, lower technical expertise, and limited management skills. They often do not have the time to gather customer information, which sometimes leads to poor decision making. The customers perceived the B2C firm to be untrustworthy, lacking quality service thereby leading to a negative image and poor reputation. The employees in a distancing mode wind up with reduced productivity and limited job satisfaction. The customers are inclined to distance themselves from this situation and are not willing to return to the Web site. The dissatisfaction of the customers' contributes to an inclination to withdraw from the firm. Previous studies suggest that customers are unlikely to purchase from a B2C e-commerce firm if they perceive their online experience is not

Figure 1. ECCRM research model



Monitoring Mode Hard Factors – high Soft Factors – low Focuses on negative transactional	***Collaborating Mode*** Hard Factors – high Soft Factors – high Focuses on positive relational components
Distancing Mode Hard Factors – low Soft Factors – low Focuses on negative relational/transactional components	***Learning Mode*** Hard Factors – low Soft Factors – high Focuses on positive relational components

sufficiently secured (Vatanasombut et al., 2004). Therefore, we propose that *RH-4: The customers in a distancing mode in an ECCRM are unlikely to continue shopping with the firm.*

RESEARCH MODEL

The ECCRM research model in Figure 1 illustrates the four modes and their impact on the both the hard and soft factors.

RESEARCH METHOD

An exploratory case study was chosen as an appropriate research method to examine ECCRM and the customers shopping time life-cycle experiences in a small business firm that engages in B2C e-commerce. The case study approach allowed us to ask *how-and-why* types of questions and enabled us to elicit subtle and rich data needed, thereby increasing our understanding of ECCRM. The questions pertaining to hard and soft factors were reflected in the transactional and relational components of communication leading to the four modes. This would be difficult if a survey research method was applied. We interviewed the manager of Firm A in the retail-marketing industry four times during the summer of 2007. Each interview lasted between 60 and 90 minutes. The manager is an IT consultant in the Institute of Entreprenurial Studies—Small Business Development Center at the University of Central Missouri, USA. Although two other employees did assist in providing us with relevant documents, the manager was the main person who contributed to the findings of this study. Evidence for the case study data was derived from the handwritten notes taken during the interviews and the tape recorded data. In addition, analysis of existing documents relating to ECCRM, day to day interactions, operating procedures, best business practices, and technical solutions were analyzed.

FINDINGS: BACKGROUND INFORMATION OF FIRM A

Firm A is an import export retail-marketing firm which conducts its business over the Internet. They sell unique accessories such as jewelry, artwork, handbags, and unique children books in Spanish and English. They cater to the needs of women, gay individuals, and young children in Spanish and African American communities. They have five full time employees, and their business transactions are conducted on their B2C Web site. They had at least 400 one-time purchase customers since they launched their Web site in 2001. Seventy percent of their customers are repeat customers today, and 90% of their customers are women whose ages vary between 30 and 50 years. Ten percent of their customers are men whose ages vary between 25 and 45 years. They come from all over the country in the United States and are average Internet users. They communicate frequently via e-mail, fax, 1-800 call centers, wireless phones, and a wireless LAN. They spent nearly $40,000 in initial IT implementation costs, and their annual IT maintenance cost varies between $4,000 and $5,000. The IT component of the Web site is transparent to the customers. Basically, customers browse the Web site, select the item they want, which then gets listed in their shopping cart. Once the shopping is complete, they hit *purchase*, and all the items in the shopping cart are listed on the sales receipt. Quickbooks is linked to Malsink, their shopping cart software. The shopping cart system allows their customers to place their orders and the bank to verify the credit of their customers. The customer is then charged the amount on his or her credit card. The system also automatically e-mails the customer and the firm acknowledging the order. Items are then shipped within 3 business days. Quickbooks is used to create the sales receipts issued to the customer. Inventory is controlled by Quickbooks as well. The Web site has databases that are linked to the product information. Firm A's business transactions include purchase order, e-mail acknowledgements, invoices, payment transactions, and delivery information. In the next section we report the findings of ECCRM on the four modes for Firm A.

Learning Mode

The learning mode in ECCRM occurs when the impact of the hard factors is low and the soft factors are high. The emphasis is on the transactional component of their e-commerce system focusing on how to attract new customers and building a relationship with the customers. The manager of Firm A commented that:

Our customers have shown a willingness to provide us information on what they need, and did provide support when we first implemented the B2C e-commerce Web site. Further, we trained our staff to exhibit care and concern to our customers when speaking on the telephone or via e-mail.

He went on to say that:

Although, initially, there were issues in the compatibility of the IT infrastructure and our e-commerce system, we relied on other forms of communication, such as the fax, telephone, and e-mail. We need to trust the customer keying in the data that the information is correct. The Web site enables us to log our customers so that we can contact them in the future.

The manager noted that:

Security was not a concern since the IT solutions were outsourced to an IS solution provider. We have a link that informs and describes our customers about the security features on our Web site. We used a third party trusting agency which prevents computer crimes and we adhere to the security principles.

The findings of the learning mode suggest the need for the firm to focus on the soft factors and facilitate the smooth flow of the transactional components. It was found that relying just on technology alone was not enough to build relationships as customers in the learning mode were keen to build credibility and trust in the firm that in turn motivated them to revisit the firm's Web site.

Monitoring Mode

The monitoring mode in the ECCRM occurs when the impact of the hard factors is high and the soft factors are low. The hard factors are not used in a proper manner thereby creating a negative relationship between the firm and their customers.

Firm A manager indicated that:

We have an account number assigned for each customer who shops on our Web site. All events are recorded against each order on a date/time basis, and memos are created and referenced/filed to each job for future reference, thereby enabling integrity of the business transactions and speed in the delivery process. This serves as a unique identifier thereby providing authentication. We believe that top management commitment is critical especially when it comes to investing in the e-commerce technical/security solution and search costs. Further, we undertake regular audit checks on our outcomes in order to manage risks.

The emphasis of the ECCRM is in the communications with the customers on identifying and resolving errors and delays. Conversations emphasize discussions on how to assure that the system performs correctly.

Of course, like any other new system we tried to simplify our business processes and provide a user friendly system for our customers. Initially there were errors, as both our employees and the customers had to learn to use Web site. There were customers e-mailing us on the functionality and errors they experienced when transacting on our Web site.

The findings of the monitoring mode suggest the need for the firm to focus on both the hard and soft factors that emphasized on the transactional and relational components of communication. It examines the customers shopping time life cycle experiences based on their ability to use the Web site correctly which will impact their intention to revisit the firm. This enabled the firm to identify their loyal and profitable customers versus the customers who have stopped shopping on their Web site.

Collaborating Mode

The collaborating mode of the ECCRM occurs when the impact of both the hard and soft factors are high. The emphasis is on the relational component of communication between the customers and the firm. The manager of Firm A indicated that:

Our employees were aware of the competitive market coverage and were confident in their capability in resolving standardized issues. The number of customers' visiting and shopping on our Web site has increased. When we first implemented e-commerce in 2001 we had between 30 to 40 regular customers, now after two years we have 300-400 regular customers and at least 4 new customers each month. Our main role is to establish the needs of our customers, and increase the variety of products and services we provide.

Firm A's manager also indicated that:

Positive feelings sometimes depend on whom you are speaking to, and can be a perception, which can change from one event to another. We are known to provide high quality products and services and our firm's image and reputation has contributed to an increase in our profits.

He added:

When you open a Web-site business, it is difficult for customers to know the firm size. Our customers thought that our business was big. A large image was impressive although in reality there were only five full time employees. The positive views, on our products, services, corporate initiatives and image, connected our customers on an emotional level as well as on an intellectual one.

The findings of the collaborating mode suggest the need for the firm to focus on the soft factors that enhances the relational components of communication and the customer shopping time life-cycle experiences. This will in turn increase the reputation and image of the firm thereby creating customer satisfaction and commitment of the customers to revisit the firm that in turn increased their profits.

Distancing Mode

The distancing mode in the ECCRM occurs when both the hard and soft factors are low. The customers do not perceive the B2C e-commerce firm to meet their needs.

Firm's A manager indicated that:

Although some of our customers were not novice customers, they continued to submit us incomplete purchase orders with errors. We had to spend a lot of time e-mailing and calling them back to explain the error. It created additional difficulties for us as we had to spend more time explaining the errors to our customers. Thus, a lack of positive behaviors demonstrated from the customers created a pattern and a situation of dissatisfaction. We used separate log-on procedures for these types of customers in order to ensure that different levels of service were provided to these customers.

The findings of the distancing mode suggest the need for the firm to focus on both the hard and soft factors exhibited by the customers that in turn impacted their transactional and relational components of communication. The firm experienced the need to spend unnecessary time on customers who were not abiding by the correct procedures that in turn created dissatisfaction for the firm and the customers.

DISCUSSION

The findings paved the way to some insights on the customers behaviors based on the impact of the hard and soft factors that were reflected in the transactional and relational components of communication leading to the four modes of the customers shopping time life-cycle experiences. The hard factors that reflected the emphasis on transactional components of communications were seen in the learning and monitoring modes, whereas the impact of the soft factors that reflected the emphasis on relational components of communications were seen in the collaborating and distancing modes. For example, while it takes time for a new customer to evolve from the learning mode to the collaboration mode the findings suggest that it may take only a couple of attempts for a customer to experience the distancing mode. We believe that the monitoring mode is the deciding stage for the customers whether to pursue the relationship with the firm leading to collaborating mode or to disband from the relationship leading to the distancing mode. Thus, each mode represents a broad reflection of the effect of both the transactional and relational components based on the hard and soft factors leading to relationship continuity. The findings suggest that although shopping online can be a simple process, firms must periodically survey their customers to determine the impact of their ECCRM solutions on customers attributes and behaviors. Based on these insights Firm A was able to identify their regular, profitable customers and customers who stopped shopping on their Web sites. Further the frequent communications with their customers via e-mail enabled Firm A to identify the needs, attitudes and behaviors of their customers thereby taking actions to increase their profit by meeting the needs of their customers.

CONCLUSION

This study expands upon the existing theory of ECCRM by explicitly considering the role of a B2C e-commerce firm in the context of CRM. The study contributes to theory as we suggest that the important characteristics of the hard and soft factors that are in turn reflected on the transactional and relational components of communication leading to the four modes of the customers shopping time life-cycle experiences. The hard factors that emphasized the transactional components focused on the outcomes of the exchange between the customers and their firms. Alternatively, soft factors that emphasized on the interpersonal relational components were characterized by conversations via the telephone and e-mail between the customers and the firm. At a simple level, we recognize that technology affects the transactional component and interactions between the customers and the firm. Technology provides a distinct basis for retaining customers that is separate from an assessment of the customers as it has an effect on profit. More importantly, we draw upon this expanded understanding over the *customers shopping time lif- cycle experiences* based on the impact of both the hard and soft factors that is reflected on the transactional and relational components of communication leading to the four different modes in ECCRM namely; learning, monitoring, collaborating and distancing modes.

This study contributes to theory as the ECCRM model provides a holistic view of the firm by simultaneously examining the customers shopping time life-cycle experiences and performances leading to the four modes. Further, the exploratory study contributes to practice as we discuss how firms that have adopted B2C e-commerce are likely to experience customers shopping time life-cycle experiences. Given that the model was tested as an exploratory study, future research should attempt to examine the ECCRM model via multiple case studies on how the hard and soft factors can impact the customers shopping time life-cycle experiences in ECCRM, thereby contributing to meaningful generalizations. We plan to pursue future research which aims to collect data from various stakeholders within and outside the firm. In conclusion, customer attraction and retention for B2C e-commerce firms remains a complex, elusive, yet extremely important phenomenon. The proliferation of the Internet has significantly threatened the ability of SMEs engaged in B2C e-commerce to retain their customers.

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Chapter 6.11

Extending Relationship Marketing to Human Resources Management Using the CaRM Approach to Personnel Recruitment

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INTRODUCTION

Since the early 1990s, relationship-oriented approaches to product and services marketing have gained increasing interest by research and practice. While the overall approach of managing customer interactions has been inherent to the ways of doing business ever since, the recent change from transaction-oriented to relationship-oriented marketing is typically considered as a major paradigm shift (Grönroos, 2004). The current boom of customer relationship management concepts and solutions is only one indicator of this development. However, while relationship marketing has been discussed in various contexts such as business-to-business and business-to-consumer marketing, little attention so far has been paid to the question of what such an approach could add to the human resources field. This is astonishing as labor markets due to demographic effects and other changes in labor offer and demand tend to get increasingly narrow. Thus, traditional approaches to personnel marketing might no longer be sufficient and new concepts for the successful recruitment of qualified staff might be needed. Therefore, our research question is: How can we transfer the concepts of relationship marketing to personnel recruitment and what are potential benefits of such an approach? In order to answer this question, we present an approach for the IS-supported management of employer-candidate relationships. We outline two major dimensions of the approach together with selected validation results. The objective is to enhance human resources information systems (HRIS) research and to present an approach that could potentially assist employers in better facing mid-term shortages of qualified staff on a drastically changing labor market.

BACKGROUND

Information technology in recent years has drastically changed the human resources function. Providing support for mainly administrative activities such as payroll and attendance management at the beginning, the past decade has been characterized by an increased usage of information technology for the attraction of qualified staff as well as for the generation and the processing of applications. Online job ads on corporate websites or internet job boards, online CV databases, e-mail and form-based applications and applicant management systems are only few examples of this trend. While this development is assumed to provide employers with means to attract large volumes of candidates at low cost (Lievens & Harris, 2003), it has also increased the complexity within the recruitment function as job seekers show different propensities to use online information and application channels. Thus, for recruiters it has become more difficult to determine which channel to choose for the posting of a specific vacancy and what application channels to promote for the different target groups. To choose an unsuited personnel marketing channel for the posting of a job ad or restricting application channels to channels that are not preferred by the target group might limit the number of incoming applications and thus lower the possibilities of successfully recruiting a candidate coming as close as possible to the defined target profile. Posting a job ad in several or too many channels and offering a wide range or too many application channels, in turn, might result in such masses of incoming applications that a rapid identification, selection and hiring of the most suited candidate might be hindered, too. As a result, a deep understanding of the each specific target group and of the respective candidates' preferences is needed in order to assure an efficient recruitment process leading to the successful employment of a suited applicant.

In parallel to this development classical marketing in the past decade has seen a shift from a transaction- to a relationship-oriented marketing approach with customer relationship management (CRM) being only one example of this paradigm shift. By creating and actively managing long-lasting customer relationships and analyzing customer data supported by information systems, this approach has been shown to substantially increase companies' profitability (Wilson, Daniel, & McDonald, 2002). Typically, customer relationship management is separated into strategy-, process- and systems-oriented approaches. While strategy-centered approaches consider CRM as a customer-focused concept of the enterprise with the objective of identifying, winning and retaining customers (Wilson et al., 2002), the process-oriented perspective aims at analyzing and improving all processes and activities related to the interaction and contact with the customer (Schmid, Bach, & Österle, 2000). Systems-oriented approaches to CRM, finally, see an integrated information system as the basis for successful customer retention (Ryals & Payne, 2001). A common element, however, often lies in the fact that CRM is considered as a closed loop in which a company dynamically learns from its interactions with its customers and feeds this information back into the future management of its customer relationships (Selnes & Sallis, 2003; Zikmund, McLeod, & Gilbert, 2003). A customer segment in this context is considered as a group of customers that within the group are highly homogeneous but as much heterogeneous from other segments as possible. This process of customer segmentation serves at reducing the complexity in customer interactions by designing the marketing measures on the segment- and not on the customer-level (Wilson et al., 2002).

In addition to these distinctions, Hippner et al. (2004) in their work separate two major dimensions of a CRM system. These are the operational and the analytical customer relationship management. Operational CRM represents all activities dealing with the management of the customer contact. As an important element in this context lies in the integration of the various customer interaction channels and of the information transported over these channels, operational CRM is also referred to as communicative or cooperative CRM (Alt, Puschmann, & Österle, 2005; Chamoni, Düsing, & Stock, 2004). An additional activity within operational CRM is represented by the implementation of the insights gained from the analytical CRM with regard to the different customer segments' needs concerning marketing, sales and other related services. Different authors with regard to these activities have suggested different forms of IS-support. Hippner et al. (2004) and Berchtenbreiter (2004), for example, suggested supporting operational CRM by means of a content management system in order to represent the unstructured information that typically arises from the interactions with customers. Also, different software modules have been suggested to support front office activities thus allowing for marketing automation (Engelbrecht, Hippner, & Wilde, 2004; Schumacher & Meyer, 2003), sales automation (Winkelmann, 2004), and service automation (Schöler, 2004).

In separation from the operational CRM concept, analytical CRM deals with the analysis and mining of customer data in order to enable an improved operational CRM. Various kinds of data are cited in literature as being suited for such approaches. These data should be stored in an integrated data warehouse that serves as a basis for different retrieval and analysis tools (Alt et al., 2005). One means to analyze such data is online analytical processing (OLAP) that allows for the analysis of relevant indicators according to criteria previously known or defined (Gallegos, 1999). A typical example is the analysis of a company's turnover according to different products, regions or periods of time. Different data operations or manipulations provide different perspectives on the resulting data cube (e.g. by shifting between levels of aggregation). However, OLAP is not suited for the exploration of data as it assumes that the user is able to specify the dimensions of analysis in advance. This shortcoming is addressed by data mining methods that allow for the recognition of patterns or unknown interrelations within a given data set (Schumacher et al., 2003). Different methods such as data classification, regression, cluster analysis, and others support the extraction of information from the data stored (Chamoni et al., 2004). However, careful attention needs to be paid to the fact that some causalities might be extracted erroneously due to accidental patterns within the data; a situation that can be prevented by integrating theoretical or statistical considerations prior to the analysis (Schröder, 2002).

THE CaRM APPROACH TO RECRUITMENT

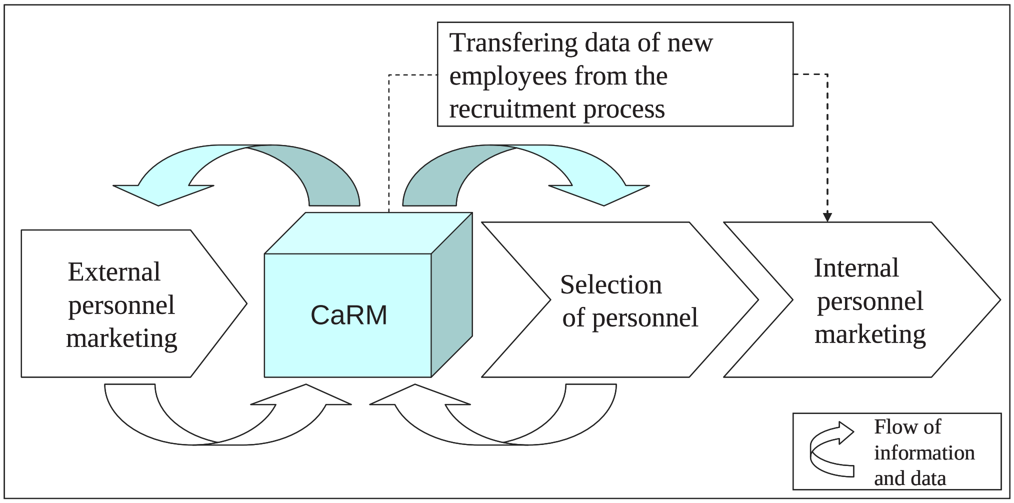
In analogy to these considerations, we designed a framework for a relationship management approach to personnel recruitment. We refer to this framework as the *Ca*ndidate *R*elationship *M*anagement or *CaRM* approach. We argue that conflating relationship marketing and personnel marketing might assist companies in facing the challenges of an increasingly competitive labor market. Of course, one could oppose that an applicant cannot be compared to a "repeat customer" or that many employers even prevent their candidates from "repeated" interactions (e.g., by sending multiple applications for the same position at different points in time or for several different positions at a single point in time). While this is certainly true, we consider the process of transforming external people into candidates and then into applicants as a relationship that is worth being managed. Also, as scarcities of different skill sets emerge on the labor market companies will be obliged to more frequently implement long-term approaches to the recruitment of highly qualified candidates for strategic positions. Finally, from the previous considerations on the increased complexity in personnel recruitment it has become clear that employers need to establish approaches that lead to a better understanding of the behavior and the preferences of their different target groups.

It is for these reasons that we consider the fusion of relationship marketing and personnel marketing as a promising goal. However, the CaRM approach is not limited to personnel marketing. It rather represents an approach that impacts the entire recruitment function and not solely the candidate attraction phase. By segmenting candidates according to their job search behavior as well as their informational needs and by systematically mining applicant data, we aim to provide the basis for a learning loop bridging personnel attraction and selection. Therefore, as depicted in Figure 1 below the CaRM approach is positioned right at the core of the recruitment function between the candidate attraction and the applicant selection stages.

Similar to customer relationship management, capturing and storing all relevant data within a single information system is critical to our CaRM approach. Therefore, we suggest enriching the candidate data provided as part of the application process by complementary data such as demographic and psychographic data and also by systemically capturing the data emerging from the interaction between an employer and its candidates. As employees dealing with personnel marketing, applicant screening and personnel selection are engaged in this process, HR experts and employees from specialized departments are in charge of gathering data. This is why the CaRM approach potentially impacts any employee involved in the recruitment process and not only the experts in charge of personnel marketing.

Once the relevant data are stored in the system, we in line with the above considerations sug-

Figure 1. The CaRM approach

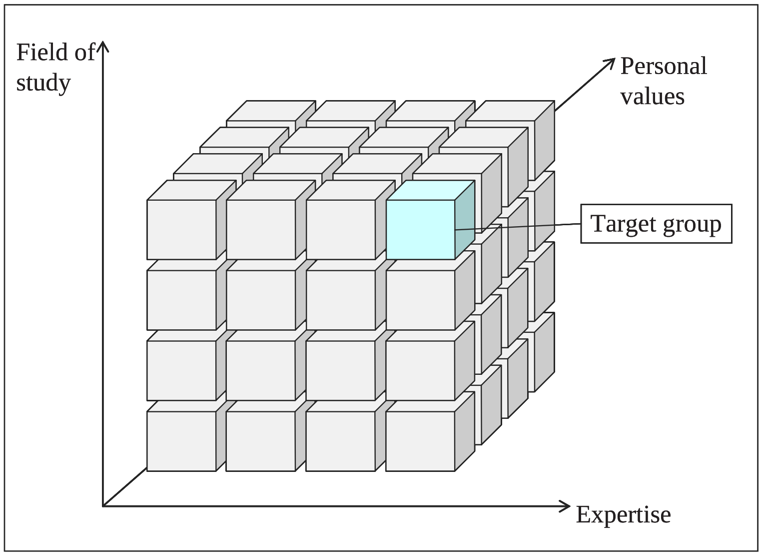


gest separating an operational and an analytical approach to the relationship management with candidates. While the operational CaRM supports activities such as the definition and implementation of the recruitment and application channel strategy for a specific candidate segment, the analytical CaRM provides the necessary information for these activities from the systematic analysis of the candidate data by means of OLAP and data mining methods. Figure 2 illustrates a sample data cube for candidate data.

In order to validate the approach, we carried out a survey with over 10,000 Internet job seekers. Data were generated in 2005 by means of a questionnaire publicly available on the internet. The questionnaire was promoted by means of e-mails, banners, and press releases. While the entire validation activities are out of scope of this article, we at least want to outline selected results from this research. The entire results from the survey can be found in Keim, König, Weitzel, Fritsch, and von Westarp (2005a).

In order to validate the approach, we used an online questionnaire containing 32 questions on the information and application channels currently used by job seekers in their job search activities. As part of the questionnaire, participants were provided with two sets of items concerning their personal values and their job or employer requirements. This list was adapted from Kirchgeorg and Lorbeer (2002). Following the data collection, we analyzed our survey data. In a first step, we considered our data on an aggregated level only. Then, we analyzed the data as part of an approach comparable to the above OLAP approach. We segmented our data according to three candidate segments being the candidates' career level, their field of studies and their occupational group. The analysis revealed that we were indeed able to identify interesting differences in the candidates' information and application behavior. Finally, in an attempt of data mining we clustered the candidates according to their personal values and job requirements. Similarly to Kirchgeorg et al. (2002), we were able to cluster our participants according to their personal values as well as their job requirements and to reveal interrelations between these clusters.

Figure 2. Sample OLAP data cube for candidate data



Despite the fact that many employers today might not feel to be in a position to capture candidates' personal values and employer requirements at the application stage, the results show that the overall CaRM approach and its methods are consistent and applicable. Also, the results already at this stage prove to be insightful for many HR experts desiring to understand the behavior of their target groups as well as the success or failure of their personnel marketing measures.

FUTURE TRENDS

Anticipating further future trends is difficult as we consider already the CaRM approach as one such potential future trend. As companies increasingly adopt applicant management systems, they in our eyes move one step toward the operational management of candidate relationships. Also, the adoption of company internal databases containing high volumes of candidate profiles provides the basis for an analytical processing of these data (e.g., see Keim, Malinowski, and Weitzel (2005b) or Keim and Weitzel (within this Encyclopedia) for the underlying adoption issues). Thus, from an adoption perspective we see strong arguments supporting the CaRM approach. Furthermore, we regard the development of IS support for personnel selection and team staffing as a major future challenge. We are convinced that such decision support will be a major element of a potential future analytical support for the recruitment function. First approaches to such decision support can be found in Malinowski, Keim, Wendt, and Weitzel (2005). Even the clustering approach previously presented could potentially be considered as such an approach as companies might want to define and recruit certain profile types from a specific subset of the data cube. Finally, the CaRM approach not necessarily needs to be limited to external candidates or applicants. We anticipate further potential in extending the approach to a company's current employees and thus by linking CaRM to the personnel development field.

CONCLUSION

In this article, we presented an approach transferring relationship marketing to the personnel recruitment field. We identified the operational and the analytical management of relationships with candidates as major dimensions of our CaRM approach. While the operational CaRM covers all aspects dealing with the direct contact between the candidate and the employer (e.g., the selection of targeted recruitment channels and instruments or the management of service-related processes and applicant touch points, the analytical CaRM comprises the systematic analysis of candidate data through data mining and OLAP methods). In order to implement such activities, companies need to pay special attention to three major and highly interrelated challenges. These are the capturing of comprehensive candidate data together with their storage in a single software system, the precise planning of operational and analytical measures and the careful implementation and analysis of these measures. Overall, a relationship-oriented approach to managing candidate relationships to us seems a promising path for any employer anticipating the future challenges of an increasingly narrow labor market.

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KEY TERMS

Applicant: A person that has actively applied for a job within a specific company either by means of an application submitted for a specific job or by means of an unsolicited application. Therefore, an *applicant* can be separated from a *job seeker* by the fact that he or she has already progressed to a later stage of the job search process (e.g., from the sole search for information to the application action).

Candidate: A person that has applied for a job or that has been actively identified by the employer and that is considered relevant for a specific vacancy. Thus, not every applicant is necessarily regarded a candidate.

Candidate Relationship Management (CaRM): A candidate-centered approach to personnel marketing and even broader personal management that uses an integrated HRIS for capturing, storing and analyzing candidate data in order to enhance the cross-medial attraction, recruitment, and retention of candidates.

Candidate Relationship Management (CaRM), Analytical: Those activities within CaRM that systematically capture and store candidate data in a data warehouse to analyze them through methods of data mining and on-line analytical processing (OLAP) and, thus, to continuously increase the effectiveness of the recruitment activities.

Candidate Relationship Management (CaRM), Operational: Those activities within CaRM that deal with managing the direct contact and interaction with the candidates (e.g., applicant touch point management and the provision of other related services).

Employer Branding: Those activities within the long-term personnel marketing that aim at pro-actively positioning an employer as an employer of choice among its key target groups. Typically, such activities include image advertisements in various channels or media. Recently, however, employers have also begun to analyze the positioning of their employer brand by questioning their internal and external target groups to derive empirically grounded employer messages. Whilst the perception of employer and corporate brand may diverge, the employer brand needs to be positioned in consistency with the company's corporate brand and, further, in distinction from competition's employer brand on the labor market.

Personnel Attraction: Any activity within personnel marketing that aims at recruiting a candidate for a concrete vacancy in the short- or mid-term (e.g., either by posting job ads in one or more online or off-line recruitment channels or by actively identifying and contacting candidates in CV databases or by any other suited measure).

Personnel Marketing, Cross-Medial: Any measure aiming at recruiting qualified staff in the short-, mid-, or long-term. Therefore, the long-term personnel marketing or *employer branding* is separated from the short-term personnel marketing or *personnel attraction*. We refer to cross-medial personnel marketing as an approach that integrates different personnel marketing channels (Internet job boards, career sections of corporate Web-sites, print media, events, executive searchers) and application channels (Web forms, e-mail, paper-based) and adapts these channels so that a streamlined job search process for each of the target groups addressed is assured.

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Chapter 6.12

Approaches and Concepts to Restructuring Human Resources Management Functions

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INTRODUCTION

Nowadays, most human resources (HR) managers are confronted with cost pressure, the demand for offering "high-quality-HR services" and the necessity for strategic contributions (Hewitt, 2004). Human resource management (HRM) with its current structures and tools is often unable to completely fulfill these requirements. Therefore, a strong need for reorganization of HR as a function is obvious. In the last few years, many efforts have been undertaken by HRM practitioners to re-structure HRM at the level of organizations as reflected in surveys or case studies from leading firms. Examples can be found in Som (2003) and Fairbain (2005). Moreover, the restructuring of the HR function has been the subject of a broad discussion among scientists and researchers in the field of management (Becker & Huselid, 1999; Caldwell, 2003, 2004; Truss, Gratton, Hope-Hailey, Stiles, & Zaleska, 2002). It is remarkable that this discussion has mainly focused on the strategic role of HRM (Lawler III, 2005), and consultants in the practical field have particularly given advice to improve the quality of HR services (Hewitt, 2004; Towers Perrin, 2005). A more complex view on the restructuring of HRM is rarely to be found.

BACKGROUND

Organizations often prefer an easy way of re-organization by simply cutting HRM costs. As

Capelli (2005) has stated when companies were downsizing, human resource functions capabilities were the first thing cut.

But, what does Restructuring of HRM functions imply?

Restructuring of HRM functions describes a more or less radical modification of roles, tasks and structures in all HR-related practices, like recruitment, placement, payment, development of human resources, and in structures and processes of the HR departments, and their co-operation with the top management, line managers, HR consultants, HR service providers, and employee representatives.

Starting from this broad view, it can be stated, that restructuring of the HRM function have to be seen as a normal part of its development. A view on the history of HRM reveals that at every developmental stage, specific roles, and tasks, and, moreover, a specific focus on restructuring of HR functions within each stage can be found (see Table 1).

The further text will focus especially on the ongoing development (i.e., the stage in which HRM acts as a "strategic business partner"). This stage can be identified in the extent to which newly structured HR departments and a new division of labor between HR-departments, line managers, and internal or external providers of HR services have been implemented.

The current reputation of HRM has been built generally upon excellent services and consulting processes as represented in stage 3. Now HRM is being increasingly asked for strategic contributions (Cascio, 2005; Lawler III, 2005; Ulrich & Brockbank, 2005). This article focuses on the "link" between the current reputations while focusing on the future role of HR.

Here, a framework will be introduced to enable an interdisciplinary and more complex approach on HR restructuring (see Table 3). It includes drivers, barriers, objects, pathways, and results

Table 1. Historical development of HRM (on the basis of Cascio, 2005)

Stages of the development of HRM	**Time period**	**Relevant tasks**	**Role**	**Focus of restructuring within the stage**
(1) HR-Partial/File-Administration ("File-maintance")	until mid of 1960s	Fulfillment of management information needs	Personnel Office	Focus on restructuring of HR data base
(2) HR-Full-Administration "Government accountability"	from the mid of 1960s until mid of 1980s	Compliance with legal & tax rules, fulfillment of administrative and legally mandated tasks	Personnel Administration	Focus on optimal, legal handling of a full range of administrative tasks, development of HR departmental structures
(3) HR Professionalization ("Organizational accountability"	in the 1980s and 1990s	Accountability for success (in single business units), effective use of HR-Tools (recruitment, development, etc.) for business success	Personnel Management	Focus on increasing professionalization of the HR departments, development of services and tools, optimizing the cooperation with other HR partners
(4) HR Strategic Integration ("Strategic business partner")	start in the late 1990s, ongoing development	"Add value to the business" (Cascio, 2005). Contributions with strategic impact, participative developed organizational strategy (strategic partnership)	Business partner and role sets, for example Ulrich (1997, 1998) and Lawler III & Mohrman (2003)	Focus on outsourcing, enabling of line managers to do HRM, inclusion of new fields (e.g., knowledge management, cultural development, creation of a new model of cooperation between HR partners)

Table 2. HRM functions and target groups

Groups of HRM functions	Target Groups
Strategic functions	Top-Management, Specific groups (high potentials, young managers)
Consulting functions	Line Managers and Employees
Service functions	All Employees

Table 3. Framework: Restructuring of HRM functions

Drivers
Globalization Need for Flexibility Intangibles Stakeholder demands IT-Technologies

Groups of HR functions	Objects of change	Pathways of change	**Results** (with sources)
Strategic Functions	Contributions to organizational success, Abilities, Skills, Values of HRM, Structures, Tasks, Activities, Tools, Quality, Costs	Change Management, Assignment of consultants, Improvement of service quality and delivery, Division of tasks, centralization, Cooperation (internal/external), Outsourcing, Cost cutting, Measurement of progress, Use of own concepts Self led/organized, Line manager responsibility, IT based services	Strategic contributions and takeover of strategic role (Cascio 2005; Lawler III et al., 2003; Ulrich. 1997, 1998) or role as strategic player (Ulrich & Beatty, 2001), support of organizational effectiveness (Lawler III, 2005), cultural change (Fairbain, 2005) or the change of mental methods (Pfeffer, 2005), "HR as key contributor to strategy planning" (Lawler III et al., 2004, p. 33)
Consulting (Consultancy Services)			Support of managers by realization of their business plans (Lawler III et al., 2003), new division of tasks--line-manager operate HRM tasks (Larsen & Brewster, 2003), the improvement of internal consultancy processes partly by means of modern HRIS, creating of HR policies (Lawler et al., 2004) or better consulting quality (Towers Perrin, 2005)
Services (Transactional services)			Centralization of transactional tasks/processes, implementation of Shared Services Centers (Bergeron, 2002; Lawler et al., 2004), specialized HR Shared Service Center, Outsourcing of transactional and consulting processes (Lawler & Mohrmann, 2003, Lawler et al., 2004) to new employee services companies (single HR service providers, consultants, employment services, and firms offering a full service in HRM), cost savings long/medium term (Towers Perrin, 2005), new vendor/ relationship management (Graddick-Weir, 2005)

Barriers
No sufficient abilities and skills for restructuring, Lack of available resources and tools, Divergent stake-holder interests, Quality externally provided solutions in HR consultancy and service conflicting interests in top management

as well as success factors and perspectives of restructuring of HRM function.

FRAMEWORK FOR RESTRUCTURING OF HRM FUNCTIONS

All activities of HRM restructuring must be aligned on the realization of the organizational strategy[1]. To differentiate activities, the framework is based on the different possibilities of HR to contribute to organizational success. It is proposed to use the widely known role set by Ulrich (as shown in 1997, 1998, and 2001) and to apply the concept of corporate value chain (Porter, 1985) to HRM (Becker, 2001). Taking this into account, three *relevant groups of HR functions* can be identified.

1. **Strategic functions:** Main objective is better strategy orientation of HR with the focus on strategic contributions. From this point, the corporate strategy should be defined collaboratively with HRM as a strategic partner (Broadly discussed by Ulrich & Brockbank (2001), Robinson & Robinson (2005) and Lawler III, Ulrich, Fitz-Enz, and Malden (2004)).
2. **Consulting functions:** Main objective is a stronger value orientation with the focus on value creation through HR activities. The relevant functions can be realized through professional consulting of line managers and employees by HRM and through facilitating and coaching line managers. These tasks were described by Ulrich (1997, 1998) as tasks of HR as a business partner.
3. **Service functions:** HRM contributes to cost reduction and proves its own efficiency. Main objective is here an improvement of service orientation with the focus on transactional processes or operational excellence. The potential to realize theses processes technically is very high. Actual examples are ESS and MSS, which allow employees/managers to do parts of HRM by themselves. These could be realized technically by human resources information systems (HRIS).

The potential for value creation is much higher by means of strategic functions as by means of administrative functions. The three groups of HR functions correspond with the three future HR product lines as defined by Lawler III et al. (2003). Moreover, different target groups could be addressed.

The drivers and barriers, objects, pathways and results of the ongoing HRM restructuring have to be seen as having a specific impact on these groups of HRM functions in order to achieve the planned service level, to create the planned value or to reach a specific strategic contribution.

Drivers of HRM Restructuring

Drivers of HRM restructuring are closely connected with the development in the corporate environment. These factors include current trends in the environment with more or less influence on the enterprises as

- **Implications of globalization**. Globalization leads to the development of supranational relation between people, falling relevance of physical locations, complex international supply links with deep effects on organizational culture and working practices as well as mergers, acquisitions, divestures change traditional structures dramatically.
- **Increasing requirements on flexibility and mobility of Human Resources**. Lifetime employment and seniority-based systems are no longer in use; due to rapidly changing market conditions actual topics are contingent work, independent contracting, and more free-market arrangements (Capelli, 2005).

- **Arising role of stakeholder issues**. Stakeholders like investors, customers, employees and their respective expectations play an increasing role for the success of restructuring processes. HRM must increasingly align its practices with the requirements of stakeholders (Lawler III et al., 2004, Ulrich et al., 2005).
- **Importance of highly committed employees and the knowledge of employees as intangible assets**. HRM must meet the relevant business demands (IBM, 2005) and the expectations of employees according to the specific business situation. Role of leadership and personal involvement as well as coaching and facilitating for the long-time commitment and retention of employees is evident.
- **Information and communication technology enable the permanent use and deployment of actual workforce information for HRM**. In 2001 Walker present technologies, which had been used for restructured HRM (elements of HRIS like work flow, manager and employee self services, interactive voice response, HR Service Center, HRIS and databases, stand-alone HR-systems such as data-marts and data-warehouses).

Barriers of HRM Restructuring

Barriers can be divided into personal, organizational, and resource related barriers. Personal barriers can be seen in lacking abilities and skills for restructuring of the concerned persons, e.g. HR manager, or responsible management staff. Organizational barriers are closely connected with interests and support of the top management teams, and other stakeholders; divergent interests may have a negative influence on the restructuring process. Moreover, lack of resources and change management tools can be seen as barriers. Last but not least, a minor quality of externally provided solutions of HR consultancy and services will have a limitation effect on an outsourcing oriented restructuring.

Objects and Pathways of Changes in HRM Functions

The changes in HR functions are targeted at the various contributions of HRM activities to organizational value creation and success, but include the skills of HRM, the structures, the tasks and activities, the used tools, but also the quality of the offered contributions, and the respective costs. They are objects of changes following different pathways.

The significant failure rate of corporate restructuring underlines the need of concept-based restructuring (amongst others Beer & Nohria, 2000). The following deficiencies are known: No clearly defined roles, no ongoing measurement of success, and no systematic application of modern tools. Noticeable is the absence of complex practical concepts (see recommendations in Hewitt (2004) and Towers Perrin (2005)).

Pathways of HRM restructuring mainly comprises:

- **Use of concepts and experiences/measurement:** The usage of new management concepts like process management, or blue prints with role and process models is often recommended. Experiences show that restructurings start regular with the **centralization of transactional tasks**. Design of the HR department is often process oriented and follows the groups of functions (transactional, consultancy and strategic processes = shared services, consultancy services and centers of expertise) and includes **outsourcing** of tasks. Objectives of restructuring (e.g., **improvement of service quality and delivery** or simple **cost cutting**, are permanently measured). Performance measurement for HRM seems to be one important way for restructuring HRM.

- **Change Management:** Restructuring of HRM is often planned and organized as specific change process and is based on **IT based remodeling** of HR-processes. Roles and responsibilities are more or less clearly defined. The shift of tasks to **line management** leads to a new shape of HRM. As a result of task centralization, outsourcing and line manager responsibility, the re-arrangement of **internal and external cooperation** marks another pathway or restructuring.
- **Self organized or self-led:** Restructuring of HRM is managed by HRM themselves (Som, 2003). By their opinions and their behavior, HR executives can effectively promote or impede restructuring. If the HR executives are not being gained as change agents, restructuring starts with a change of management. Often companies use **assignment of consultants** for the preparation of restructuring of HRM.

Actual Status and Success Factors

At the moment, it must be considered that most companies are at the beginning of restructuring the HR function (Towers Perrin, 2005). The previously mentioned pathways can be mainly found in large organizations.

A precondition for successful restructuring is the definition of the future role of HRM. The advanced role set (see Lawler III et al., 2004, p. 23; Ulrich, 2001/2005) should be considered. These new roles include on the one hand new roles for HR professionals as business strategist, coach, designer and deliverer, facilitator, and on the other hand, three roles as manager, business and strategic partner (Lawler III et al., 2004, p. 23-42). That means upcoming different contributions to organizational value creation.

First experiences of HRM restructurings show the following groups of success factors:

- **Cost handling and expectancies:** It seems that cost savings in transactional processes through HR outsourcing are possible, but only in a medium and long-term perspective (Towers Perrin, 2005). Costs are not the only reason for outsourcing of HR services; other considerations as service quality and accessibility to the latest technology are important too - a single focus on cost can sub-optimize the efforts (Lawler et al., 2004).
- **Quality of services:** The quality of transactional and consultancy HR services--often internally or externally realized by means of HRIS--must secured permanently, because success of HRIS and HRM in the field of administration and consulting are closely connected (Becker et al., 1999, p. 295; Lawler et al., 2004, p. 32).
- **Cooperation with external providers:** If HR processes are outsourced HRM have to manage the cooperation with external providers effectively. Only HRM could define and assess the service delivery level of HR services. The long-term success depends on the company-vendor relationship (Towers Perrin, 2005).
- **Importance of strong management:** A strong management of HR restructuring is necessary to meet the expectancies of stakeholders (Ulrich et al., 2005) as well as to reach the own objectives. Ongoing strategic contributions by HRM are expected. That means that companies have to design and retain expertise in relevant HRM fields. If they lose expertise, they will be unable to take strategic tasks (Som, 2003, p. 286).
- **Measurement of own restructuring:** Specific metrics can be seen as a fundamental basis for a successful restructuring. A professionalized HRM is able to do this task effectively. Without an accurate measurement, it may impossible to determine how successful the restructuring of HRM will

be (Hewitt, 2004), which will consequently lead to problems with the legitimacy of HRM activities.

FUTURE TRENDS

Restructured HRM increasingly and systematically influences leadership processes, organizational culture, and organizational effectiveness, especially by means of new management tools - which are developed, introduced, and controlled by HRM.

The ongoing outsourcing of transactional HR-processes will cover other HR-processes like recruitment and consulting processes, as shown for recruitment processes (Sommer, Brauner, & Simon, 2005). HRM must furthermore develop its own strategic competence to be able to give performance related contributions to realization of the corporate strategy with main fields in change management, intangibles, and new organizational capabilities.

Furthermore HRM measures and developments have to be based definitely on a HRM own operational model ("Value chain") as well as an own value base. That means the overall "Values" of HRM: Visibility, credibility, responsibility, and accountability will be more important. Future HRM must be based, developed, and measured increasingly on these basic values.

CONCLUSION

The linkage between HRM systems and company performance is evident (for further descriptions see Bowen & Ostroff, 2004, Pfeffer, 2005) characterizes the tasks of HRM more comprehensively as "important keepers and analysts of an organization's culture." Furthermore HRM has proved to be a key source of organizational effectiveness - organizational design, change management etc. (Lawler et al., 2004, p. 39-40; Lawler, 2005). In order to effectively manage the HR function, HR management needs to measure and report a broad range of indicators (Hewitt, 2004; Saratoga Institute, 2006).

A successful restructuring of the HRM function will support a fundamental change from service oriented personnel administration to strategy focused HRM. The quality of restructuring of HRM function builds therefore the basis for the future role of HRM.

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KEY TERMS

Consulting Functions/HR Consultancy Services: HRM is accepted as business partner and key part of the management team. It provides services and tools that enable line managers to do HRM by themselves. HRM also provides coaching and knowledge support in the area of people development and other HRM subjects.

Delivery Models: Approach for restructuring of HRM. Applying of business principles to HRM, HR can be organized along lines of business principle, focusing on different activities and deliverables like service delivery, policy expertise & consulting processes ownership, business partnership.

Employee Self Services (ESS)/Manager Self Service (MSS): Employees are able to view company and personal information. They could change individual information, put in employment related enquiries, apply for new jobs internally, or book measures of HR development. Managers have access to specific applications, which enable them to retrieve information on HR issues (policies, manuals, plans, strategies etc). Managers are allowed to run scenarios to salary increases, personnel costs, skill development etc.

HR BPO (Human Resources Business Process Outsourcing): HR BPO occurs when an organization outsource specific HRM tasks, or processes to a vendor. One actual example is recruitment process outsourcing (RPO), which means outsourcing of all recruiting relevant processes to a (specialized) provider.

HR Center of Expertise: Provides high-quality services with strategic impact, like competency & knowledge development. This Center provides strategic value by experts, who can redesign HR related processes and are able to develop and implement new HR policies. The Center also ensures that all HR practices are strictly aligned with corporate strategy.

HR Shared Service Center: Centralization of HR processes in one entity. Enables companies to achieve economies of scale by establishing a separate entity within the company to perform HR services (payroll, payments of benefits, and other transactional services like travel and expense processing).

Human Resource Management (HRM): Involves all management decisions and actions that aim at gaining competitive advantage by using its human resources effectively. These include providing of capable, flexible, and committed people, managing and rewarding their performance and developing relevant competencies. HRM runs HR practices like recruiting, retention, development, and use of human resources. HRM is often realized by specific HR-departments.

Service Functions of HRM: HRM has to deliver HR services efficiently. It could be measured on customer/employee satisfaction and costs. These services are mainly transactional services (like payroll/benefits). At present many large companies have centralized (HR shared service center) or outsourced transactional services.

Strategic Functions of HRM: HRM is an important strategic partner of the top management and key contributor to strategic planning and implementation as well as change management. HRM must give impulses for value creation (strategic HR programs, talent development).

ENDNOTE

[1] We are aware of the fact that this claim is normative, as a lot of stage models of HRM growth.

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Section VII

Critical Issues

This section addresses conceptual and theoretical issues related to the field of strategic information systems, which include failures and successes in system implementation. Within these chapters, the reader is presented with analysis of the most current and relevant conceptual inquires within this growing field of study. Particular chapters also address service quality in supply chain management, petri nets, and privacy and security in customer relationship management. Overall, contributions within this section ask unique, often theoretical questions related to the study of strategic information systems and, more often than not, conclude that solutions are both numerous and contradictory.

Chapter 7.1

Information System Development Failure and Complexity:

A Case Study

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ABSTRACT

This chapter examines the causes of failure in a Web-based information system development project and finds out how complexity can lead a project towards failure. Learning from an Information System Development Project (ISDP) failure plays a key role in the long-term success of any organization desirous of continuous improvement via evaluation and monitoring of its information systems (IS) development efforts. This study reports on a seemingly simple (but only deceptively so) failed ISDP to inform the reader about the various complexities involved in ISDPs in general, and in developing countries in particular. An existing framework from contemporary research is adopted to map the complexities found in the project under study and the critical areas, which lead to the decreased reliability and failure in Web-based information system development, are highlighted.

INTRODUCTION

Information and Communication Technologies (ICTs) are globally recognized as an enabler of economic and social growth, and Information

Systems (IS) can play a key role in accelerated growth and development if applied properly. In the developing countries, there is much talk of "development leapfrogging" by deployment of Information and Communication Technologies (ICT). Developing countries are making direct deployment of the latest technologies, techniques, and methodologies for the use of information systems without the step-by-step use of previous technologies already abandoned in the Western-developed countries. In this scenario, most development efforts in the field of Information Systems are overshadowed by organizational dissatisfaction and schedule and cost overruns resulting in project abandonment and failure. The following quote from a UN report (Gilhooly, 2005, p. 25), mentioning Least Developed Countries (LDC), sums up the severity of the situation:

> *Failure to urgently and meaningfully exploit the available means to bridge the digital divide may consign many developing countries, particularly LDCs, to harmful and even permanent exclusion from the network revolution.*

In this chapter, our focus is Information System Development Project (ISDP) failure from the perspective of a developing country. Learning from an ISDP failure plays a key role in the long-term success of any organization desirous of continuous improvement via evaluation and monitoring of its information systems development efforts. The "learning from failure" factor assumes a higher level of significance in the context of developing countries. In developing countries it is very important that the scarce resources are optimally utilized in such a way that the probability of failure is minimized. This study reports on a seemingly simple (but only deceptively so) failed ISDP to inform the reader about the various complexities involved in information systems development projects in general and in developing countries in particular.

This chapter is organized in five sections. In section two we describe the general information system development process and the associated rate of failure in this industry. Section three discusses the relationship between failure and complexity. A case study is presented in section four, followed by conclusions in section five.

BACKGROUND

Most of the IS research reported in the literature falls in three main categories, that is, positivist, interpretive, and critical, and there is widespread consensus that interpretive style with a critical stance is most suited for researching the IS-related issues in developing countries. The research is interpretive in nature, and an interview approach is used for investigations. The research is of significance to a wide audience in the IS community who are interested in understanding the impact and influence of various factors on failure of an ISDP in the peculiar environment of a developing country.

An organization may have one or many business processes (work processes) producing products, services, or information. In order to run properly, these processes need support from:

- **External environment,** including regulatory policies, supplier, and competitor behavior; and
- **Internal environment,** in the form of resources and managerial and organizational commitment.

Information systems support or automate the business or work processes by processing the information which is usually limited to capturing, transmitting, storing, retrieving, manipulating, and displaying information. An innovative information system usually changes the existing business/work processes in order to make them more suitable for automation.

A typical organization is created, established, and eventually evolved through a mix of indigenous factors like social, cultural, technical, and political mechanisms and interventions. IS are tools that contribute to the effectiveness and efficiency of the certain processes of an organization; therefore, IS development efforts in the organizations of a developing country have to be oriented towards local innovation needs and prevalent professional techniques and methods. These techniques and methods bear a strong influence of the above-mentioned indigenous factors. In order to understand and analyze information systems in organizational context, it is useful to first review the issues that cast a strong influence on the implementation and success or failure of an IS. The theory of information systems has discussed these issues in different pedagogical forms. For example, Alter's theory (Alter, 1999) defines an information system as a particular type of work system that "processes information by performing various combinations of six types of operations: capturing, transmitting, storing, retrieving, manipulating, and displaying information". The fourteen statements characterizing a work system in general and an information system in particular, as described by Alter (Alter, 1999, p. 8) are given below:

1. **Definition of work system:** A work system is a system in which human participants and/or machines perform a business process using information, technology, and other resources to produce products and/or services for internal or external customers. Organizations typically contain multiple work systems and operate through them.
2. **Elements of a work system:** Understanding a work system requires at least cursory understanding of six elements: the business process, participants, information, technology, products, and customers.
3. **Environment of a work system:** Understanding a work system usually requires an understanding of its environment, including the external infrastructure that it relies upon in order to operate and the managerial, organizational, regulatory, and competitive context that affect its operation.
4. **Fit between elements of a work system:** The smooth and painless operation of a work system depends on the mutual balance and alignment between the various elements of the system plus adequate support from the external environment.
5. **Definition of an information system as a work system:** An information system is a work system whose internal functions are limited to processing information by performing six types of operations: capturing, transmitting, storing, retrieving, manipulating, and displaying information.
6. **Roles of information systems in work systems they serve:** An information system exists to produce information and/or to support or automate the work performed by other work systems.
7. **Degree of integration between an information system and a work system it serves:** The information system may serve as an external source of information; it may be an interactive tool; it may be an integral component of the work system; the information system and work system may overlap so much that they are virtually indistinguishable. The information system may also serve as shared infrastructure used in many diverse work systems.
8. **Content vs. plumbing in information systems:** An information system can be viewed as consisting of content and plumbing. Its content is the information it provides and the way that information affects the business process within the work system. Its plumbing is the details that concern information technology rather than the way information affects the business process.

9. **Impact of an information system:** An information system's direct impact on work system performance is determined primarily by how well it performs its role in the work systems it supports.
10. **Definition of a project as a work system:** A project is a time-limited work system designed to produce a particular product and then go out of existence.
11. **Phases of a project that creates or significantly changes a work system:** A project that creates or significantly changes a work system goes through four idealized phases: initiation, development, implementation, and operation and maintenance.
12. **Impact of the balance of content and plumbing in a project:** For projects of any particular size, those in which both content and plumbing change significantly have more conceptual and managerial complexity than projects in which the changes are mostly about content or mostly about plumbing.
13. **Work system success:** The success of a work system depends on the relative strength of internal and external forces supporting the system versus internal and external forces and obstacles opposing the system.
14. **Inheritance of generalizations, truisms, and success factors:** Generalizations, truisms, and success factors related to work systems also apply to information systems and to projects (because these are work systems).

Information System Development Project

According to Alter, an Information System Development Project is also a work system, though a time-limited one. The development process of an information system incorporates a high level of innovation, and therefore inherently possesses uncertainty of results. Chris Sauer (1993) divides this process into four stages as shown in Table 1. These stages are identified by the objectives and problems they posses, and at each of the four stages there are some influences from supporters, users, and developers on this innovation process.

ISDP Failure, Definitions, and Classification

All human endeavors, scientific, technological, or other result in success or failure. This success or failure outcome is also related with technological and organizational efforts regarding development of information systems. Generally success is praised at every level, and itself defends its characteristics and long-term effects; however, it is considered better to disown a failure. In a particular project, both success and failure can be companions, that is, when the project is facing a status of partial failure. Richard Heeks (2000) describes these three statuses of an information system as:

- **Total failure:** In this type of failure, a system is either not implemented or it is discarded soon after the implementation.
- **Partial failure:** In some cases a system is implemented and used for some period of time; however, the system fails to meet some of its primary objectives. This type of failure can also result in producing some undesirable byproducts or features in that system. In other words, the system only covers a subset of its objectives. Partially-failed projects are also referred to as challenged projects in literature.
- **Success:** The success is straightforward, a status of project where all the objectives of all the stakeholders are fulfilled by the resulting system.

Many researchers have believed that the study of failed information system projects can enrich information systems' body of knowledge by making us aware of the dynamic and cross-

Table 1. Phases of information system development

Phase	Activities
Initiation	• Detection of performance gap • Formation of attitudes • Development of proposal • Strategic decision-making
Description: The efficiency of certain work/business processes and tasks can be improved with an information system. These candidate processes and tasks are identified in the initiation phase, and an analysis is carried out about the extent and nature of changes that are necessary for improved efficiency; also, the people likely to be affected by these changes are also considered. A cost benefit analysis is carried out to ensure that the benefits of the proposed information system outweigh its costs, and then necessary resources are allocated for the project.	
Development	• Development of abstract system • Development of concrete system • Establishment of project infrastructure
Description : In this phase, the information system and supporting documents are produced and the related procedures are defined.	
Implementation	Introduction of concrete system to operational and organizational context
Description: In this phase, the new system is introduced in the workplace and users are trained to use it.	
Operation	Operation, maintenance, and enhancement
Description: In this phase, the new system is accepted and is running smoothly in the work environment. In case a major change is required by the users, a new iteration of the four phases will start.	

cutting reasons that lead to partial or full failure. An information systems development project can fail due to any number of reasons and the possible list can easily stretch to triple figures. Therefore, in order to understand the reasons that lead to failure in information systems development it is important to first understand the different categories of failure. One classification of failures is proposed by Chris Sauer (1993) and it defines the following five categories of failure:

- **Correspondence failure:** When a particular ISDP is not able to achieve its predefined objectives, it is categorized as correspondence failure, for example, the selected project was not able to meet the objectives defined in the contract.
- **Process failure:** When a development process is not able to produce the desired system or could not meet the resource limitations, it is categorized as process failure.
- **Interaction failure:** Sometimes, it happens that the users are not satisfied with the delivered system or some portion of the delivered system, which leads the users to lose interest in that system, and hence the level of system use is decreased subsequently. This situation is referred to as interaction failure.
- **Expectation failure:** A project always starts with some tough and high expectations of its stakeholders; however, the resultant product may not be able to fulfill the expectations of any or all stakeholders, thus resulting in expectation failure.

- **Terminal failure:** This is the case when a project is abandoned or cancelled before the final delivery. Termination of a project is the last thing that can happen to a failing project, that is, when there are no hopes of meeting any of the objectives of the project, it is terminated.

ISDP Failure Statistics

Many researchers have attempted to study the extent of failure in the IS industry. A milestone study in this area is the Chaos Report of 1994 by the Standish Group (1994). They surveyed 365 companies and conducted a number of focus groups and interviews in order to determine:

- The scope of software project failures
- The major factors that cause software projects to fail

The Chaos Report stated that 16.2% of projects were successful, that is, these projects completed on-time and on-budget, with all features and functions as initially specified. 52.7% of projects were partial failures, that is, these projects were completed and they became operational, but were over-budget, over the time estimate, and offered fewer features and functions than originally specified. 31.1% of projects failed, that is, they were canceled at some point during the development cycle. This research survey also tried to determine the most important success, partial failure, and failure criteria. Table 2 lists the three criteria in descending order of importance.

Table 2. Criteria of success and failure

	Success	**Partial Failure**	**Failure**
1.	User Involvement	Lack of User Input	Incomplete Requirements and Specifications
2.	Executive Management Support	Incomplete Requirements and Specifications	Lack of User Involvement
3.	Clear Statement of Requirements	Changing Requirements and Specifications	Lack of Resources
4.	Proper Planning	Lack of Executive Support	Unrealistic Expectations
5.	Realistic Expectations	Technology Incompetence	Lack of Executive Support
6.	Smaller Project Milestones	Lack of Resources	Changing Requirements and Specifications
7.	Competent Staff	Unrealistic Expectations	Lack of Planning
8.	Ownership	Unclear Objectives	Did Not Need It Any Longer
9.	Clear Vision and Objectives	Unrealistic Time Frames	Lack of IT Management
10.	Hard-Working, Focused Staff	Use of New Technology	Technology Illiteracy

Table 3. Failure statistics

	The Robbins-Gioia Survey	The Conference Board Survey	The KPMG Canada Survey	The OASIG Survey
Year	2001	2001	1997	1995
Country	USA	USA	Canada	UK
Survey Size	232	117	176	45
Survey Method	Not Mentioned	Interview	Questionnaire	Interview
IS Type	ERP	ERP	Multiple	Multiple
Failure Rate	51%	40%	61%	70%

To emphasize the gravity of the prevailing problem of failure in IS projects, some more reports are examined and a summary of findings is presented in Table 3 (IT Cortex, 2005).

- The Robbins-Gioia Survey was primarily focused on studying the implementation of Enterprise Resource Planning Systems in 232 companies. Out of these 232 companies, only 36% had experience of ERP implementation. The success or failure of the ERP implementation was measured based on perception instead of some objective criteria. Fifty-one percent of the companies perceived their ERP implementation as unsuccessful.
- The Conference Board Survey also studied ERP implementation. The most important finding of this survey was that 40% of the projects failed to achieve the business case within one year of going live. Projects covered in this survey were 25% over budget.
- The KPMG Canada survey was focused on identifying the reasons that lead to failure of IT projects. The survey reported that 61% of the analyzed projects were judged as failure. In this survey, more than 75% of projects were late and more than 50% of projects were over budget.
- The OASIG Survey reported that 7 out of 10 IT projects fail in some respect.

These statistics show the edge of the iceberg in the ocean of information system developments. The above-mentioned reports are concluded in these statements:

- An IT project is more likely to be unsuccessful than successful;
- About one out of five IT projects is likely to bring full satisfaction; and
- The larger the project, the more likely the failure.

These surveys are from the developed economies of the world. The financial costs of these failed projects no doubt present a constant threat for the companies in these countries; however, these countries have a solid financial base. This solid financial base lets them absorb the losses incurred by the failed projects. Now let us see some of the statistics of developed countries where the financial base is not strong enough, and the impact of a single project failure can do a lot of damage.

ISDP Failure Statistics for Developing Countries

Information Technology (IT) innovation is now considered necessary for development; during the last two decades, an understanding has emerged that IT can effectively be used to narrow the gap between the industrialized and developing countries. Information systems are now an important part of the diffusion and implementation of IT. In developing countries, information system development efforts are most widespread in areas of governance, health care, education, finance, and poverty alleviation. The main thrust of these initiatives has been to apply technology appropriately in such a manner that its adoption brings the perceived socio-economic benefits. There have been cases where imported information system solutions have been used as a starting point for adaptation, but mostly developing countries and donors have focused on developing appropriate and sustainable local information systems. The emerging trend is that most of the information system initiatives have not been appropriately conceived or developed, and therefore they have failed to fulfill the desired outcomes. There is not much empirical evidence available on whether information systems failure rate is very similar or widely different in developing countries as compared with developed countries. Very little research has been conducted in general IS failure in developing countries, and in the particular area of information systems for e-government there are some statistics available.

In developing countries, e-government is a representative area of IS development as it involves sufficient financial and technical resources. Richard Heeks (2003) presents a generic situation in his report about success and failure rates of e-government projects in developing countries. This report presents findings of multiple surveys and studies which help to draw a wider picture. The estimates from past surveys present a situation that encourages Heeks to conclude that the failure rate in developing countries is higher than in the developed countries. The success and failure rates estimated in the Richard Heeks (2003) report from past surveys are in Table 4.

Results of some more existing studies from developing countries are summarized as:

- Braa and Hedberg (2000) have reported wide-spread partial failure of high-cost health information systems in South Africa;
- Kitiyadisai (2000) has concluded that in the public sector, IS initiatives failure cases seem to be the norm in Thailand;
- Baark and Heeks (1999) found that all donor-funded projects in China were partial failures; and
- Moussa and Schware (1992) concluded that almost all World Bank-funded projects in Africa were partial failures.

These findings tell us that at least one quarter of the projects in the developing countries tend to fail, and this rate may be as high as 50%. The success rate range is 15% to 20%. A majority of the projects tend to end in what is termed as partial failure where major goals of the project were not achieved or there were significant undesirable results. These statistics of success and failure in developing countries become even graver when other factors pertaining particularly to the underdeveloped world are also taken into consideration. For example, as a general rule the investments involved in big IS projects are always high from a developing country's perspective, and if the project fails, the resultant losses incur long-term

Table 4. Success and failure rates in developing countries

Classification	**Literature**	**Poll**	**Survey**
Success	15%-	20 %	15%
Partial Failure	60%+	30 %	50%
Total Failure	25%+	50 %	35%

negative effects on the progress of a developing country. Also, IS development companies in developing economies are small and do not have sufficiently deep pockets to survive the impact of a failed project. As a result, a high failure rate in the IS industry indirectly impedes the growth of the IS industry.

ISDP Failure and its Effects on Developing Countries

Information systems projects are initiated in developing countries typically in institutions like governance, management, healthcare, and education, and usually the general aims are to increase efficiency, introduce transparency in working, and improve accountability. The above-mentioned institutions in developing countries are very local in context and have deep historical roots. The evolution of these institutions has been different from that of the similar institutions in the developed countries. Information system projects in developing countries are usually perceived as pure technical initiatives aimed at making the functioning of an organization or institution more efficient and effective. The current prevalent IS strategies have matured in the developed countries and thus have a strong association with a particular way of management and administration style. It is difficult to embed these IS strategies in local institutions of developing countries without regarding social and organizational aspects.

The main objectives of an information system are to enhance capabilities of an organization and to help the organization save monetary resources by reducing workforce, travel, communication costs, and so forth (Mirani & Lederer, 1994). A good information system is expected to help an organization meet its information requirements at all levels and produce the appropriate information results. The information systems of e-government projects are meant to provide access to information at all levels of society with faster retrieval or delivery of information, with features like concise and better format, flexibility, and reliability. The aim is to improve the responsiveness of public organizations. These benefits are expected to fulfill the needs of a developing country, save its resources and provide better living standards to its society at minimum cost. This particular goal is an attempt to bridge the gaps of digital divide in the world and to compete in the race of progress. A typical IS project requires a high level of investment in terms of resources and efforts. Once a project is started, expected results are projected at all levels of society and stakeholders. Unfortunately, if a project fails, it generates much more relative damage in a developing country than in developed countries. With the failure, not only all the prestigious and scarce resources involved in that project are lost, but it is considered as a setback to the progress and development of the country. In the long run, this failure is considered as a bad example for future investments in that type of IS project. This scenario discourages further attempts to develop information systems projects in the developing country. Hence a developing economy takes a long time to fully recover from the effects of failure in a large-scale IS project.

Web-Based Information System and Reliability

The failure in Web-based information systems is an area which is being studied with great interest. The case study presented in this chapter provides us an in-depth analysis of the causes of deficiency in reliability of a Web-based application. This lack of reliability not only decreased the use of the application, but also made the higher management reluctant to enforce its use on a regular basis.

Web-based applications, like the academic records management portal in our case study, are a unique type of information systems which interconnect a large number of users with the organization and cater to variable access rates. As the pool of users is big, the variation of influences is also wide ranging, which makes the user preferences a significant factor in the development of such applications.

With the increasing use of Web interfaces across organizations, for example, corporate and supporting applications, comes a dramatic increase in the number of users of the resulting systems. Due to this trend of connecting more and more of an organization's staff and clients together via Web interfaces, the system design models are becoming more user-centric, and place user requirements higher on the priorities list. Moreover, user satisfaction is also a major performance and quality indicator. This trend is also evident in our case study. As we report, the development team tended to focus totally on the user satisfaction and kept on incorporating the new and changing user requirements in the project design even to the last stages of development. This factor brought the Web application closer to failure due to a decrease in reliability.

Learning Lessons from a Failure

The IS failure in developing countries carries more importance for learning and investigation of failure causes, as it not only wastes the scarce and precious allocated resources but also discourages further investment. The opportunity costs are certainly higher in developing countries because of the more limited availability of resources such as capital and skilled manpower. This situation is best described (Heeks, 2000, p. 4) in the following words:

The failures keep developing countries on the wrong side of the digital divide, turning ICTs into a technology of global inequality.

For these types of reasons, a failure in development of IS in developing country poses a significantly important area of study. In countries like Pakistan, where domestic market and domestic IS demand has traditionally been very low, ISDP failures discourage further demands and growth in IS industry. This scenario has established the need for studying ISDP in Pakistan, especially the failed ones. We believe that there are more opportunities and lessons for learning from failed IS projects, than there are from the successful IS projects. We are not aware of an existing study that has reported on the extent of failed IS projects in Pakistan. This chapter is a first step to fill this gap. We have chosen one small and simple IS project to study ISDP failure in Pakistan. We would also like to point out that a single case study can provide no basis for estimation of overall failure/success rates in Pakistan, and further work needs to done in this direction.

ISDP FAILURE AND COMPLEXITY

In this section we discuss the type of factors that can participate in an information system development failure and the associated role of project complexity in failure.

ISDP Factors and Dependencies

In this section we discuss what type of factors can participate in an information system development failure. During the four stages of the information system development process (initiation, development, implementation and operation), the development process is influenced by various factors; however, the degree of influence of these factors varies at different stages. There is no definite list of factors and no definite degree of influence which they make on the process. In order to understand the different possible factors, it is useful to discuss them from different perspectives. One perspective is that of the user factors (Havelka, 2002); these include:

- Biasness of users towards system performance;
- Commitment of users towards providing support to project;

- Communication skills of the users: whether or not the users can elaborate the needs and shortcomings of delivered system;
- Computer literacy levels of the users: whether or not the users can understand barriers and bottlenecks of common systems;
- Extent of users' participation in requirement gathering phase to the training phase;
- Users' know-how about the organizational processes and work flows; and
- Users' understanding of the requirements of the new information system.

Ananth Srinivasan (1987) has discussed organizational factors and the type of effects that these make on the IS development process. These include:

- Available resources (both human and financial): The human resources affect the development process positively, but increased financial resources are related to team disagreement;
- External influences on the development process: The degree of external influence on the system development effort needs to be carefully monitored and controlled; and
- Project team's exposure to information systems: Systems exposure in the firm allows an increase in the degree of awareness among project group members about the different problems encountered by users and systems staff.

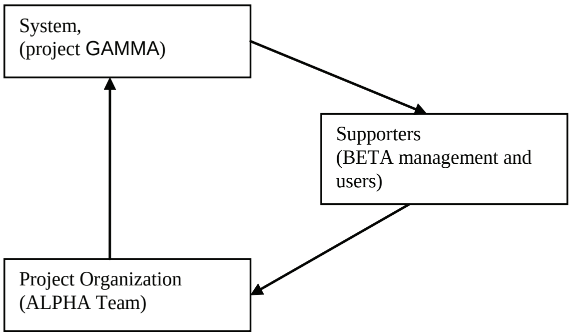
There are also some exogenous factors involved in influencing the development process as discussed by Chris Sauer (1993). These factors are cognitive limits, technical process environment, organizational politics, structure, and history. The environment is a collection of some other factors such as suppliers, technology, customers, competitors, interests, regulators, and culture.

All of these factors exist in their respective contexts and influence the information system development project. This is not a definite list; however, it helps to understand that there exist different factors when the system is studied with different perspectives. To examine the roles and dependencies of these factors in an integrated environment of information system development project, Chris Sauer presented Triangle of Dependencies (Sauer, 1993). The triangle of dependencies presents a cycle of interaction between supporters/users, the project development organization, and the system (under development) itself.

Model of IS Project: Triangle of Dependencies

The project organization (ALPHA in this case study) is defined as a group of people who, at a particular point in time, are occupied with the development, operation, or maintenance of a given information system (project GAMMA in this case). The information system must serve some organizational stakeholders and thereby function

Figure 1. Triangle of dependencies



as a resource for the project organization in gathering support. Supporters (BETA and its employees in this case) provide support in terms of monetary resources, material resources, information, and so forth. This triangle is depicted in Figure 1, and it is not a closed triangle. Each relationship is subject to a variety of exogenous factors which influence how it will affect the rest of the triangle. It was obvious that some resources were given to ALPHA development team by BETA management and the development of project GAMMA started. ALPHA delivered documentations and presentations on the working and status of the project to BETA at different milestones, to win the support from them by satisfying their needs.

It is important to keep in mind that information systems are developed and exists to fulfill the needs of stakeholders, and it is important for stakeholders to support the system in return. As the project organization plays the creator role for the system development, it is not possible to do it without any support from the users. Thus this situation exists like a triangle where the user organization supports the developers so that they can develop a system which fulfills their needs. If the system satisfies the users, they support the developer's organization in the development process, which enhances the system for further needs.

Dependencies of the Factors

This triangle clearly presents three sides of the software development process. It starts with the flow of support from supporters to project organization, the second side is the relation of system to supporters and the third side is the relationship of project organization to the information system. In the next paragraphs, the sides and corners of this triangle are discussed in detail.

The project organization is the group of people who are involved in the development of the system. Different people play different roles in the complete information system process, for example, development, implementation, and maintenance. The team leader plays an important role; he guides the whole team towards a particular goal. The competency of the team in understanding the problem and scope of the problem, as well as the development model they follow, are two of the major factors beside many others which influence the project.

The supporters are the people who support the project organization by providing them with resources as well as problem scope and definition. The resources, including monetary resources, material resources, information, social legitimacy, and control of strategic contingencies, are provided by the supporters to the project development organization. The supporters can also be categorized as funders (because they provide financial resources), power brokers (because they exert influence on project organization), and fixers (because they provide information and control decisions) (Sauer, 1993). Users of the system are an important part of the supporters as they not only provide basic information and requirements but also provide feedback to the funders and power brokers to make long-term decisions. It is important to note that the factors like organizational politics, nature and sources of power, history, and environment of the organization are the factors which make direct influences on the triangle.

The relationships among the system, project organization, and supporters are also interesting to examine. Each relationship contains different types of characteristics and factors which also influence the whole system. For the supporters-project organization relationship, the most significant thing is the flow of support. If the system satisfies the supporters, then the support for the system is there; if the system does not meet the goals, as perceived by the supporters, then the flow of support becomes problematic. The supporters-project organization relationship is based on human cognitive behaviors and is directly affected by organizational structure and politics. The second relationship is the system-supporters relationship, which also depends on the organizational factors. The needs of the organization for the system may change with time, due to which the system may become unacceptable. There can be some political changes due to which the degree of satisfaction may diminish. Factors related to users (biasness, skills, commitment, and understanding of needs) as well as the technical process by which the system is being evaluated directly influence this relationship. The relationship between project organization and system has a technical orientation, as it mainly consists of a technical process of information system development. This process consists of designing, creating, implementing, and making changes as required by the supporters. In this relationship, factors like communication and cooperation among team members, tools for development, requirement specification, the team's exposure to information systems, development process, and skills have influences. There are also some factors which come from the other sides of triangle to affect this relationship, for example, structural changes in the user organization can cause changes in requirements, and the system may need to be modified accordingly. The project organization might be at a stage where it cannot afford any shortage of support from the supporters, and the system may also be at a stage where it needs major changes and as a result may overshoot schedule. These types of problems demand a great skill set from the team leader.

Flaw

As discussed in the previous section, there are many factors which influence an information system development project, and these factors have different dependencies among each other. Every factor influences the project, and its effect is important for the success or failure of the project. Thus one cannot say that a particular factor should be ignored or its influence should be negated. These influences create a state of balance between different stakeholders and can make a project successful. However, at some stage the effect of these influences makes some aspects of the process uncontrollable, but at the same time, helps other factors to render positive influences. These unbalanced influences create flaws in the process, and the result is a flawed system/project (Sauer, 1993). The factors which highly influence a system and then tend to create flaws and make hurdles in the success of an IS project are termed as risks (Ward, 1995).

Information systems development process is open to flaws, and every information system is flawed in some way. However flaws are different from failure. Flaws are a characteristic of the system itself and also of the innovation process. Flaws are never desired by any stakeholder, for example, project organization, users, or supporters. Flaws are corrected at a cost or are accepted at some other cost. One technical type of flaw is a bug, which either stops a running program or destroys the results. Another type of flaw is any system characteristic which the users find inconvenient or otherwise undesirable, for example, a particular data entry form. This kind of flaw can also be corrected or accepted at a cost. There may also be flaws in the development process that are introduced by a decision about how to proceed in a particular step in the process. A particular decision may give the desired result with perhaps a greater cost, or may produce some other flaws.

Thus flaws are problems which occur as a consequence of events in the development process. Unless there is support available to cope with them, they will have the effect of reducing the system's capacity to serve its supporters or of resulting in further flaws. As this capacity to serve the supporters decreases and cost of managing the flaws increases, the project becomes more prone to failure. No stakeholder can continue to support the costs of flaws forever. In the long run, they will start to take notice of rising costs and undesirable results and reduce their support. When the support dries up, the system lacks the necessary resources and tends towards failure.

Complexity

We have discussed flaws in information systems and their negative effects on information system development, and one may reach the logical argument that flaws of a system should be removed. However, as these flaws are caused by interconnected factors, removing a flaw can generate negative effects on other parts of system. This situation renders complexity into the information system development process, where removing one flaw can develop other flaws. The definition of complexity varies in different contexts. Baccarini (1996, p 202) defines complexity as:

The complexity can be defined as an interaction of several parts which can be made operational differently and in interdependent ways.

Suppose we have a particular system in which there are many components. All these components have some intra-component dependencies. Each component may be independent and may have a particular behavior and influence in the whole system. Every component is not only dependent on its internal dependencies but is also affected by other components. These inter-component dependencies help the components to make a complete system for a particular purpose. All these components interact with each other to fulfill requirements and dependencies of other components. As all the components are independent, and have their own intra-component structure, they can work and behave differently if some changes occur in their internal composition. When these components work in a system, they can operate in different ways, and can have different effects on the system at different times. One or more than one independent component can lead to a situation where it has different effects on the system, and these influences can create an imbalance in the system's working. Now the problem solving can produce a complex situation, that is, which factors of a component should be negated to let the system keep working?

A similar situation arises in an information system development project, where the project is a collection of many different sub-processes and components. Each sub-process is not only separate but also dependent on the other components of project. In this type of system, the complexity is a situation where we have to leave a negative effect of a component on the system to let the system not be destroyed due to negative effects of other components. Thus the complexity of most information systems means that:

Cost of leaving a flaw uncorrected may be significant because of consequential effects it might have on other parts of system. (Sauer, 1993, pp. 63-64).

Suppose in a particular project a new requirement is made by the user and the project is delayed because of this particular requirement. Now if the requirement is not provided in the system, the user is not willing to accept the project, and if the requirement is fulfilled the project is delayed. This is a complex situation where we need to leave one flaw to avoid consequential cascading effects on the project. The factors involved in creating imperfection lead toward increasing the complexity of an ISDP and subsequently decrease its probability of success.

Complexity and Failure Relationship

Although flaws are in every system, they are not the cause of every failure; however, flaws lead a system towards failure. The relationship between flaws and complexity has been discussed in the previous section, and we saw that complexity also leads an information system towards failure. The complexity which is caused by the flaws is one of the major risk factors involved in the failure of information system development projects. Presence of complexity is considered one of the biggest risk factors involved in project failure (Barki, Rivard, & Talbot, 1993). Level of complexity and time duration of project are directly related to failure. As the complexity of the project increases, the time duration needed to solve the problems also increases, and on the other hand the sense of urgency also creeps up and wrong decisions are made. One way to reduce the level of project risk and failure is to reduce the level of complexity (Murray, 1993). British Computer Society (2003) found that the most common attribute underlying the failed projects was the high level of inherent complexity in the failed projects. Thus it is obvious that to improve ISDP success rate and the rate of return on IS investment, organizations must address the problem of complexity in ISDP and reduce it within manageable limits (Xia & Lee, 2004).

Virtually every IS project will increase in complexity once it has been initiated. Sense of urgency in announcing the end date and addition of post-initiation components/technology are two major causes of complexity for an IS system (Murray, 1993). Size is also a source of increasing complexity, because to solve a bigger problem the project is decomposed in smaller components, and thus complexity of interaction between the components increases (AlSharif, Walter, & Turky, 2004). This implies that complexity is one of the major causes of failure of information systems, thus studying the complexity of an information system can reveal the causes of failure. Dissecting a particular failure in the light of complexity will help us to understand the areas and flaws which should be provided more careful analysis in the development process.

Classification of Complexity

Complexity is one of the major reasons for information system development project failure, which encourages one to study an information system development project and analyze different complexities related to it. For this purpose we select a framework for ISDP complexity to classify different complexities. In this classification the ISDP complexity is divided into four different categories including technological and organizational factors. Xia and Lee (2004) classifies complexity in two major dimensions, organizational and technological, and then plots it against a third dimension called uncertainty for both the organizational and technological dimensions. As a result, four classifications emerge which are depicted in Figure 2.

Structural Organizational Complexity

A project always gets maximum influences from the organizational environment for which the project is being developed. The current organizational environment and the business processes present their own influences and complexities. This category of complexity presents the nature and strength of the relationships among project elements in the organizational environment, including project resources, support from top management and users, project staffing, and skill proficiency levels of project personnel.

Structural IT Complexity

The technology is itself a factor which causes many complex situations in the development project. Information technology not only includes the hardware, but also represents the software engineering and project development factors. This category represents the complexity of the relationships among the IT elements, reflecting

Figure 2. Taxonomy of ISD projects complexity

Organizational vs.	Structural Organizational Complexity	Dynamic Organizational Complexity
Technology	Structural IT Complexity	Dynamic IT Complexity

Structural vs. Dynamic

the diversity of user units, software environments, nature of data processing, variety of technology, need for integration, and diversity of external vendors and contractors.

Dynamic Organizational Complexity

As the time passes in the stages of development of an information system project, there come many changes in organizational environment and its business processes. The dynamic organizational complexity covers the pattern and rate of change in ISDP organizational environments, including changes in user information needs, business processes, and organizational structures; it also reflects the dynamic nature of the project's effect on the organizational environment.

Dynamic IT Complexity

Information technology is rapidly growing and changing. In the life span of an information system development project, there come many changes in the underlying information technology platform and tools for software engineering. This dimension of complexity measures the pattern and rate of changes in the ISDP's IT environment, including changes in IT infrastructure, architecture, and software development tools.

Now let us discuss some of the factors from each of the categories and understand their effect on increasing the complexities. In a particular project, the users may not provide the type of support needed by the project organization. In this situation, the requirements may not be provided correctly to the development team, which in turn may produce a faulty system which may not satisfy the needs of users or supporters. This situation can be worse if the top management does not give sufficient support, as the financial support is directly under the control of top management. The formation of the development team also plays a crucial role, as lack of team staffing or their skills can delay the time lines and lose further support. Then there are also some organizational factors from both of the users' and developers' organizations. As time progresses, there are some changes in the organizational environments and some new factors emerge from this situation. There may be some changes occurring in the organization itself, for example, the business processes of the organization are changed by the management. The management structure of the organization can also change; and this can cause changes in the organizational needs and rules. These changes can also be due to the new information system, and in this case the developer has to face an opposition from different sectors of the user organization. Some organizations do not have a defined set of business processes or have flexibilities in them; due to adoption of information systems, these flexibilities are limited and this scenario can also cause opposition from the users.

The nature of the project also poses its own complexities, for example, if the project involves multiple user units or involves different vendors and contractors. This type of project is open to different stakeholders to impose their decisions, and prone to different influences and flaws in return. These factors are summarized in Table 5.

THE CASE STUDY

In our case study, the developer is referred to as ALPHA and the client is referred to as BETA. ALPHA was one of the leading software houses in Pakistan operating as an independent business unit of a large and reputed international company. BETA was a top bracket public sector university. The ISDP was a Web-based portal for academic records management referred to as project GAMMA in this case study.

Research Methodology

In order to understand the factors which led the project GAMMA to failure, we conducted several

Table 5. Factors of ISDP complexity (Xia & Lee, 2004)

Complexity Factor
Structural Organizational Complexity - The project manager did not have direct control over project resources. - Users provided insufficient support. - The project had insufficient staffing. - Project personnel did not have required knowledge/skills. - Top management offered insufficient support.
Structural IT Complexity - The project involved multiple user units. - The project team was cross-functional. - The project involved multiple software environments. - The system involved real-time data processing. - The project involved multiple technology platforms. - The project involved significant integration with other systems. - The project involved multiple contractors and vendors.
Dynamic Organizational Complexity - The project caused changes in business processes. - Users' information needs changed rapidly. - Users' business processes changed rapidly. - The project caused changes in organizational structure. - Organizational structure changed rapidly.
Dynamic IT Complexity - IT infrastructure changed rapidly. - IT architecture changed rapidly. - Software development tools changed rapidly.

in-depth qualitative interviews. These interviews were flexible and exploratory in nature. In these interviews our later questions were adjusted according to the response of the interviewee in answering the earlier questions. Our aim was to clarify the earlier responses, to follow new lines of inquiry, and to probe for more detail. The overall interview style was unstructured and conversational, and the questions were open-ended and designed to elicit detailed, concrete information.

The persons interviewed included the ALPHA Project manager and the ALPHA technical team lead, and the BETA team lead, BETA coordinator, and a few users at BETA. The answers that warranted more clarification or were, to some extent, conflicting to the views expressed by the other side were further probed in the second round of discussions. ALPHA and BETA interviews were segregated from each other. Interview settings included individual and collective participation of the interviewees. The information collected was mapped on contemporary theoretical frameworks discussed in Sauer (1993) and Xia and Lee (2004) to analyze the responses and understand the role of different factors that led to the failure of our specific case under study. The information was then examined with the help of Taxonomy of ISDP complexities, and factors of each category were identified.

In the sections bellow, the process of different phases of information system development is discussed.

The Team from ALPHA

ALPHA had a team of skilled software engineers, and the average experience of team members was three-and-a-half years. The manager of the ALPHA team had software project management experience of six-and-a-half years. The ALPHA team comprised of a blend of analysts, designers, coders, and testers. ALPHA followed the incremental development approach for projects with a time period of more than eight weeks, and hence the same approach was followed in this case.

The Team from BETA

BETA made a focal team comprising of senior faculty members from different departments led by one Head of the Department. The focal team at BETA was mandated to collaborate with the ALPHA team. The responsibilities of the focal team were to help the ALPHA team to capture the information about policies and procedures of the academic and administrative departments and units of BETA. Its main role was also to help ALPHA understand the processes and verify the requirements against specific processes. The focal team acted as the client representative and in the later stages also tested the portal and gave feedback to ALPHA team.

The Complete Process

At the start of the project, a preliminary set of requirements was agreed upon between the BETA focal team and the ALPHA team. A total of eleven modules were identified, out of which eight modules were deemed to be more critical than others. The technological requirements were not rigid, and it was generally agreed to encourage the platform-independent technologies including Java and Linux. Regarding the choice of database, BETA preferred to use Oracle as it already had the license. Next the ALPHA team analyzed the preliminary requirements by collecting the data and observing the business processes and procedures. Both of the teams visited different academic departments and held meetings with the heads of the departments and different other employees. The same was done in the administrative units to record the data and procedures of different business processes. After analyzing the collected information and additional requirements, a standard requirement specification document was developed and agreed upon.

In the meanwhile, some significant changes occurred at BETA. Due to some routine and policy decisions, some of the members of the focal team from BETA were transferred, and newly-appointed persons took their place. As the people changed, the mindset changed and the vision about the project also changed. Changes at the organizational level of BETA led to some new requirements emerging from nowhere and caused frequent changes in the old requirements.

Surprisingly, ALPHA team had to face many objections on the already-settled requirements, which were conveyed from the user departments and the end users themselves. The new members of the BETA focal team were not clear about the scope and objectives of the project GAMMA, and they also did not agree with the version of the requirements provided by the former members of the BETA focal team. Due to this kind of divisive environment, a huge time was lost in the advancement of the project. ALPHA team was willing to work according to the satisfaction of the client organization and hence wanted to listen to the client's focal team members. As there was no consensus on requirements within the client organization, ALPHA decided to conduct some presentations and meetings with the representatives of all departments and the focal team.

After some presentation and discussion sessions, the analysis of the requirements with a conclusive set of requirements was presented, and the software requirements specification document was once again finalized after incorporating the revised requirements.

At this stage, in order to minimize the impact of organizational changes on the project, the management of BETA appointed a software engineer to lead the BETA focal team with the mandate that the newly-appointed lead person will work continuously in the next phases until the completion of project GAMMA. The new lead person coordinated with the ALPHA team and helped them to complete the trial version of the project. ALPHA finalized the trial version of the project and deployed it at BETA. In April, 2004, the first version of the project was deployed at BETA, and testing was done by ALPHA's testers using real data.

At this stage, training sessions were held by the ALPHA team members to guide the key potential users at BETA, with the objective that these people will use this portal and identify errors, bugs, and changes. As per the evaluation and trial report of the project, the users complained about a number of deficiencies. They reported variances in the expected and actual implementation of different functionalities. There were errors in data processing which caused the potential users at BETA to lose their interest. They also complained that the training was of very basic level and was not properly designed and executed. The ALPHA team was of the opinion that people attending the training sessions were mostly used to using an older existing IS system and thus were reluctant to shift to the new system. Their association and familiarity with the older system created hesitancy and an attitude of disinterest which prevented them from appreciating and exploring the full functionality of the new portal.

It was observed that for some particular processes there were no standard operating procedures, and different departments followed different procedures. This situation demanded flexibility in different data structures and functionalities of the GAMMA system. As an example, the pattern of student registration numbers varied in different departments. Such anomalies caused some requirements changes, even at the later phases, and delayed the implementation.

At this stage, the person who was hired earlier and was leading the BETA focal team through the development phase left BETA for another job. This particular development compelled BETA to restore the old structure of the focal team of BETA. Now the Head of the Department of Computer Sciences was assigned the role of team lead by the client organization. The project at this stage required transferring the existing data from the old system to the new system, and new data entry as well as testing the real-time application behavior. The developers from ALPHA provided scripts to convert data from the old system based on SQL server to the new system. However, according to BETA, the scripts did not work as per requirements which had to be modified time and again. BETA formed another team referred to as "Testing Analysis Team", to test the portal, and the team members were provided training by ALPHA. Moreover a person was selected from each faculty as master trainer, who was entrusted the task to further train the end users within his faculty. This task took another six months of time and further delayed the successful implementation.

The project started in September, 2002, with the planned completion date of December, 2003. A formal audit was conducted by the external auditors, engaged by ALPHA, in December, 2003, who found that the delay was justified as the requirement engineering phase took a much longer time as discussed above. The project took off a little in September, 2004, when the Head of the Department of Computer Sciences started to lead the team to implement the project. However, the project implementation came to a standstill in December, 2004, when the client organization desired deputation of full-time experts by the ALPHA organization to supervise the implementation, which included training of the end users to use the system and subsequently adopt it. ALPHA expressed their inability to depute an expert without charging further expenditure to BETA.

At present the status of the new portal is that it is being used as a passive repository of data. The new system has not been adopted by the end users, and the system that earlier existed is in use at the organizational level. ALPHA has received part of the agreed payment amount and has an outstanding claim for the balance payment from BETA. Both organizations consider it a failed project. BETA considers it a failure as it has not been implemented and adopted at the organizational level. ALPHA considers it as a failed project because, besides the financial loss, the product is termed unsatisfactory by the end users and has not been successfully deployed and adopted at organizational level.

The main reasons for the failure of this simple IS project can be summarized as follows:

- Adaptation and modification of underlying organizational processes in such a way that they become conducive for automation is an issue deeply intertwined with project definition and has to be tackled in the very beginning. Once the processes have been reengineered, only then the scope of an automation project can be fully visualized by all the stakeholders. This factor was initially ignored in the project GAMMA when the first version of project requirements was specified. Halfway through the development process of project GAMMA, the inadequacy of the organizational processes of BETA, in terms of their capacity to lend themselves to automation, was realized.
- The existing organizational processes of BETA were not fully mature. Introduction of a new organization-wide IS system for records management and decision-making implied a number of changes in the way things were done at BETA. Alignment of organizational processes and the IS systems was very important for successful implementation of GAMMA. The end users at BETA were not ready to adopt the changed organizational processes necessitated by the introduction of new technology.

The various complexity factors (Xia & Lee, 2004) and their impact on project GAMMA is summarized in Table 6 and Table 7.

CONCLUSION

The main aim of the GAMMA project was to implement a Web portal for the academic and administrative records management of BETA. Hence system GAMMA was required to capture, store, and process data for a number of departments within BETA. Each department had its own perspective regarding the policies and procedures of data and records management. Being in the same organization, these processes were interlinked and processed similar data.

The different departments of BETA created complexity for the requirement analysis team to decide on a particular set of requirement specifications. On the other hand, the users also did not provide sufficient support, and their behavior was

Table 6. Structural complexity categories and their impact on GAMMA

Complexity Factor	Effect in this case	Level of Risk
Structural Organizational Complexity	Yes/ No	
- The project manager did not have direct control over project resources.	No	
- Users provided insufficient support.	Yes	High
- The project had insufficient staffing.	No	
- Project personnel did not have required knowledge/skills.	No	
- Top management offered insufficient support.	No	
Structural IT Complexity		
- The project involved multiple user units.	Yes	High
- The project team was cross-functional.	Yes	Medium
- The project involved multiple software environments.	No	
- The system involved real-time data processing.	No	
- The project involved multiple technology platforms.	No	
- The project involved significant integration with other systems.	Yes	Low
- The project involved multiple contractors and vendors.	No	

Table 7. Dynamic complexity categories and their impact on GAMMA

Complexity Factor	Effect in this case	Level of Risk
Dynamic Organizational Complexity		
- The project caused changes in business processes.	Yes	High
- Users' information needs changed rapidly.	Yes	High
- Users' business processes changed rapidly.	Yes	Medium
- The project caused changes in organizational structure.	No	
- Organizational structure changed rapidly.	Yes	Medium
Dynamic IT Complexity		
- IT infrastructure changed rapidly.	No	
- IT architecture changed rapidly.	Yes	Low
- Software development tools changed rapidly.	Yes	Low

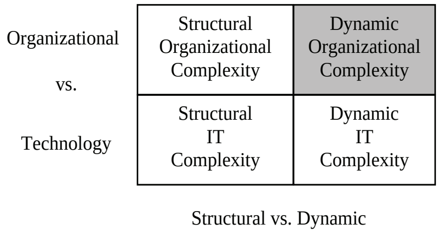
critical. The users from the lower management just pointed out the flaws in the system, even if they were because of flaws in the organizational processes of BETA. They did not accept the changes in business/organizational processes which were caused by the new information system. On the other hand, the business processes kept on changing due to their own needs as the people were also changing in the BETA organization. The changes in business processes caused the rapid change in information needs. At the technological dimension, there were also some changes in

IT architecture and software development tools, which caused more complexity in managing the project on target. The analysis shows that Dynamic Organizational Complexity, Figure 3, contributed most to the project failure in this case.

One of the important objectives of IS in developing countries is to bring about improvement in organizational and business processes. The information systems support the current processes to enhance the operations and improve information processing, which is helpful to the organization for making its business processes more efficient. These improvements are not without incurring any risk, as modifications or improvements are prone to introduce complexities (Heeks, 2000). However, this case study shows that the changes towards improvements in the processes caused by IS were not accepted by the supporters, which in turn increased the weight of various risk factors. On the other hand, the change in processes, due to the organization itself, caused delays and led the requirements to change significantly, which in the end proved fatal for the project. The inability of the development team to freeze the requirements and stick to the standard requirement specification is a major cause of the failure. However, the business scenarios, in developing countries like Pakistan, demand this type of flexibility in business agreements and job specifications.

With the help of this case study, we are able to identify a major problem area in the development of information systems in general and Web-based applications in particular. The lack of standard operating procedures in business processes and the evolution of new knowledge of business processes and technology encourage the managers of an organization to demand more features as well as the flexibility in them. The managers want to include many processes in the Web-based information system while these processes are either immature or are in phase of standardization; consequently, this demands extra flexibility from the developers and consumes more time. On the other hand, these immature processes are prone to changes as a result of political or structural changes. These business processes become the first target of new management to show that they are making changes in the organization. A weak legal environment in the developing countries like Pakistan does not allow the development team to challenge the client on the basis of service level agreement. This leaves only one choice for the developer's organization to adjust the demands (which look small as they come in pieces at a time) of the client, so that the support can be won from the client in the shape of financial resources. After some time it is realized by the developers that the small changes have combined, and there is a big requirement change demanding huge amounts of extra effort and time. The developers try to make these efforts and invest time in the project; however, at a certain moment it is realized that the complexities have been increased beyond control, and the project is heading towards failure.

Figure 3. Crucial area in ISDP complexity with respect to case study



Organizational vs. Technology	Structural Organizational Complexity	Dynamic Organizational Complexity
	Structural IT Complexity	Dynamic IT Complexity

The dynamic organizational complexities demand that a project should cover the business processes which have been standardized, or the information system should be allowed to standardize these processes. It is also the responsibility of the organization to show respect to the agreements and demand minimum changes in the requirements. In case of political and structural changes, a project should be owned by the organization, and the changes should not affect the project scope.

The responsibility of the developers is also high, as they should be aware of these complexities and adopt a strategy to cope with them. They should be able to take strong business and technical decisions to restrict the changes in requirements to a minimum level. On the technical end, they should be able to provide maximum flexibility in a minimum time frame. It can be concluded that responsibility of these types of failures cannot be given to one stakeholder; rather it is the responsibility of both the developers as well as the client organization to facilitate a project towards success.

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Chapter 7.2

Critical Insights into NHS Information Systems Deployment

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ABSTRACT

This chapter discusses a systems methodology called strategic assumption surfacing and testing (SAST) that was used to understand the design and deployment of information systems in the healthcare context. It is based on the experiences of conducting SAST with a group of healthcare professionals, working in the National Health Service (NHS) in England. This application of SAST in the NHS setting highlighted deep politico-cultural concerns in the organizational setting, and it helped towards the conception of a normative inclusive approach for health informatics design and deployment. This approach introduces the understanding that the development of information systems in healthcare is a complex agenda, the success of which demands the active involvement of all stakeholders through all the key stages of the process. Critical perspectives on SAST have also been considered and the assumptions fostered towards arriving at the conclusions, have been highlighted.

INTRODUCTION

The responsibility of provision of healthcare services in England rests with the National Health Service (NHS). The NHS is the largest employer in Europe with an annual budget set to exceed £92 billion in 2007/08 (Department of Health, 2005). In October 2002, the NHS launched the National Programme for Information Technology (NPfIT) with the objective to create an integrated healthcare information system (IS) supported by information technology (IT). NPfIT has an anticipated investment of over £6.2 billion (Health

Informatics Community, 2004). However, there has been tremendous scepticism amongst key stakeholders regarding the success of NPfIT due to its lack of consultation with end users. The fundamentally top-down policy-led approach to the design and implementation of NPfIT and its lack of adherence to effective IS project principles have come under much spotlight as contributing to the feared failure of the project (Ballard, 2006).

This chapter argues that effective deployment of healthcare IS can be achieved by considering the interaction between a diverse range of factors within the organizational setting. This kind of an approach is inherent in the systems philosophy of management thought. Systems thinking has influenced a range of methodologies and techniques that facilitate stakeholder participation, boundary critique, and inclusive decision-making. Boundary critique (Midgley, Munlo, & Brown, 1998) is the idea that one's understanding of the world is bounded by the position and worldview they occupy. Therefore, the more one's boundaries are critiqued, the more informed and inclusive do understanding and perspective become. Strategic assumption surfacing and testing (SAST) is one such methodology that has been discussed in this chapter. Experiences from a SAST exercise with a group of NHS professionals and its resultant normative approach to health informatics has been illustrated.

HEALTH INFORMATICS AND THE SYSTEMS APPROACH

The NHS model of healthcare information system is epitomized in its NPfIT project, which in turn makes the promise to re-create the NHS as a high-tech environment. NPfIT aspires to deliver an integrated healthcare system for the NHS in England with its core in effective IS. The main elements of NPfIT are as follows:

- **NHS Care Record Service:** This is the central database of patients that will be available to authorized clinicians in the country, whenever and wherever required.
- **Choose and Book:** This is the electronic booking service whereby general practitioners (GPs) and other primary care staff are able to make hospital bookings at the convenience of their patients' date, time, and place.
- **Electronic Transfer of Prescriptions:** This service seeks to electronically link up the prescribers and dispensers of medicines in England. The objective is the connection between all GPs, community pharmacies and other dispensers.
- **Picture Archiving and Communication Service:** This enables medical images like X-Rays and scans to be stored electronically that can be viewed by clinicians in their video screens or computers. This is expected to eradicate hard films for recording radiographic medical images.
- **NHSmail:** This is the national e-mail and directory service that will be provided free of charge to NHS staff.
- **NHS Network (N3) Broadband:** This is the fast and reliable broadband service that will support the whole system. It is claimed to deliver the robust demands that will be made by the new system to deliver all the above services.

The previous developments, if implemented as planned, are set to pose the NHS as a truly high-tech organization with state-of-the-art IS support.

NPfIT and Related Challenges

Despite record levels of investments in NPfIT, there is considerable scepticism within the NHS and beyond that the project is heading towards failure. The Institute of Public Policy Research warned "that the program could be undermined by a failure to consult properly with medical professionals, a dearth of IT skills within the healthcare service and poor understanding of exactly what the health benefits are supposed to be" (Sherriff, 2004). Research and expert opinion suggest that core activities like clinical engagement, staff training, and system compatibility may have been compromised in the design and deployment of NPfIT. Gillies (2000) similarly notes that the primary reason why IT has not been a success in the NHS is that "IT has been technology driven not information driven" (p. 16). There are various factors resulting in this situation. Important ones among these may include the sheer size of the NHS, which posits tremendous challenges, management-clinician conflict where both perceive each other's roles as differing in common grounds, and underestimation on the complexity that IS projects have to deal with. For success in a project like NPfIT, clinical engagement and user commitment are paramount, along with the appreciation that different factors do not operate in isolation, but in interaction with one another. This kind of an understanding is the focus of the systems approach, which is discussed in more detail below.

The Systems Approach

Systems thinking is the philosophy in management thought that encourages holistic understanding. It supports the idea that organizations are constituted with elements that are in interaction with one another, and this interaction gives rise to the character and nature of the system (Jackson, 2003). Hence, emphasis is shifted from individual elements to the interrelationships between elements. Systems thinking encourages boundaries to be approached with criticality, and that boundaries can always adapt as a result of its interaction with its environment. Hence, a systems approach argues for the "sweeping-in" of immediate and non-immediate factors that influence the behavior of complex systems (Churchman, 1968). It therefore lends an inclusive and participatory perspective in the decision making process. As Hammond (2002) illustrates in Table 1, a systems approach has considerable implications for organizational planning and decision-making – those that are indicated in the left hand column; these ideas are in contrast to the ones in the right hand column:

Systems thinking can be of tremendous value in the design and deployment of IS. This is pertinent to the implications of considering the human, technological, and contextual factors in the conception and design of organizational IS. A systems approach can enable the understanding that IS of the present day are dominantly technology enabled human activity systems within specific contexts. Xu comments: "Systems science has been considered the basis of information systems. A wealth of research in information systems in the framework of systems science has produced an astonishing array of theoretical results and empirical insights, and a large suite of tools and methods" (Xu, 2000, p. 105).

The systems approach has influenced a wide array of methodologies and techniques to foster stakeholder involvement and facilitate participative decision making in complex situations. One of such methodologies is SAST. SAST has been discussed below in theory and practice in the context of IS design for the NHS. SAST has

Table 1. Social implications of systems theory: Contrasting views (Hammond, 2002, p. 431)

Participatory decision-making processes	Hierarchical decision-making processes
Self-organization	Externally imposed order and control
Free will, creativity, spontaneity	Determinism

been selected as an appropriate methodology in the current context as it facilitates decision making when there are two groups with distinctly opposing viewpoints. In this case, these are the management-led approach and the service provider-led approach in healthcare IS. This has been discussed in more detail below.

STRATEGIC ASSUMPTION SURFACING AND TESTING (SAST)

SAST is a methodology that was developed by Mason and Mitroff (1981) to enable managers to deal with complex situations in modern organizations. Mason et al. prefer to call complex problem situations "wicked problems" where issues are multidimensional, interconnected, and uncertain. Wicked problems that arise in these situations have social, political and organizational ramifications. Their understanding was governed by the idea that "in tackling wicked problems, problem structuring assumes greater importance than problem-solving using conventional techniques" (Jackson, 2003, p. 137). This leads to the understanding that unless the formulation and structuring of problems are addressed effectively in the beginning, we may end up tackling the wrong problems. SAST is therefore designed to formulate and explicate assumptions that people harbor in organizations.

SAST has been greatly informed by the following ideas of Rosenhead (1987), as described by Jackson (2003):

- A satisficing rather than optimizing rationale
- An acceptance of conflict over goals
- Different objectives measured in their own terms
- The employment of transparent methods that clarify conflict and facilitate negotiation
- The use of analysis to support judgement with no aspiration to replace it
- The treatment of human elements as active subjects
- Problem formulation on the basis of a bottom-up process
- Decision taken as far down the hierarchy as there is expertise to resolve them
- The acceptance of uncertainty as an inherent characteristic of the future and a consequent emphasis on keeping options open (p. 138).

Influenced by the philosophy of Churchman (1968)[a], Mason et al. embarked on a systems project that would accept the existence of a variety of worldviews, or *Weltanschauungen*, as an unavoidable prospect and embrace divergent subjectivity as a strength. Further, all worldviews are restrictive and a holistic perspective can only be achieved by synthesis of a variety of worldviews. A systems mindset would encourage one to question and formulate ones own assumptions and worldviews, and critically debate the same with opposing assumptions and worldviews (Churchman, 1968; Mason et al., 1981). Borrowing from Hegel, SAST is driven by the understanding that in any organization there would be a dominant set of worldviews--*thesis*, an opposing set of worldviews, *antithesis*, and there is always a possibility for the opposing worldviews to enter a state of constructive debate, and arrive at a higher level of understanding, *synthesis* (Jackson, 2003). This is however a never ending process, and the synthesis would always give rise to opposing set of beliefs. What is important for Mason et al. is that the worldviews and beliefs are derived from deep rooted assumptions that people hold in their minds. Management decisions are in turn dependent on these assumptions and beliefs. However, an effective organization is one that is able to formulate these assumptions and counter assumptions amongst its members and learn how it can behave differently from the knowledge that emerge. As Jackson notes:

> *An organization only really begins to learn when its most cherished assumptions are challenged by counterassumptions. Assumptions underpinning existing policies and procedures should therefore be unearthed and alternatives put forward based on counterassumptions.* (p. 141).

Constructive criticism and investigative debate is central to the previous philosophy. This philosophy is essential for "wicked problems" in complex organizations where not only there are a variety of opposing assumptions and beliefs, but also a tendency to subjugate the assumptions of the weak and the underdogs. SAST has therefore been designed to be participative, adversarial, integrative, and managerial mind supporting (Jackson, 2003). Decision-making process ought to involve different stakeholders with different assumptions and different ideas about how problems should be addressed. Hence, the situation should be adversarial, apart from being participative. Further, there ought to be the opportunity to bring together divergent views to a higher level of integrative understanding from which decision makers can gain deeper insights into wicked problems. Hence, this methodology has the potential to make a real contribution in the practical and operational level. The methodology of SAST follows four stages (discussed in detail in the next section): group formation, assumption surfacing, dialectic debate, and synthesis. The following is an account of SAST in action in the high-tech NHS environment.

A SAST exercise was conducted with a group of NHS professionals in June 2006. The purpose was to examine if the dominant and opposing viewpoints in the context of IS in the NHS can be brought together in synthesis. This was intended to inform the design of a route-map for IS in the context of UK public sector healthcare. This exercise was supported and funded by the NHS North and East Yorkshire and Northern Lincolnshire Network of Cardiac Care (NEYNLMCN).[b] The following discussion follows the methodology of SAST and the insights it generated in the exercise.

Group Formation

Group formation is the first stage where participants are divided into two distinct groups. The effort should be to "maximize convergence of perspectives" (Jackson, 2003) within each group and "maximize divergence of perspectives" between the groups. The result is two groups of opposing viewpoints with each group consisting of relatively like minded people.

There were eight participants in the exercise: one consultant clinician, one general practice manager, two nurses, one information support officer, one clerical staff, one service improvement facilitator, and one service improvement manager. The conflicting idea that was prevalent in the group was the design and deployment strategy of NPfIT and how a new health informatics strategy could be conceived and implemented. Certain participants believed that the prevalent top-down approach to the current NHS IS strategy was working and making progress. This was the dominant perspective overtly cherished by the NHS management. They believed that the new NPfIT system could be used for improvement in patient care and for the monitoring of clinicians' performance. They were of the opinion that there had been considerable consultation with frontline service providers before NPfIT was implemented. This represented the viewpoint of the management-led approach to health informatics. At the same time, there were other participants who believed that there had not been appropriate consultation before NPfIT was implemented. This was the opposing viewpoint. They believed that the NHS was wasting its resources in delivering functions that are not required by patients and the public. They were of the opinion that NPfIT was in a way imposed upon them by the management. This represented the service provider-led approach to healthcare information systems. They advocated that system specification and definition ought to come from frontline service providers like the clinicians, and that administrative staff should also have a say in the system as their role would radically change with the deployment of the new systems.

Considering the overt difference of opinion between the participants, they were divided into the following two groups, based on the approach they favored:

- **Group-1 (management-led approach)**
  - General Practice Manager
  - Service Improvement Facilitator
  - Service Improvement Manager
- **Group-2 (service provider-led approach)**
  - Consultant clinician
  - Nurse 1
  - Nurse 2
  - Clerical member of staff
  - Information support officer

The result was two groups where difference of opinion was maximized between the groups. However, as the following stages will show, this methodology facilitated the opposing groups to structure assumptions, many of which were quite similar instead of being opposing.

Assumption Surfacing

This is the second stage where the aim is to formulate and express key assumptions that members in the groups harbor. As Jackson (2003) notes, this should be done in a "supportive environment," where the aim should be as "imaginative and creative" as possible.

This stage may be facilitated with three methods: stakeholder analysis, assumption specification, and assumption rating. Groups can be asked to conduct a stakeholder analysis to identify who they think the relevant stakeholders in a particular project are, in terms of who the affected parties would be as a result of the implementation of a particular project. Groups may then be asked to specify their assumptions for each of their stakeholders. These specifications should be related to how these would influence the success of the project under consideration. Groups may then be asked to rate their assumptions in a chart rating them against two criteria: importance and certainty. A spokesperson from each group then has to make a presentation about the assumptions.

To facilitate this stage, both the groups were asked to state who they thought the stakeholders were in the implementation of IS in the NHS. The groups brainstormed their views in different rooms and agreed to a list of stakeholders. Following were the results:

- **Group-1 (stakeholders)**
  - Clinical professionals
  - Finance department of NHS
  - General public
  - Government, including the Department of Health (DoH)[c]
  - Healthcare IT Leads
  - IT Industry
  - Managers
  - Media
  - Patients
  - Regional and local NHS organizations
- **Group-2 (stakeholders)**
  - Administrative staff
  - Clinicians
  - General public
  - Government including the DoH and the Treasury[d]
  - Industry (Pharmaceutical and medical equipment companies)
  - NHS Management
  - Patients
  - Private healthcare providers
  - Suppliers (IT services including software and hardware and telecommunications)

  - Support staff (e.g. IT staff)
  - Universities (Research and epidemiology)

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The groups were then taken forward to the method of assumption specification, where they had to state what their assumptions were. These assumptions were thought to effect the success of NHS IS strategies, with specific consideration to NPfIT. The responses were as follows:

- **Group-1 (assumptions)**
  1. IT industry has vested interest in personal gains.
  2. The media wants to portray a negative image and always wants to highlight problems.
  3. The media should be more positively engaged by NPfIT.
  4. The general public have a one-sided view, as portrayed by the media.
  5. The general public has a lack of confidence in NPfIT.
  6. The IT industry has a conflict of interest.
  7. The general public has a lack of understanding of the aims of NPfIT.
  8. The general public believes that money should rather be spent on healthcare and on professionals, than on IT.
  9. The government expects too much too soon from a complicated project.
  10. The government has an unrealistic timeframe for delivery of the project.
  11. The government is politically driven and does things that are locally irrelevant.
  12. The healthcare sector has a lack of expertise and lack adequate IT staff to deliver the project.
  13. The finance department underestimated resources needed for the national and local delivery of the project.
  14. Clinicians believe that they have not been consulted.
  15. Clinicians have an unrealistic expectation of participation.
  16. Clinicians have a fear of their IT skills.
  17. Patients are mostly not interested in getting involved.
  18. There is lack of training capacity to ensure skills for delivery.
- **Group-2 (assumptions)**
  1. NPfIT will go over cost. It is a white elephant.
  2. Administrative staff will be resistant to change.
  3. Administrative staff has no time to work with the new systems.
  4. Clinicians are not computer literate.
  5. Clinicians are time limited to work with the new systems.
  6. Patients are not computer literate.
  7. Clinicians are conservative to accept change.
  8. The government is control freak. It wants to control professionals with the information from NPfIT.
  9. Clinicians are sceptical about success of NPfIT.
  10. Patients want local treatment.
  11. Private healthcare services are only interested in profit.
  12. Clinicians are sceptical about patient confidentiality in the new system.
  13. NHS managers need numbers.
  14. Suppliers see NPfIT as an opportunity for profit.
  15. Administrative staff will find it difficult to use the new system.
  16. The treasury wants to keep costs under control.
  17. Patients lack knowledge about the system.
  18. The government wants to impose solutions all the time.

19. Universities need to do more research for information and funding.
20. Private healthcare services are always after more NHS work.
21. The government will blame someone else when the system does not work.

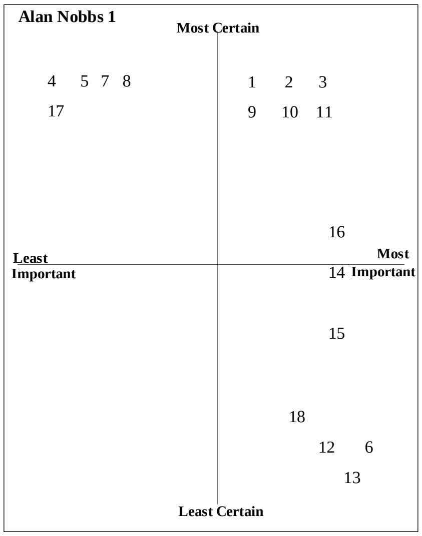
The groups then rated their assumptions in a chart against the axes of certainty and importance. A spokesperson from each group then presented their stakeholders, assumptions, and ratings to the other group. At this stage, it was interesting to note that although both the groups were supposed to be opposing in their viewpoints, there were many issues, which were common to both the groups. In addition to this, there were few elements, which both the groups seem to support as the root cause of many of the challenges faced by NPfIT. This is elaborated in more detail in the discussion below focusing on the presentation by each group.

Group-1 Assumptions

Group-1, which favored a management-led approach in healthcare information systems, believed that the IT industry had a vested interest in the implementation of NPfIT. The group however felt that this was a "gross assumption" in their part and they were not certain about it. The group felt that the media had a big role in portraying the NPfIT negatively. The media always highlighted problems rather than adopting a balanced position. This led to increasing scepticism of the project amongst clinicians and the general public. It was the view of group-1 that the media ought to be more "positively engaged" by NPfIT and the wider NHS as it is a "very important" stakeholder for the long term success of the project. This is because the media shapes public opinion. They also assumed that the general public had a fairly one-sided view about what NPfIT was, influenced purely on what they heard in the media. The public also suffered from a general lack of understanding about the aims and objectives of NPfIT. The public would rather be interested to see money being spent on healthcare *per se* and healthcare professionals, rather than support systems like healthcare IS.

The group thought that the government was to blame for making the project too complicated. This is because the government wanted too much sophistication in too little time. Therefore, the government had a "fairly unrealistic" time frame for delivery of the project. Moreover, it was the view of the group that the project was politically driven rather than being locally relevant to patients and clinicians. Members of group-1 also felt that there was a lack of expertise of IT skills in healthcare to realistically deliver the project. They felt that the finance for delivery of the project was also being underestimated. However, they were not certain about this as this may be the result of media reporting, and the way viewers, including the group itself, were picking up messages from the media. Regarding clinical consultation, the group felt that even it may have been misled by the DoH with the idea that appropriate consultation had taken place. The group was not sure whether or not clinicians were consulted appropriately. At

Chart 1. Assumption rating by group-1



the same time, they also felt that clinicians had an unrealistic expectation about what participation and consultation was supposed to mean, as consultation with every clinician is unrealistic. Fear of IT and skills deficit amongst clinicians was also featured as assumptions that came in the way of the success of NPfIT. Related to this, the group also featured that there was a general lack of appropriate IT training across all levels in the NHS.

Group-2 Assumptions

Group-2 favored a service provider led-approach to health informatics. Members of this group were certain that inspite of phenomenal investments in NPfIT, it was not yielding any of the anticipated benefits. However, at the same time, they also believed that administrative staff, patients, and clinicians may not be sufficiently IT literate to work with the new system. This may also have led to resistance to the change process, creating more challenges for the project. They also believed that patients lacked appropriate knowledge about the system and there was no appropriate initiative made to educate the public about the new system. The group highlighted that there was no realistic planning for training and development of clinical staff.

Group-2 was also critical of some of the objectives of NPfIT. For instance, one of the hallmarks of NPfIT is patient choice, but the group was confident that patients wanted local treatment. This discards one of the most important features of NPfIT itself. Members of this group also had grave concerns about patient confidentiality in the new system. They believed that the new system has been deployed without much consideration of security of access to patient details, which puts confidential patient information at risk.

This group also assumed that clinicians were conservative of change and not receptive to the new IS. This was creating grave challenges for the successful implementation of NPfIT. It was the view of this group that inspite of knowing about these challenges, the DoH did not take any specific measures to address them. The DoH rather proceeded with its own plan of deploying a system that would enable itself to have more control over the clinicians and management processes.

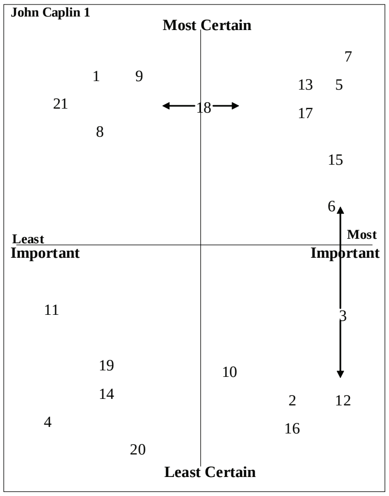
The previous insights interestingly shifted the blame from NHS managers to the government itself. This brought group-2 closer with group-1 in some of their viewpoints. The unintended consequence of these insights was that the groups already started to sympathize with each others' position within the organization.

Dialectic Debate

This is the third stage where both the groups are asked to debate the assumptions and viewpoints of each other. Whilst facilitating this stage, consideration should be paid to the following points (Jackson, 2003):

- How are the assumptions of the group different?
- Which stakeholders feature most strongly in giving rise to the significant assumptions made by each group?

Chart 2. Assumption rating by group-2



- Do groups rate assumptions differently?
- What assumptions of other groups does each group find the most troubling with respect to its own proposals? (p. 144)

After a certain period of time for which the debate has proceeded, groups can be offered an opportunity to modify its assumptions. This is called "assumption modification." However, as the following narration of this particular exercise will show, participants from both the groups were already beginning to see common grounds even before the following stage of anticipated consensus.

Group-1, that represented the management-led approach to healthcare information systems, was of the opinion that much of the resistance to NPfIT from clinicians was a generation issue. Members of this group felt that there was no problem with the younger clinicians accepting the new systems and they are more adept in using IT. They therefore felt that probably the problem would solve itself over time when the younger generation of clinicians would replace the older generation. This was however, taken with much contempt by group-2, who advocated that the main issue with NPfIT was its lack of consultation. This was immediately refuted by group-1 who was of the opinion that clinicians have never recognized their initiatives in helping them with service improvement.

As the debate progressed, the groups also began to see some common grounds. For instance, one of the key members of group-1 expressed scepticism of the DoH actually carrying out robust consultation with clinicians and patients about its IS strategies. They thought that they themselves might have been misguided by the DoH. In this regard, group-2 added that no one had actually ever approached them and asked what they really wanted. They felt that management would always make decisions about NHS reorganization or implementation of new strategies in complete isolation from clinicians. Identifying themselves closer to group-2, group-1 felt that there was always talk of a patient-led NHS, but the NHS never asked patients before it formulated its policies. Most of the consultation process in the NHS were actually "information giving" sessions, rather than consultation sessions, in which patients and the public are just informed about what the NHS was going to implement. When policies fail, management would try and backtrack the consultation process with patients and the public. This insight from group-1 immediately reflected a disparity between the NHS managers and the government, represented by the DoH. This disparity was more pertinent in discussions surrounding the choose-and-book feature of NPfIT, which offers choice of five treatment sites for patients in England. Group-1 felt that this was the "most ridiculous" feature as both patients and clinicians prefer local treatment. This view was immediately accepted by group-2. However, the managers felt that they had to work towards supporting Choose-and-Book as they had to deliver what they had been paid to deliver. Failure to do so would probably see their funding withdrawn. Hence, group-1 was surfacing frustration with their own position in the sense that they were implementing a strategy, some of its features they themselves did not support.

Both groups-1 and -2 expressed concern about the performance of the private companies that were contracted to deploy NPfIT. It was highlighted that there was considerable delay in the deployment of specific features of NPfIT, and some of the features that had been deployed were not functioning as expected, or not functioning at all. At this stage, it may be easy to blame the contracted companies for the fiasco. However, the participants suggested that there was a lack of realism that existed not only in the side of the NHS, but also in the side of the suppliers regarding what could be delivered and in what time scale the same could be delivered. However, at this stage, group-1 was again radical to question whether the contracted companies were failing to deliver due to their incompetence, or because the NHS did not clarify its specifications in the

Chart 3. Changed assumption rating by group-1

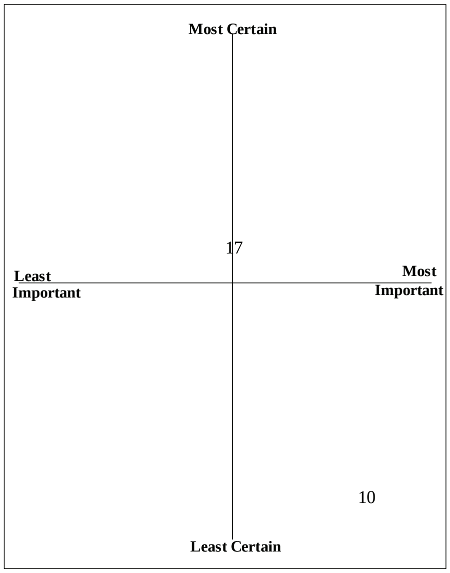
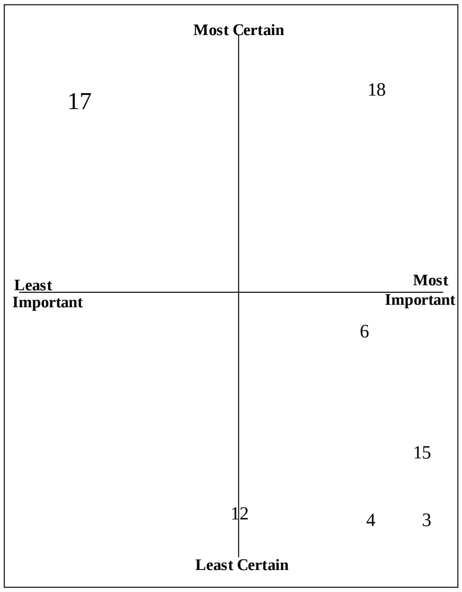


Chart 4. Changed assumption rating by group-2



first place. One member of group-1 said: "If we can't tell them exactly what we want and stick to it, they are bound to go wrong."

However, it was stated by both the groups that people's expectations and demands change from time to time, and change is unavoidable. There was some agreement at this stage that IS should have built-in flexibility so that it can be adaptive to changing requirements. Group-1 believed that this can be possible only through true "partnership working" between management, clinicians and the public right from the beginning. Partnership working is about involvement of key stakeholders in the whole process of design and deployment of strategies. Certain comments from group-1 indicated that NHS management itself was operating under the pressures of DoH. This issue becomes more explicit in the discussions that followed.

After a lapse of time, the groups were asked if they would like to change ratings of any of their assumptions or the assumptions themselves. Participants returned to their own groups and spent sometime discussing how their assumptions have been informed and influenced after the debate and discussion. Both the groups decided to change how they rated certain assumptions initially. The following charts show the ratings that were changed.

The groups then discussed their assumptions again and started to consider how the present unwelcome situation in health informatics in the NHS could be addressed. This led to an interest to envisage a normative approach for health informatics that would be able to involve stakeholders in partnership, with the element of learning built into the model so that system flexibility and change is not seen as a challenge, but as an opportunity for the system to evolve. Working toward this approach was the final stage of this exercise.

Synthesis

This is the final stage of SAST where the previous stages are expected to lead to a synthesis of views. This will be the result of modification of assumptions, negotiation, and accommodation of viewpoints. Synthesis is expected to result in a reformed strategy for the organization to adopt. However, if the groups fail to arrive at a synthesis of views, the problematic assumptions and conflicting viewpoints should be taken up for further research and consideration.

In the exercise under consideration, the final stage was concentrated on both groups working towards overcoming their differences and envisaging a normative approach for public sector health informatics. This stage facilitated the groups to be critical of their own boundaries and perspectives. It implied the groups "sweeping in" the viewpoints of the opposing group and conceives a more inclusive approach towards healthcare IS. All insights in the discussion to follow have been the result of a synthesis of ideas of both the groups, and represent an approach conceived by the participants supported by the facilitator.

This approach to health informatics in the NHS ought to follow the following stages.

Needs Assessment

The conception of ideas for new IS emerges only from the need of such ideas to improve the operational situation. In the healthcare sector needs may be realized at the level of healthcare service delivery for the improvement of services and enhanced effectiveness in care delivery. If systems are introduced without any need these can be a dangerous toll on organizational resources and efforts. Once needs are realized, they have to be assessed to see if there is actually a requirement to introduce new IS or can those needs be met with existing facilities. Once needs are assessed and there is an agreement that new IS is a requirement, should service providers and management conceive of the new technology. If new systems are introduced without any need, they may come as a management-led initiative to cater to management needs. This can lead to members of an organization feeling imposed by new systems and not being committed to what has been introduced. Therefore, the conception of any new system is the realization and assessment of needs by members of the organization.

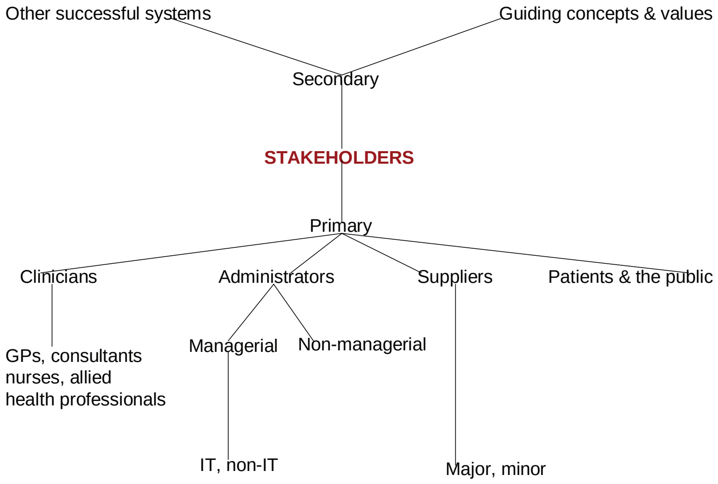
Stakeholder Analysis

Once management is convinced that there is a need for the introduction of new IS, there ought to be an understanding of who the stakeholders are in the new project. A thorough stakeholder analysis should be initiated to identify all those people who would be involved in the project or would be affected by it. Therefore, it goes beyond just the people who would use the system. A set of primary and secondary stakeholders were complied. This list was by no means meant to be exhaustive. For a health informatics project in the NHS, stakeholders would include what is detailed in Figure 1.

In the previous map, stakeholders are categorized into primary and secondary stakeholders. It was the view of the groups that other successful systems should be noted as secondary stakeholders. These are systems from where learning can be gained for the development of the new IS. This is because designing a system from scratch may lead to lack of realism in what can be achieved and how the system can be designed. This may further lead to lack of direction posing considerable challenges in the deployment of the system. Other successful systems would be specifically from the healthcare sector, but not confined geographically to the area for which the system is designed for. Insights may be drawn from successful systems in other countries. The guiding concepts and values that influence the new system and that which would be influenced by the new system have also been considered as stakeholder values. Primary stakeholders include clinicians, administrators, suppliers and patients and the public, who would be immediately effected by the new system (See Figure 1).

There should be a prime initiative to understand how the stakeholders should be involved in partnership right from the beginning. This should move beyond just information giving about the project, and there ought to be true consultation and partnership working from the beginning.

Figure 1. Stakeholder map for information systems in the NHS



System Specification

Needs assessment and stakeholder analysis may lead to the specification of what is actually desired from the system. This involves understanding of what the vision of the system is, what the vision of the organization is, and what can be realistically delivered. In a healthcare organization the vision may be to improve the quality of care; this will be supported by a whole gamut of technological activities and features. However, everything may not be possible to be delivered in a realistic sense. This was feared to have happened with NPfIT, in which the planners demanded too much within a limited time span. System specification should therefore be realistic and should be aligned with the organizational culture (discussed in more depth in the next stage). In another sense, this may also be called the stage of feasibility study to examine whether the whole idea is feasible or not. At this stage there may also be the requirement to go back to the first stage of needs assessment if there arise any scepticism about the success of the specified system.

It has to be realized that IS is integral to the process of healthcare service delivery. Therefore it has to be noted that the specified system is not treated as just one more piece of IT, but that which supports effective healthcare delivery underpinned by a systemic approach.

Context Analysis

Every organization is different. Design and implementation of any IS has to be suited to its context including the core business, the people and its culture.

The core business of the NHS include collating and dealing with confidential patient information. This entails that the nature of information that would be dealt with by the system is highly sensitive and confidential. This is a significant and decisive factor in the design of new systems. Any IS should regard confidentiality of patient information and safety of patients as its top priority. For instance, the NHS Care Record Service, in NPfIT, would record information for the whole population of England registered in the system. This sort of information is unlike of anything that can be found in other businesses. Security services and access criteria to manage and maintain this information is specific to the healthcare context.

If the system has to be developed effectively, it has to take the specific nature of this information into consideration.

In terms of people, the NHS employs highly qualified professionals. It has to be noted that these professionals cannot be forced by management to adopt an IS that the management wants. Any IS would have to prove its potential functionality and benefits to the professionals and patients. This is best achieved when professionals are directive of the design of the system. This takes us back to the first point of needs assessment, the primary impetus for the development of new IS. Due to the nature of work, it is the professionals who would normally recognize the need of new IS. Therefore, the participation and active involvement of professionals is paramount.

Organizational culture is important because any change not respecting culture may face stiff opposition to the change process. Organizational culture will include existing levels of receptivity of IT amongst staff, and also myths and stories associated with the same. The NHS finds itself in a unique position within healthcare as well, due to its sheer size and disparate organization. Myths and stories include comments such as one that was featured in the exercise by group-2: "we have not seen a single government IT project in a large scale succeed." This is an example of cultural scepticism of IS projects in the NHS. These feelings and opinions should be taken into consideration in the design of new IS. Scepticism ought to be understood and addressed in a manner that is culturally sensitive and appropriate to the organization.

Application of a generic IS model for the NHS will not be adequate, but any approach needs to be firmly based in the context itself including core business, people, and culture.

Risk Analysis

System specification may be followed by understanding the nature of risks the IS may face. Risks may be both technical and human. Following are some of the technical risks that may surface:

- Failure of the systems to be delivered on time
- Failure of the technology to deliver what has been aspired to be delivered
- Failure of suppliers to deliver what they have been contracted for
- The system failing to cope with changes in requirements and project specification
- Confidentiality of patient information breaking down
- Rapid change in technology rendering the original systems to be obsolete

Inspite of involving stakeholders appropriately, and considering the socio-cultural factors of new IS, there may still be human challenges in the way of implementing successful systems. Following are some of the human risks that may come with an IS project:

- Staff unwilling to use the new system
- Staff incapable to use the new system
- The system clashing with the organizational culture

The analysis of potential risks may even require designers to go back to the first stage of needs assessment and follow up the rest of the stages. Risk analysis is a crucial stage and if this is not undertaken in a detailed and critical manner, there will always be the fear that in spite of undertaking the rest of the stages effectively, the system may still fail.

Development & Implementation

The previous stages are expected to provide a robust background for the development and implementation of the desired IS. This is more the technical aspect of IS. The challenges here are to select the appropriate contractors and suppliers who will be able to technically deliver what they have been asked to. Success for the technical teams can be achieved with their work in partnership with the rest of the stakeholders.

It may not be appropriate to regard the implemented system as the final solution. Human expectation and system specifications are deemed to change. IS ought to be developed in such a way that changes do not threaten the existing system, but aids in the evolution of existing systems. This is what brings us to the overarching idea of cogenerative learning, discussed below.

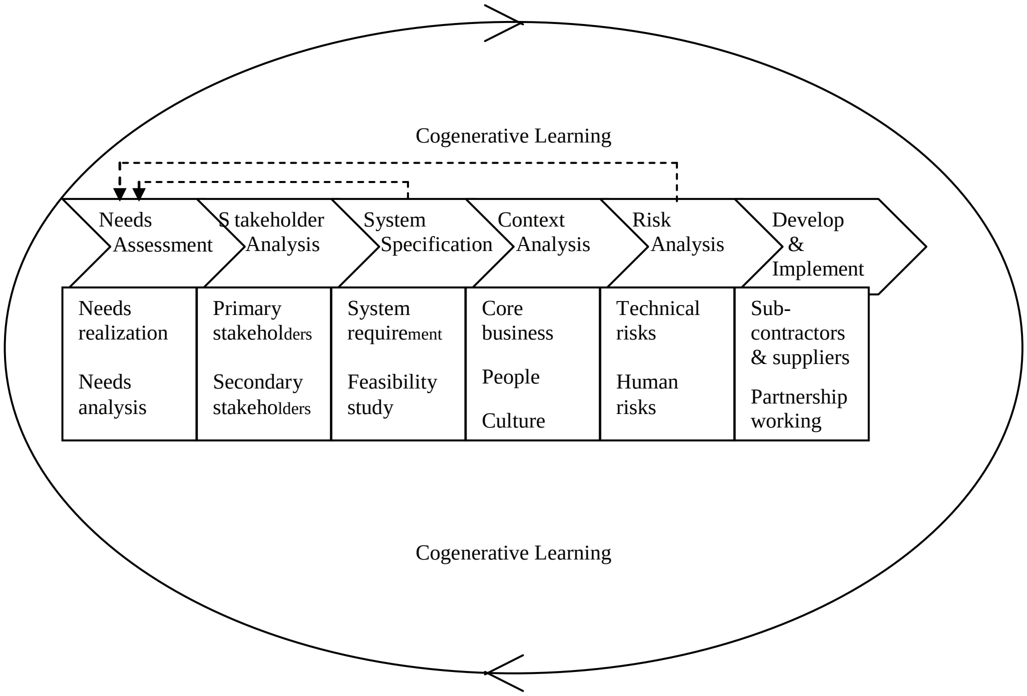
Cogenerative Learning

The idea of cogenerative learning is borrowed from Elden and Leven (1991) who talk of the term in the context of action research. They are of the opinion that cogenerative learning is the process where the power relations between the researcher and the research participants dilute, due to the active process the researcher involves the participants in. They note:

> *The insiders are not simply sources of data or sanctioners of studies and reports but actively help create and codetermine in every phase of the research process--especially in creating new meaning. They are not merely consulted in each phase of knowledge production; they participate as* cocreators. *We call this empowering participation.* (Elden et al., 1991, p. 133)

In the context of IS implementation, system designers, managers and planners ought to work cogeneratively with system users, "the insiders," to encounter challenges, learn from pitfalls and cherish knowledge. This has to be achieved in partnership and not in isolation between stakeholders. Constant learning ought to be integrated into IS so that the system is able to evolve from one stage to another and technology is designed to be adaptive. Cogenerative learning may be treated as the overarching philosophy. This lends the iterative angle to the IS design approach.

Figure 2. Normative approach to healthcare IS



The previous approach has been illustrated in Figure 2.

The previous model indicates a normative approach for healthcare IS, as informed by the SAST exercise. The insights that have been discussed in the above paragraphs are pertinent in the context of UK public sector healthcare. These insights were conceived by professionals working in a wide range of roles within the NHS. Hence, these insights and the resultant normative model for healthcare IS are invaluable for health informatics designers and planners in the context under consideration.

WEAKNESSES OF THE APPROACH

The previous discussion attempts to present SAST as an effective approach for the enablement of organizational decision making. However, taking a critical perspective, there may arise several aspects where the effectiveness of SAST can be called into question. This section highlights some of these critical aspects.

First, the methodology starts with the identification of participants into two diametrically opposing groups. However, it is not always necessary that even though participants are divided into two opposing groups, they will need to have radically opposing viewpoints. As this exercise shows, although there were two opposing groups, there were numerous instances where members of one group closely identified with the viewpoints from the ‘opposing’ group. The whole idea of maximising divergence of perspectives between the groups may be context dependent. Hence, although SAST aspires to unearth assumptions, it itself starts with an assumption that viewpoints of members from the two groups will always be radically opposing. This introduces a fundamental critique to the whole methodology.

Second, SAST has been portrayed above as an “ideal type” approach for management decision making, which has been aptly applicable in the context of healthcare IS. However, when it comes for the actual implementation of the approach in real life, SAST is best only as an “ideal type” approach. It has the limitation of optimistic simplification. Jackson (2000) notes that the methodology assumes that if the people’s attitudes change, so will the social system. This indicates to the methodology’s simplistic assumption that social systems are readily adaptable to human systems. However, given the tremendous complexity that gets incorporated into social systems once alterations and new structures are introduced, it may not be very simplistic to alter the same social systems. In the “ideal typical” approach previously taken for the formulation of a health informatics model, SAST has not allowed these challenges to be surfaced.

Third, the SAST approach does not pay due attention to the influence of power relations in the environment in which the exercise takes place. It presumes that in the dialectical debate stage every participant in the teams will present arguments and defend their own stands equally competently to arrive at an understanding. However, if participants come from a different set of hierarchy in the organization, certain members may be reserved about their participation. In the current case study, debating on the situation and arriving at a consensus inspite of radically opposing viewpoints was certainly possible. However, under what conditions this was made possible is also to be scrutinized. This stems from the feedback that was received after the exercise was conducted. One of the participants said that her inputs and vocal arguments were possible because she already knew the rest of the participants very well and felt comfortable to share her opinion; however if the group were different, her involvement could have been very different. A similar feedback was shared by another participant as well. Hence, the whole dimension of power and repression in the overtly consensual atmosphere needs to be considered. This may introduce a Foucauldian dimension of power into the methodology, which SAST very clearly does not consider.

Fourth, arrival at consensus in this particular exercise should not give the impression that consensus is a definite outcome of SAST. There may be cases where no consensus is arrived even after extensive deliberation, and that differences widen instead. This can happen due to a variety of reason including lack of enthusiasm of participants, power relations or simply because the methodology is not situated for that particular context. DP Dash (Dash, date not available) cites his experience of an instance where he applied SAST with two opposing groups, but could not reach a consensus. As he notes "Despite attempts at assumption negotiation and modification, it proved impossible to arrive at any overall synthesis during the final stage of the methodological process" (Dash, date not available). However, the whole idea of consensus is overplayed in the methodology and it gives an impression that a single or repeated deliberation of SAST will certainly lead to a consensus of opinion. Therefore, the idea of consensus at the end of SAST should be regarded with some criticality and it should be recognized that consensus is context and situation dependent.

CONCLUSION

Application of SAST in the context under consideration yielded interesting conclusions for IS design and deployment in the high-tech NHS environment, and for the methodology itself. These conclusions have been summarized in the next three levels.

Methodological

- The application of SAST was found to be a successful intervention strategy in the conflict situation of IS development in healthcare. SAST not only helped bringing the two opposing groups to a level of agreement, but it also identified the common grounds that both the groups had, but did not receive an opportunity to articulate prior to the exercise. Therefore, methodologically, SAST was found to be a useful tool in context under consideration. The systems approach was able to effectively consider a range of socio-technical factors in the design and deployment of healthcare IS.
- It was understood from the feedback that the effectiveness of SAST can be context and situation dependent. The impression that the methodology offers regarding the universal arrival at consensus at the end should be regarded with certain scepticism and consensus and for that matter the progress of the methodology is dependent on the kind of participants, the agenda, and the power relations between participants.

Organizational

- There was a new light on the often perceived conflict between management and clinicians in the NHS. It was understood that management itself had to operate within the pressures of the government. It was agreed in the exercise that many of the strategies adopted with respect to IS were not management led, but government led. Management itself did not agree with some of these strategies, but had to support these as they had no choice. This insight shed new light on how decisions were made in the high-tech NHS environment. This also carries great ramifications on organizational development factors in the context under consideration.
- It was the view of the groups that some of the decisions taken by the DoH were meant to meet political ends, rather than for the best interest of the NHS. As the groups suggested, NHS management itself may have been misled in many instances by the DoH with regard to the inclusiveness and robustness of planning for IS strategies. This portrays the NHS as organizationally fragmented and politically secretive.

Operational

- Healthcare IS is best supported by robust needs analysis, stakeholder analysis, feasibility study (system specification), context analysis, and risk analysis, before systems are designed and deployed.
- IS ought to be designed not as fixed solutions, but as systems that are capable to change and transform. This is specifically pertinent for healthcare due to its multi-dimensional and complex nature. Healthcare IS should be designed as complex adaptive systems, which is able to adapt to complexity and change in the wider environment. This character should be built into healthcare IS projects.

The previous conclusions carry pertinent implications for the design and deployment of healthcare IS. Introduction of new IS in a high-tech environment is not straight forward, but it has to be sensitive to a diverse range of factors. If this is neglected, the chances for success of the new IS may be compromised. A systems approach is vital in cases where issues are divergent and complexity is a rule rather than an exception. Application of systems methodologies like the one discussed in this chapter can be of immense benefit in understanding these issues and enabling variety to be addressed with variety for greater success in complex projects. It may be appropriate to conclude with the following quotation:

In information systems development, it is necessary to systematically view information systems as a socio-technical system and develop information systems using a wide spectrum of technologies, which is superimposed over the complex socio-technical interactions. Systems science provides the basis for taking such a broader view of information systems (Checkland, 1981, 1988; McLeod, 1995, Sommerville, 1996 in Xu, 2000, p. 106).

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ENDNOTES

[a] Chuchman's (1968) fundamental idea is that every worldview is terribly restricted and to make sensible decisions for lasting beneficial effects, one needs to "sweep in" a variety of opposing perspectives and worldviews. He advocated that whilst it is not possible to know everything, it is indeed beneficial to understand the implications of the lack of comprehensive knowledge. Therefore, self criticality in theory and practice was central to the work of Churchman and his philosophy.

[b] NEYNLMCN is responsible for design and deployment of service improvement strategies for cardiac care in the North and East Yorkshire and Northern Lincolnshire region of England. This is headed by Alan Nobbs with a core team of four staff and representation from a range of service providing professionals.

[c] In the UK, the responsibility of the provision of health and social care welfare is under the Department of Health (DoH) and Social Security. DoH was formed in 1966 as a result of a merger between the Ministry of Health and the Ministry of Social Security. DoH is answerable to Parliament for the strategic control and direction of the NHS and social services. DoH is therefore the apex government body for healthcare matters in the UK (Source: Department of Health).

[d] The Treasury is the United Kingdom's economics and finance ministry. It is responsible for formulating and implementing the Government's financial and economic policy (Source: HM Treasury).

[e] Epidemiology is the scientific study of factors affecting the health and illness of individuals and populations, and serves as the foundation and logic of interventions made in the interest of public health and preventive medicine (Source: Wikipedia online dictionary).

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Chapter 7.3

Quality Assurance View of a Management Information System

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INTRODUCTION

Strategic management has been widely applied in public and private organizations. Strategic management adapts educational institutions to their environment, which includes the educational policy, local demand for labour and other circumstances. The increased autonomy of educational institutions has emphasised the role of strategic management. Quality assurance has also gained more attention in recent years when plans have been made to establish the European Higher Education Area (Berlin Communiqué, 2003).

European countries develop their own national solutions for evaluating and demonstrating the quality of degrees (FINHEEC, 2006). There are no European or national agreements that provide any specific approaches or tools for the management of higher education institutions (HEIs) (Maassen & Stensaker, 2003). Each HEI is responsible for defining its management and quality assurance systems. Strategic management is a strong candidate for the management system for Finnish HEIs, but there is more variation in the quality assurance systems. Quality assurance refers to quality management and improvement. Quality is understood as the ability of an institution to fulfill its mission or a study programme to fulfill its aims (Harvey, 2007; Harvey & Green, 1993).

The purpose of this chapter is to describe the management information system (MIS) which integrates strategic management and quality assurance. Institutional quality audits have shown that quality assurance is quite often separate from the general management system of HEIs. By contrast, a well-functioning quality assurance system produces evaluative information about results and processes and then management uses this information to develop processes. Management at each institutional level determines the corrective action. While providing support for strategic management, the management information system can also contribute to continuous improvement, which is the core of quality assurance.

The balanced scorecard approach developed by Kaplan and Norton (1996, 2001) translates the strategy into action and provides a framework to integrate the strategic management and quality assurance approaches. This chapter describes the case of the Turku University of Applied Sciences (TUAS). At the TUAS, the implementation of the strategic plan includes, among others, budgeting, action plans and HR plans, which are stored in the MIS portal. The balanced scorecard is used to create an understandable structure for the strategic and action plans which include quantitative measures. All these management and quality assurance tools are provided for the managers and personnel as the tools of the MIS portal.

BACKGROUND

Quality Assurance in Higher Education

The Bologna Process Finland has developed its own approach to quality assurance in higher education. The approach is based on the quality assurance systems of HEIs and external quality audits at the institutional level. The quality assurance systems of all Finnish HEIs will be evaluated by the Finnish Higher Education Evaluation Council (FINHEEC) by 2011. Each institution is responsible for the development of its own quality assurance system. HEIs have the responsibility to define what they mean by quality and how they manage and enhance quality. The external audits aim to evaluate how the quality assurance system of an institution performs as a tool for quality management and enhancement. The institutional quality audit ascertains whether a quality assurance system produces useful information for continuous improvement (FINHEEC, 2006).

When building a quality assurance system, the first step is to define the concept of quality. In everyday language, the word “quality” has been associated with excellence. However, fitness for purpose is the approach to quality accepted by most quality agencies. Fitness for purpose sees quality as fulfilling a customer’s requirements, needs, or desires. In higher education, fitness for purpose is understood as the ability of an institution to fulfill its mission or a study program to fulfill its aims (Harvey, 2007; Harvey & Green, 1993). This is the definition adopted in this chapter. At the institutional and faculty level, quality is defined in the institution’s mission, strategic plan, and annual action plans and evaluated against these plans.

The concept of quality assurance has various definitions in different contexts. According to Woodhouse (1999) quality assurance refers to the policies, attitudes, actions, and procedures necessary to ensure that quality is maintained and enhanced. Quality assurance is defined in this chapter to include strategic management and the performance of the internal processes. A similar interpretation is given by FINHEEC (2006), which states that quality assurance is part of strategic planning and includes the management process and the internal processes of HEIs. Quality assurance refers to the procedures, processes, and systems which safeguard and improve the quality of an HEI, its education, and other activities. At the level of HEIs, the quality assurance system refers to the entity composed of the quality assurance organization, the respective responsibilities, procedures, processes, and resources.

The relationship between the strategic management and quality assurance of higher education institutions could be interpreted as a new conceptualization for some of the most essential features of quality assurance. From our viewpoint, two basic ideas of quality assurance are continuous improvement and management's commitment. According to Beckford (2002), the principle of continuous improvement is an explicit part of the thinking of many quality gurus. Furthermore, John Oakland says, "Quality must be managed, it does not just happen", and Beckford argues that without adherence to the quality management system, it is impossible for the organization to know how well it is performing.

It is evident that management is an essential element of quality assurance. Mostly it is only the managers who possess the power and resources needed for carrying out the planned development steps (corrective action). One way to look more profoundly at the relationship between strategic management and quality assurance is to emphasise the fitness of purpose and use the phases: plan, do, check, and act (PDCA). This is known as Deming's cycle (Beckford, 2002). The cycle has been used in various quality awards. The Malcom Baldrige quality award has renamed it and uses the words: approach, deployment, results and improvement (ADRI) (Woodhouse, 2003).

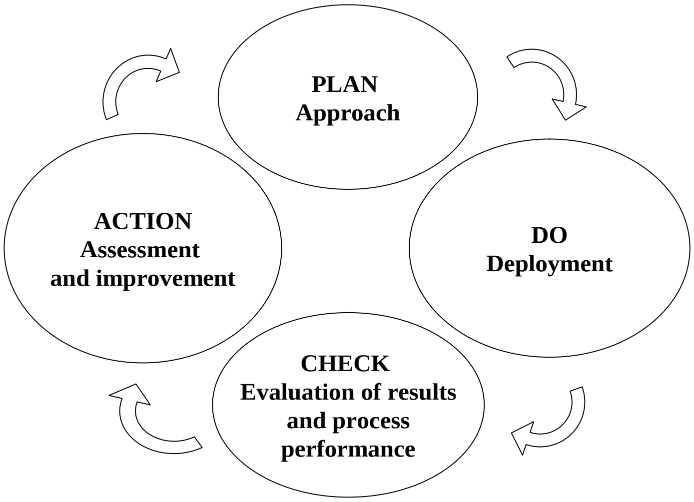
Figure 1 presents the quality cycle of continuous improvement. The approach is about planning what will be done and how it will be done. Deployment is about how to implement these plans. The results are the consequences of these actions. At this point, the results may be accepted as such and no changes are made to the approach or deployment. Often results are unsatisfactory and objectives have not been achieved. Then a systematic reflection about what approach and deployment led to these results may suggest useful improvement measures (Woodhouse, 2003).

MAIN FOCUS OF THE ARTICLE

The Quality Map

The concept of the quality map is introduced to describe the quality assurance of an organization. The quality map is a visual representation of the cause-and-effect relationships among the objectives of education policy, regional strategies and the institutional strategic plans. It provides an insight into the management, personnel and stakeholders to understand the main elements of quality assurance. The quality map is a graphical representation of quality assurance. We have

Figure 1. Quality cycle of continuous improvement



developed the concept of a quality map from the strategy maps introduced by Kaplan and Norton (2004). A quality map describes the essential characteristics of the quality assurance system like a road map, but omits all the minor details.

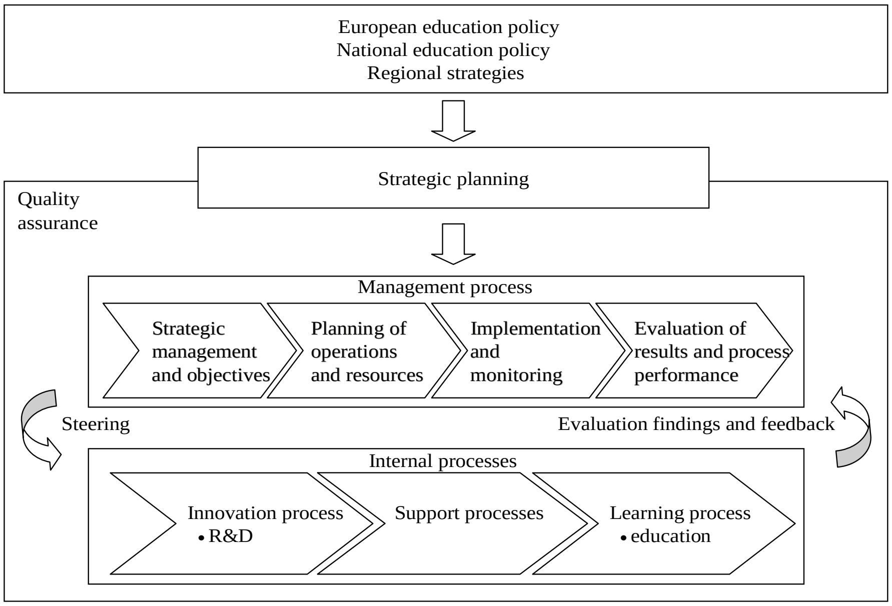
Figure 2 describes the quality map of the TUAS. The quality map shows that quality assurance is a comprehensive concept including the strategic planning, the management process and the internal processes and structures of the organization. There is a continuous flow of communication and interaction between these elements. The description of the quality assurance system is an attempt to formalize the diffuse knowledge and context-sensitive procedures.

The management process includes sequential planning and management activities. They include the strategic management and objectives, the planning of operations and resources, implementation and monitoring, and finally, the evaluation of results and process performance. The strategy process produces the strategic objectives for the planning period. The operations of the internal processes are aligned with budgeting and human resources planning. The achievement of results is regularly monitored and ensured to achieve the desired objectives during the planning year. Finally, the achievement of objectives is evaluated and reported to stakeholders.

The main internal processes include the innovation process (research and development), support processes (support services) and education (teaching and learning processes). The strategic planning and quality assurance overlap. The involvement of students, members of the personnel and external stakeholders in strategic planning is an important means of quality assurance.

The linkages between the management process and internal processes describe the guidance and information flows which have to be taken into account in the continuous improvement of activities. The aim of the management process is to steer the development of internal processes. Another linkage is the feedback and evaluation results from different sources, which include students, employers and self-assessments. The action plans

Figure 2. The quality map of the TUAS



located in the MIS are used to collect and store the steering information and development steps which may be based on self-assessment, feedback, or external evaluation.

The Management Information System

Without proper management tools it would be nearly impossible for administrators and evaluators to know how well the institution, department, or program is performing. The introduction of the balanced scorecard approach in 2002 laid the foundation for developing the management information system at the TUAS. Balanced scorecards were planned for all the administrative units of the institution. It was evident from the beginning that without any proper tools the maintenance of the scorecards was troublesome. The consistent aggregation of the scorecards to the upper organizational level needed automation. The data collection from the various data sources also needed automation. It was evident that the new MIS would provide clear benefits as required generally for development projects of this kind (Galliers & Sutherland, 1991; Galliers, Swatman, & Swatman, 1995).

The development and description of the management process started at the beginning of 2004. The entire management process was described in detail. About 700 concepts were defined and the data model was developed. More detailed process descriptions and specifications for the services provided by the portal were written to facilitate the automation of the process. It is important that the management process be entirely developed and described before the planning of the information system. It is also important that there is a well-defined and widely used approach to communicate and implement the strategic plans. The balanced scorecard approach clearly fulfills this requirement (Kettunen, 2004, 2005; Kettunen & Kantola, 2005). The first services of the portal were launched in the autumn of 2005 and the implementation continued through 2006.

The MIS portal was developed to support the management process. The members of the personnel have diverse user rights and roles in the interactive management tool. The administrative units are able to draft their strategic plans, action plans, budgets and human resources plans. The action plan of the units is important, because it describes the implementation of the strategic plan, timetables and responsibilities. The action plan also defines the development steps based on the evaluative information produced by the quality assurance system. The portal has been planned to be accessible to the personnel and to make the strategic planning understandable. The portal takes advantage of the data warehouse.

Data warehousing effectively utilizes the various data sources including personnel administration, financial planning, and student and study registers. The data warehouse captures data from data sources, makes transformations, and directs data to an integrated database (Guan, Nunez, & Welsh, 2002; Inmon, 1996). Sometimes these are called extract, transform and load (ETL) processes. Before the introduction of the data warehouse, the data were scattered and undocumented. Data collection was also unreliable because it was to a large extent collected manually from separate data sources or personal files.

The Management Information System Integrates Strategic Planning and Quality Assurance

The MIS is an electronic platform which effectively integrates the elements of strategic planning and quality assurance. The MIS provides strategic plans which are then implemented using the action plans and the tools for budgeting and human resources planning. This is evident when one compares the stages of the quality cycle (Figure 1) with the tools of the MIS portal. The strategic and action plans represent the approach stage of the cycle. The action plan contains reliable quantitative information about results and process performance. This information strongly supports management in the search for strengths and weaknesses. The MIS portal can be seen as an evaluation tool which supports the evaluation of the results stage of the quality cycle.

The action plan includes not only information about process performance but also about how to improve processes. The development steps on the basis of assessment are decided by the management at each institutional level. At the TUAS, the development steps are stored in the MIS as part of the action plans of the institution, its faculties and programmes. This is an illustration of how the portal supports the assessment and improvement stage of the quality cycle.

The action plan must identify the strategic initiatives and development steps at different organizational levels. The action plan must identify the timetables and individuals responsible for the planned tasks. All in all, the action plan is an electronic document where the implementation of strategic plans and development steps of quality assurance meet.

The effectiveness of strategic planning and quality assurance is crucial in how the strategic initiatives and development steps based on the evaluations and feedback can be integrated into the core institutional processes and functions. It is evident that these two approaches of management are most efficient when they are transformed into action close to teaching and learning. These approaches should be implemented at the different organizational levels of the institutions including the departments, degree programmes, teachers and students. Strategic planning and quality assurance must be implemented in the action plan, curriculum, course implementation plans, teacher workload plans and personal study plans of students.

FUTURE TRENDS

An obvious future trend is that electronic tools will be widely used in supporting the management process. The strategic plan is updated every fourth year at the TUAS, but the implementation of the strategy and detailed planning of activities are annually performed following the management process. The measures describing the strategic objectives are updated annually using the MIS portal and agreed in the internal target discussions. These group negotiations are led by the Rector and have strong steering elements, because the tasks are directly derived from the strategic objectives and written into the action plans. The target values of the measures are updated and agreed in these target discussions.

The second obvious trend is the harmonization of the MISs in the different HEIs. There are plans to collect a database of the process descriptions among Finnish universities. The concepts related to institutional management have also been defined and collected. A vision has been presented in the working group of the Ministry of Education that a national data warehouse should be planned to collect the information on students, degrees and ECTS credits in a common database to facilitate student mobility. There is also a need to integrate the national statistical databases of the universities and universities of applied sciences, which are separate nowadays and have different structures.

CONCLUSION

The concept of the quality map was introduced in this chapter to describe the integration of strategic management and quality assurance. The quality map is a visual description of how education policy and regional strategies are used to define the strategic objectives of the institution. The strategy map also describes the management process and the main internal processes of the institution. The visual representation of quality assurance helps the management, employees and stakeholders of an organization to understand the main elements and linkages of quality assurance.

This chapter shows that the different approaches of management can be integrated using an MIS. An advantage of the electronic management tool is that it supports the management process and the internal activities of the organization. It is a virtual platform for consistent strategic planning in the different organizational units. It is also a platform for quality assurance based on internal and external evaluations. This study also supports the view that the balanced scorecard is a useful tool for the basis of the MIS and the integration of different management approaches and tools.

The open MIS increases strategic awareness among managers and members of the personnel. The integration of management approaches and the alignment of the strategic objectives in the different organizational units help management to create a shared understanding among the personnel about the implementation of the strategic plan and the development steps based on the information produced by the quality assurance system.

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KEY TERMS

Balanced Scorecard: The balanced scorecard approach is a framework for the communication and implementation of the strategy. The balanced scorecard approach translates the strategy of an organization into tangible objectives and measures and balances them typically into four different perspectives: customers, financial outcomes, internal processes, and learning.

Higher Education Institution: Higher education institutions include traditional scientific universities and professional-oriented institutions, which are called universities of applied sciences or polytechnics.

Management Information System: A proper management information system presupposes modelling the entire management process and tailoring all the necessary components of the information technology support system to meet the needs of the organization. The management information system should include a description and measures of how the strategic objectives will be achieved.

Quality Assurance: Assurance of quality in higher education is the process of establishing stakeholder confidence that provision (input, process and outcomes) fulfills expectations or measures up to threshold minimum requirements. Quality assurance refers to the procedures, processes and systems that safeguard and improve the quality of a HEI, its education and other activities.

Quality Enhancement: Enhancement is a process of improvement. In relation to higher education quality, enhancement may refer to: (1) individual learners when it means improvement of the attributes, knowledge, ability, skills, and potential of learners; (2) the improvement in the quality of an institution or study programme.

Quality Management: Quality management emphasises the importance of management's commitment to quality. Quality must be managed; it does not just happen.

Strategic Management: Strategic management is a matter of bridge building between the perceived present situation and the desired future situation. Strategy implies the movement of an organization from its present position, described by the mission, to a desirable but uncertain future position, described by the vision.

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Chapter 7.4

Information Feedback Approach for Maintaining Service Quality in Supply Chain Management

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ABSTRACT

Maintaining the service quality in a supply chain has become a challenging task with increased complexity and number of players down the line. Often several supply chains cross over the common resources, calling for the sharing of resources and prioritization. This leads to the definition of pre-specified service quality as seen by the end user of the supply chain. In this chapter, a feedback mechanism that conveys the status of the supply line starting from the tail end is discussed. The advantages of using a predicted and shifted slippage or loss rate as the feedback signal are highlighted. Based on the feedback, the source is expected to change the rate of transfer of the commodity over the supply chain. With this, the resources would get utilized effectively, reducing the stranded time of the commodity down the line. The service quality in terms of delay and loss rate gets improved.

INTRODUCTION

The enormous business size in recent days call for distributed supply units to be located across the globe and connected through a sophisticated network. Throughout this work, these isolated business structures are referred to as mobile business units. They resemble the distributed computing environment in the sense that a time-bound, constraint-based command, signal, and information get exchanged among them.

In this work the concept of differential feedback is explored for the effective utilization of the information for the communication among the members of the supply chain. The model that translates individual behavior to the collective behavior of the chain is given. The resource contention for communication along the chain is addressed and the solution is modeled.

Maintaining a constant agreed ratio of defects or losses—quality of service (QoS)—in a supply chain is often tricky. The problem gets further complicated when the supply chain contains multiple source streams. In this work, a differential feedback-based model has been developed to predict the defects or losses. A shifted version of the same will be used as a feedback signal. Simulation results show that the number of defects observed at any point in the supply chain gets reduces with the shifted feedback signal. With the defects getting reduced, for a given demand at any point down the supply chain, the quantum of input may be reduced with differential feedback to achieve the same performance. The defense supply and deployment into the battlefield, the fair mixing of reactants in a chemical reaction chamber, and so forth stand as good examples.

The shifted feedback information from the end user or any other intermediate player in the line may be used to achieve some additional quality of service deadlines such as the absolute delay guarantee, fraction of the service loss, and so forth. The same would be agreed up on with the different units down the line, well in advance. Simulation results prove that the usage of shifted signals can stabilize the QoS and improve the service quality in terms of overall successful operations in a given time. This reduces the stranded time of the information or loss along the supply chain.

Analysis shows that a system exhibits self-similarity to maximize the entropy (Manjunath & Gurumurthy, 2005a). It is proved that, to maximize entropy, the system makes use of differential feedback of different degrees. They form various levels of abstraction and by and large carry redundant information (Manjunath & Gurumurthy, 2005a). The self-similar property has been exploited here to maintain the quality of service constraints

Because of abstraction and redundancy, even if a portion of the information is lost or if it is required to predict the future uncertainties with minimum available information, it can be repaired or re-synthesized using the available information.

The self-similar property of the component induces interesting properties into the system. This property may be used as lead-lag components in controlling the information transfer over the network. Closed-loop feedback is utilized to control the signals transferred over the network. Intermediate self-similar structures or switches may modulate feedback signals and control the system behavior.

In order to meet the real-time transfer of the signal, stringent service quality parameters are defined over the data transfers down the supply chain. This chapter provides techniques to meet these requirements with minimal resources. In-time flow of the commodities to the end user is the basic requirement in a supply chain. The tools and techniques used to meet this goal are different in different supply chains. The example of real-time transfer of information for the end user is considered throughout this chapter. The supply chain involves various routers, switches, and media in between. The goal is to get the real-time performance in the chain with minimal retransmissions. The concepts may be easily extended to any other form of supply chain.

A supply chain has four areas of decision: location, production, inventory, and transportation or distribution. It is known that the rate of production bears a direct relation with the rate of consumption. However, the other factors during the transportation, such as the influence of adjacent supply chains and the stranded time of commodities within the chain, need to be considered. In this chapter, these factors are explained in depth.

Simulation plays an important role in the modeling of a supply chain before it becomes operational. It provides a closer look at the issues that may crop up in a supply chain and handle them appropriately during the implementation.

Supply chains have to make two categories of decisions—he long-term strategic and short-term operational decisions. A lot of data is required for making decisions. A model-based approach is extremely helpful to reduce the sample size. The model consists of an auto regressive (AR) and a moving average (MA) part. The ARMA followed by a non-linear limiter can enhance the predictability in the data set. The model described here is called differentially fed artificial neural network (DANN) (Manjunath & Gurumurthy, 2002) and is a variant of ANN.

BACKGROUND

A supply chain is basically a network from production to the consumption, involving the producer, the end consumer, and the intermediate distribution agents or brokers. The underlying philosophy of a supply chain exists in diverse fields such as manufacturing industries, the troops deployed in the battlefield, and so forth.

In an industrial supply chain, the material undergoes changes metamorphically along the chain. The models that describe the supply chain are very specific in nature. In this work a more generic approach has been taken.

The literature in supply chain management dates back to the work of Geoffrion and Graves (1974). Their work describes an optimal flow of multi-commodity logistics from the plants to the end users. This model is further explored in Geoffrion and Powers (1995) as a review of the evolution of the distribution strategies.

In the supply chain the intervening agents can have distinct characteristics.

Cohen and Lee (1985) gave a framework for manufacturing strategy analysis, with several stochastic sub-models describing the supply chain. Finally these sub-models got integrated heuristically, which they presented in Cohen and Lee (1988). The other successful implementation of the supply chain model is at General Motors by Breitman and Lucas (1987). The optimal resource utilization in a supply chain has been considered by the work of Cohen and Lee (1989). Another cost and time optimization model has been considered in Arntzen, Brown, Harrison, and Trafton (1995).

Differential feedback of the status of the commodity that flows along the supply chain improves the performance of the supply chain. Here the differential feedback model is introduced (Manjunath, 2004).

The different components of an organization, such as marketing, distribution, planning, and production in the supply chain, operate quite independently with their own agendas and priorities. The marketing department targets maximum profit while the production division calls for more investment. The scientific way of bringing together these conflicting goals is the theme of supply chain management.

The real-time supply chain solution has to provide up-to-the-minute information for the end user. Hence the quality of the information is very important. The system cannot afford to undo the implications of usage of information of bad quality or transmit the data again. Stringent service quality parameters are imposed over the supply chain. Especially when multiple chains pass through the common resources in between, priority would come into the picture for the logical sharing of the resources.

INFORMATION FEEDBACK FOR SUPPLY CHAIN

When feedback information—that is, the information to the source about the status at the tail end of the supply chain—is provided, the system starts exhibiting interesting behavior (Manjunath & Gurumurthy, 2002). As a result of feedback that uses a set of previous values, the feedback signal exhibits multi-resolution property. That is, the output signal can be expressed as a weighted sum of a set of orthogonal signals, each of which is a replica of the other but for a scale (Manjunath & Gurumurthy, 2003). These replicas are called hyperplanes, as they form a linear transformation in the hyperspace. Any of these hyperplanes may be obtained from the other plane by convolving with a Gaussian pulse of appropriate scale factor.

The architecture is based on feedforward and feedback paths. The feedforward path consists of the actual information or data or commodity flow departing from the source depending up on the simulation application. It is data packets in a communication network, a commodity in a product supply chain, and investment in a finance supply chain. The feedback signal comprises the position and status of the commodity or information as observed at the destination. The differentially fed neural network sits as a controller in the loop comprising the source, the forward path, the destination, and the feedback path.

The presence of such a controller imparts all of its properties to the system. That is, the supply chain on either direction behaves as a system with differential feedback provided.

In general, when a controller is used as an estimator, it starts throwing the output depending up on the underlying algorithm and decision rules. An ideal estimator gives the weighted sum of the outputs from the different estimators. When the differentially fed controller is used as an estimator, there will be different output for each order of the differential feedback. The ideal controller is the one that corresponds to infinite ordered feedback. As the order of differential feedback is increased, it starts moving closer to the ideal estimator. Also, any of the estimators may be expressed as the weighted sum of other estimators.

The feedback information in a supply chain results in the reduction or increase of the source operation rate. It in turn helps in proper supply line scheduling. Based on the congestion status, different congestion control algorithms are used. Each one of them may be thought of as an estimator. A DANN works as an ideal estimator to replace all of them.

Since the differentially fed artificial neural network is a part of the loop, its presence has profound effect on the traffic in the loop. Traffic here refers to the movement of the commodity or the like. The DANNs make use of a large number of previous samples for decision making. Decisions thrown out by such a system contribute to long-range dependency in the movement of the commodity or the traffic. The abstract levels of hyperplanes of DANN contribute to self-similarity of the traffic when observed over different time scales.

In essence, insertion of DANN in the traffic loop makes the entire network behave as a differentially fed neural network, manifesting all its properties. The network here refers to the forward and feedback paths. Hence DANNs play a role more than replacing the conventional ANNs in traffic shaping. The traffic shaping involves maintaining the schedules, reduction in the delays, and reduction in stranded times or reschedules, while keeping up the agreed service parameters.

A multi-bit closed-loop feedback mechanism is assumed here, with the bits representing the drop or failure probability and express congestion status of the network. The notification signal or feedback signal is time shifted to get better performance. This algorithm is called random early prediction (REP) (Manjunath, 2004). Generally, feedback-based control is used in systems that need precise adaptive control. Any mismatch in the feedback would drive the system into an unstable region.

Models of the traffic are critical in providing a high quality of service. The complexity of traffic in a network is a natural consequence of integrating diverse ranges of members from different sources that significantly differ in their traffic patterns as well as their performance requirements over the same path.

Shifted Feedback in Data Network Supply Chain

The similarities between supply chain model and the data propagation over a network are exploited in this section. Basically the data network is a particular form of the supply chain. The concept developed with the networks is applicable for all variants of the chain. This perception throws all the associated problems of the network on to the supply chain. Consider two different classes of the data flow. It may be generalized for multiple classes. The relative service parameters come into the picture when the different classes of the flow contend for the common resources such as the operating path, buffering space, or docking space that tend to get choked and require the maintenance of a fixed ratio of the flow members.

The resource status in a network may be simulated with the DANN included. The application of a DANN component in network traffic shaping may be studied with this setup, and the parameters of the DANN may be fine tuned until the desired response is achieved. The simulations are basically used to analyze and tune the quality of service metrics and allow exploring different implementation options by conducting experiments.

The simulation setup and the underlying methodology is valid for other supply chains as well.

In the proposed scheme the predicted version of the probability of cell loss is given as feedback to the source. The DANN gets the training data from the background RED algorithm. For some time, the DANN will be in a learning phase. It then predicts the data and arbitrary k steps in advance. This is provided as the feedback signal to the source. The source then re-computes the transmission rate. It may be seen that the cell loss ratio has been reduced with feedback.

In a simulation, 42 data points computed with RED are used for training. The input consists of 20 sources supporting background traffic that exist over the entire simulation time. The maximum buffer size is 8,000 and the cell size is 512. The total cell loss ratio of an ordinary RED scheme is found to be 1.6. With a neural network prediction, it has been reduced to 0.05, and in a first-order differentially fed neural network, it is reduced further to 0.04.

It is desirable to keep the variance of the resource occupancy less. The variance can be brought down with the increase of the differential feedback order. The use of a differentially fed artificial neural network in Web traffic shaping has been explained at length in Manjunath (2006). As the order of differential feedback increases, the error reduces.

The proposed input rate prediction process captures the actual input traffic rate reasonably well. In the steady state, the average queue size changes more slowly compared to the instantaneous queue size. This means that the proposed active queue management method is successful in controlling the average size at the router in response to a dynamically changing load, and there is no global synchronization among the sources. There will be some large variation of mean queue length during the initialization phase. This is because it is assumed that the queue is initially empty and it takes some time for the proposed scheme to operate correctly.

Because the proposed scheme randomly drops incoming packets according to the severity of the incipient congestion, there is no global synchronization. The large variation of the transient queue size is due to the bursty input traffic.

With the number of traffic sources that exist from the start to end of the simulation increasing from 20 to 80, the total probability of cell loss or area under the error signal remains the same. However, the variance of the queue length is considerably reduced with the proposed scheme. The reduction in the variance is more pronounced with large traffic.

The variance will be reduced with increase in the prediction. This happens for some time. Again the variance shows upward trend. This is because the autocorrelation function of a long-range dependent series exhibits oscillations. As the number of sources increases, LRD is more pronounced, with peaks of correlation separated far apart.

RED detects incipient congestion by calculating the average queue size at each packet arrival. In other words, in RED, congestion detection and the packet drop are performed in a small time scale. On the contrary, in the case of the proposed scheme, the congestion detection and the packet drop are performed at different time scales. When network congestion occurs, it takes some time for a traffic source to detect the congestion and reduce sending rate to resolve the congestion situation.

The shift for which further increase of shift shows a reverse trend in the variance increases with the increase in the load.

The proposed scheme can reduce the time for a traffic source to detect congestion, because the congestion detection is determined in a large time scale. In case an incipient congestion is detected at a large time scale and a packet is lost within a sequence of packets, the successfully delivered packets following the lost packets will cause the receiver to generate a duplicate acknowledgement ACK. The reception of these duplicate ACKs is a signal of packet loss at the sender. So, the traffic sources can detect incipient congestion before it really occurs.

By using the proposed scheme, the source can respond to the incipient congestion signal faster than in the case of using RED gateway. Therefore, both the average queue length and the variation of the average queue length are smaller when the gateway uses the active queue management scheme proposed in this chapter rather than when the gateway uses RED. Because the proposed active queue management scheme can control the average queue size and the variation of the average queue size while accommodating transient bursty input traffic, it is well suited to provide high throughput, low average delay, and low average jitter in high-speed networks.

The variance of queue is found to vary linearly with the shift given to the feedback signal for different traffic loads. This confirms the existence of a constant term in the variance modulated by a variable term. The slope is independent of the load, while the constant depends on it.

Since the variance can be written as variance = k_1+k_2/shift, k_1 and k_2 being constants, the plot of variance against the reciprocal of shift is a straight line. The constant variance term represents the bias. The second term happens to be the multi-resolution decomposition of variance and is the sum of n terms, n being the order of differential. By the weighted averaging of hyperplanes, the two parts in the second term can be replaced by a single term of highest degree or shift**.** The plot of variance against load also behaves similar to variance against the shift. In both cases, the variance initially gets reduced and later increases.

The growth of buffer size is a reflection of the efficiency of the algorithm followed in routing the cells. When differential feedback concept is applied, the maximum buffer occupancy is reduced, resulting in reduced cell loss. Depending on the network condition and the kind of traffic, an appropriate algorithm or rule may be applied for packet scheduling and discard. A set of ANNs, each learning a different scheduling algorithm, may be used. Any of them may be triggered based on the cost function, once again decided by another ANN. Each scheduling algorithm is an estimator. A single differentially fed ANN may be used since an ideal estimator can replace all the Bayesian estimators. A differentially fed neural network can merge and learn the multiple rules in one shot. It results in reduced hardware as well as improved switching efficiency in routing of the cells. It may be observed that the differentially fed ANN-based estimator outperforms the multiple scheduling schemes.

The past history associated with the differential feedback imparts a kind of long-range dependency in the output. With this, the switch performance is found to be better in terms of maximum buffer size and the total time to flush the cells. The proposed algorithm is independent of the underlying scheduling algorithm. Green is another standard scheduling algorithm like RED. The proposed algorithm of random early prediction works well with Green. For small shift, variance is reduced with not much change in the cell loss. It is the reverse for large shifts.

The peak instantaneous value falls as the sources go off. When more sources come on, with shift, it builds slowly and thus reduces rapid fluctuations of Q size. When Q changes rapidly, queuing models do not work well.

When the optimization problem does not yield a solution, meaning that it is impossible to satisfy all service guarantees simultaneously, some of the QoS guarantees are selectively ignored, based on a precedence order specified in advance. Due to the form of the constraints, the optimization problem is non-linear and can be solved only numerically.

The computational cost of solving a non-linear optimization upon each arrival to the link under consideration may be prohibitive to consider the implementation of an optimization-based algorithm at high speeds. The REP algorithm is effective in providing proportional and absolute per-class QoS guarantees for delay and cancellation or reschedule. The closed-loop algorithm reacts immediately when the routes are going from underload to overload and reacts swiftly when the routes go from overload to underload. This indicates that the delay feedback loops used in the closed-loop algorithm are stable.

Proportional delay differentiation does not match the target proportional factors when the route is underloaded, due to the fact that the algorithms are work conserving and therefore cannot artificially generate delays when the load is small.

Results for ratios of delays indicate that proportional loss differentiation (i.e., schedule cancellation) is achieved when the outbound route is overloaded and traffic is dropped. However, it is not met in any of the algorithms when the queue falls to 0. This implies that the algorithms basically manipulate the queue of the flow members and scheduling of the members to meet the relative delay and loss guarantees. With this the REP feedback loops used in the closed-loop algorithm appear to be robust to variations in the offered load, and the results of the REP closed-loop algorithm are found to be better than the one without any shift.

The delays and losses experienced by classes are monitored. It allows the algorithm to infer a deviation compared to the expected service differentiation. The algorithm then adjusts service rate allocation and the drop rates to attenuate the difference between the service experienced and the service guaranteed. A prediction-based feedback control is used to achieve proportional delay differentiation. Absolute differentiation is expressed in terms of saturation constraints that limit the range of the controller. The control loop around an operating point is made stable through differential feedback, and a stability condition is derived on the linearized control loop. The stability condition gives useful guidelines for selecting the configuration parameter of the controller.

ISSUES AND SOLUTIONS

It is quite possible that the supply chains from the various producers to the consumers crisscross or intersect each other, calling for a kind of contention for the resources. The contention could be in various forms, in terms of financial investment or storage space.

The first step towards resolving this contention and optimizing the supply chains is to define service classes for each of the chains passing through the intermediate agents or the brokers. In addition, for each of the service classes, a set of quality parameters is defined. Both the absolute value and the relative value of these parameters are important for optimization. It is a requirement to keep the absolute parameters within a certain agreed limit and the relative parameters at a prespecified constant value. Various algorithms and implementation schemes exist considering the optimal utilization of resources.

In the REP method of meeting service quality parameters, a differentially fed artificial neural network is used as a system level controller.

The broker model, whereby the intermediate agents apparently shield the actual source from the destination and often act as virtual sources down the line, may be thought of as an extreme case of the supply chain. In such a scenario, the service quality constraints are to be met by all the agents in between.

The issues arising out of the transfer of commodity down the line and the solution based on shifted feedback were discussed separately in the previous section. The other issues in supply chain management (SCM) are highlighted here. Having a common goal among the players of the supply chain is a tough task. Each element down the line will have its own agenda. Appropriate common goals and interfaces need to be defined so that the individuals align themselves towards the goal. The interfacing can be meaningfully defined only if the units commit to adhere to some quality guideline. However, it requires some time.

Interoperability is a major issue in the communication along the supply line. It may be improved with a common protocol with a machine-independent language such as XML.

The language description would be bound to the commodity and would be interpreted by all the players along the line.

The SCM models are required to be scalable. The required scalability may be brought in with the help of a DANN. The model remains invariant with the inclusion of additional flows, the only change being that the loss rate would increase faster.

FUTURE TRENDS

The increased dimensions in the organization call for the usage of collaborative and Web-based technologies for data collection. The data handling and integration systems in a supply chain come with increased communication and quality capabilities. This happens through increased collaboration among the elements of the supply chain down the line.

Supply chain components make use of a variety of software. Integration of these components and software under one platform would gain momentum, paving a path for new software in the market.

The concept of distributed computing, multi-agent software and technology is getting in to the supply chain. The elements of the supply chain are quite often located at distinct physical and geographical locations. The data or commodity exchange among them can happen through a shift-based protocol. The protocols of distributed computing are expected to bring some order into the data exchange within the supply chain.

Advanced prediction of end user behavior would continue to contribute to the success of the manufacturing supply chain: it reduces the overhead on inventory. Further, development and usage of the customized prediction software tools as a part of the SCM suit would gain momentum. The usage of prediction of the health of the supply line has been explained in the previous sections.

Supply chain automation would be a common call in the future. The usage of automation software would enter into all forms of the supply chain. With the SCM software, it would be possible to automatically route the commodities all along the line. A variant of the software is electronic shopping, where the end user can directly negotiate with the distributor over the Internet and bypass the supply chain. This results in faster movement of the commodities. The Web services are coming along the supply chain. With this, it is possible for all players of the supply chain to get into a common platform and instantly interact over the Internet.

With supply chains involving digital contents, it is possible to specify the distribution patterns and rights through the associated meta-languages. The contents would be sold as commodities involving various middlemen like distributors and resellers, each having a specific rights over the contents.

The nature of the supply chain gets complex with the inclusion of more players. Often the chains would contain branches or mergers down the line. Some of the chains could include parallel paths in between and increase the complexity further. The SCM software has to consider all these scenarios.

CONCLUSION

The timely management of an end-to-end supply chain has become a challenging task in large and medium enterprises with distributed units scattered across the globe. In this chapter, the supply chain has been treated in a generic way, and no assumption has been made on the nature of the chain. It could be the data transferred over the Internet or the supply of arms to the ground troop deployed in the war field.

The different issues of the supply chain including the secure and timely movement of the commodities are addressed, and a solution has been sought based on a type of feedback from the tail of the supply chain to the head. The feedback includes a time-shifted version of the extrapolated loss or delay parameter of the commodity as seen by the destination. The feedback signal controls the overall flow in the supply chain.

The problem of resource contention at the intermediate nodes in the supply chain as a result of multiple flows has been defined, and the solution in terms of relative quality parameters has been explored.

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Chapter 7.5

Supplier Capabilities and eSourcing Relationships:

A Psychological Contract Perspective

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ABSTRACT

The forces of globalization have influenced organizations to extend the concept of IT outsourcing to IT-intensive business process outsourcing (eSourcing). Most of the research on managing outsourcing relationships has focused either on legal contracts or on strategic partnerships. Advocating a different viewpoint, researchers like Rousseau (1995) found that in reality everyday working of contractual relationships was governed by individual's subjective interpretation and was fundamentally psychological in nature. The objective of this paper is to posit a relationship step model which projects a vital relationship management capability plus psychological contract perspective for eSourcing. It incorporates the stance of relational contract, interorganizational relationship and psychological contract theories. Using the qualitative research paradigm, the research model is preliminarily explored with case studies of two eSourcing suppliers. The exploratory results of this research indicate that relationship management capability of suppliers is an important factor shaping the outsourcing value proposition. [Article copies are available for purchase from InfoSci-on-Demand.com]

INTRODUCTION

The concept of outsourcing has spread from traditional informational systems (IS) outsourcing structures into new outsourcing service configurations, like IT-intensive business processes. This kind of outsourcing has been defined as 'eSourcing' by Carnegie Mellon University's eSCM-SP. The primary drivers for this trend are increasing competitive pressures, a need to access world-class capabilities and a desire to share risks.

The eSourcing relationship begins with a contract between two parties - the client and the supplier. Both these parties must possess certain capabilities in order to make the engagement successful. Kern and Willcocks (2001) in their study on IT capabilities for clients found that supplier capabilities are critical for outsourcing success. Despite the growing interest in vendor capabilities, there has not been an in-depth examination of these capabilities and how they generate value in outsourcing relationships (Levina & Ross, 2003). Additionally, most of the prior research on outsourcing relationships has focused either on legal contracts or on advocating strategic partnerships for managing the relationship. But in reality, everyday working of contractual relationship is governed by individual's subjective interpretation, because all contracts, whether written or unwritten, are fundamentally psychological, i.e. existing in the eye of the beholder (Rousseau, 1995).

Rousseau's 1989 seminal research triggered much of the contemporary empirical work on the employment psychological contract. Adopting Rousseau's view, Koh, Ang and Straub (2004) have defined a new perspective on managing IT outsourcing relationships. They state that it is the individual's beliefs and perceptions of these obligations rather than written contract that drive their behavior. Hence to get a complete picture, it becomes relevant to view the sourcing relationships from the psychological contract perspective. Addressing these gaps, this paper aims to propose a relationship step model for eSourcing suppliers using a psychological contract lens. This study aims to explore how relationship management capabilities of suppliers help in fulfilling supplier obligations and hence add business value.

The paper proceeds as follows. In the next literature review section, we discuss the main concepts of the paper. We then move towards development of a model by delineating the theoretical foundations and the dimensions of relationship management capabilities. Next, we examine the relationship management capabilities via the psychological contract lens and posit a relationship step model for eSourcing suppliers. We then describe the methodology adopted for exploratory research and discuss the two case studies. We conclude with our initial findings, limitations and directions for future research.

LITERATURE REVIEW

eSourcing

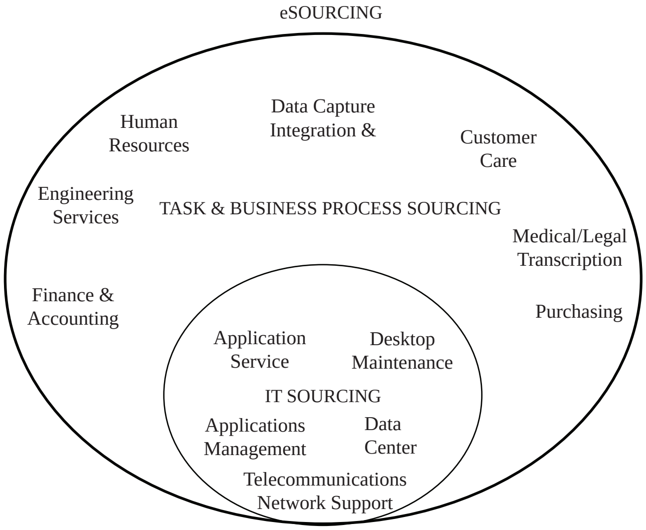
eSourcing or IT-intensive sourcing, uses information technology as a key component of service delivery or as an enabler for delivering services (Hyder, Heston & Paulk, 2004). It includes traditional IT sourcing, and task and business process sourcing (see Figure 1).

eSourcing is often provided remotely, using telecommunication or data networks. Carnegie Mellon University's eSCM-SP states that these services range from routine and non-critical tasks that are resource intensive and operational in nature to strategic processes that directly impact revenues. Adopting this view, we define eSourcing as "the delegation of one or more IT-intensive business processes to an external provider that, in turn owns, administers and manages the selected processes based on defined and measurable performance metrics."

Capabilities

Organizational capabilities are the abilities underlying high performance in specific spheres of business (Dawson, 2005). They are the result of deliberate investments in organizational structure and systems to make important improvements in those routines and practices (Zollo & Winter, 2002).

Figure 1. Types of eSourcing Services (Source- Hyder et al. 2004)



Client-Supplier Relationships

Outsourcing relationship can be defined as a state where client and supplier organizations are connected or related to via individual managers for the duration of the contract period of an outsourcing venture (Kern & Willcocks, 2001). A survey based study conducted by Goles (2001) highlights that higher vendor-client alignment, teamwork, balance of control, and process agility in the relationship will lead to more successful outcomes. Most of the research on managing outsourcing relationships has focused either on legal contract, with tight contractual mechanisms recommended to reduce opportunistic behaviors (Ang & Beath, 1993; Lacity & Hirschheim, 1993) or on advocating strategic partnerships for managing the relationship (Kern & Willcocks, 2001). *Relationship management* depends on carefully planning and formulating the contract, devising operational structures, outlining the interactions and leveraging and forming relational behaviors (Kern & Willcocks, 2001). From literature we learn that informal (interpersonal trust) and formal (contractual) aspects of the relationship are equally important (Poppo, 2002; Sabherwal, 1999) and need to be developed (Levina & Ross, 2003).

Business Value

IS research on the value generation potential of an outsourcing relationship has considered three factors: client characteristics, vendor characteristics, and the vendor-client relationship (Goles, 2001). An important factor shaping the outsourcing value proposition is the vendor's own capabilities (Goles, 2001; Saunders, Gebelt & Hu, 1997). Thus from the supplier perspective, business value addition would depend, to a great extent, upon the relationship management capabilities.

Business value addition can be operationalized via overall *satisfaction* with the contract, the *desire to retain* the outsourcing partner (Saunders, Gebelt & Hu, 1997) and increase in the level of *trust* (Lee & Kim 1999). Satisfaction is a common measure of success in IT outsourcing research (Susaria, Barua & Whinston, 2003; Koh, Ang & Straub, 2004), and is used as a proxy for the perceived effectiveness of the relationship. Satisfaction is also predictive of future actions (Poppo & Lacity 2002), and is closely related to the parties' intention to continue the relationship, either in the current contract or in subsequent repurchase (Koh, Ang & Straub, 2004). Also, it is more costly for suppliers to acquire new customers than to retain existing ones (Koh, Ang & Straub, 2004).

Trust is an indicator of partnership quality (Lee & Kim, 1999) and can be used to measure business value addition as the increase in the level of trust is more likely to result in the increase in the success of the relationship. Trust has been defined by Mayer, Davis and Schoorman (1995) as the "willingness of a party to be vulnerable to the actions of another party, based upon expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party". In simple words it is an expectation that a certain party can be relied upon even if there is a possibility of opportunism. Trust is rather an abstract and intuitive construct which is individual centric and is likely to have psychological connotations.

THEORETICAL FOUNDATIONS

Client and supplier relationships can be studied from varied theoretical perspectives. In this research paper we focus on three theories from literature. These are – relational contract theory (RCT), interorganizational relationship (IOR) theory and psychological contract theory. Together these theories cover an organizational, behavioral, legal and psychological perspective of the sourcing relationship:

i. **Relational Contract Theory (RCT):** RCT states that all contracts include contractual relations (Macneil, 1974). The core of the theory contains two key elements: the description of contract behaviors, which are the norms that arise in exchange relations and the dimensions of contract discreetness, which can be from discrete to relational.

ii. **Interorganizational Relationship Theory (IOR):** IOR is concerned with the reasons and conditions for forming relationships (including socio-political and economic aspects) and their structural behavioral and process dimensions (Oliver, 1990; Van de Ven & Ring, 1994). IOR theory provides a useful approach for understanding and analyzing the causes and conditions for the formation of a relationship, and the structural behavioral and interaction dimensions (Kern & Willcocks, 2001).

iii. **Psychological Contract Theory:** A psychological contract refers to an individual's mental beliefs about his or her mutual obligations in a contractual relationship (Rousseau, 1995). Koh, Ang and Straub (2004) assert that a psychological contract perspective offers a more inclusive view of mutual obligations between the contracting parties in outsourcing. Mutual obligations imply that the supplier agrees to make specific contributions to the customer in return for certain benefits from the customer. Their research findings highlight that fulfilling customer-supplier obligations explained a significant amount of variance in outsourcing success.

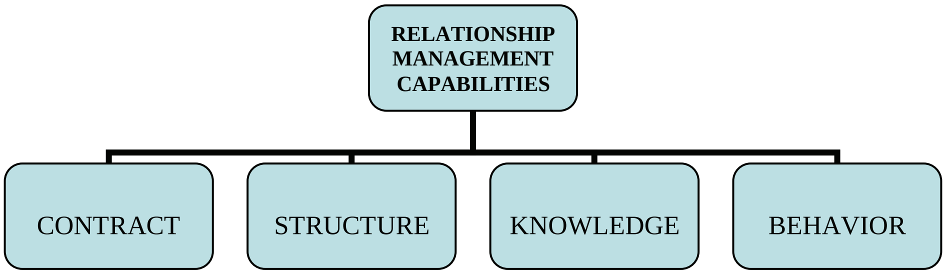
TOWARDS DEVELOPMENT OF A RELATIONSHIP STEP MODEL

Relationship Management Capabilities

We extend and adapt some of the IT outsourcing relational dimensions, identified by Kern and Willcocks (2001), to eSourcing relationships and posit the following four dimensions of relationship management capabilities of eSourcing suppliers (see Figure2).

i. **Contract:** Contracts are essentially vehicles for 'relational development' (Macaulay, 1963). RCT offers the theoretical foundation for investigating the contract dimension of eSourcing relationships. Ang and Beath (1993) in their study of outsourcing contracts demonstrate that unlike the sug-

Figure 2. Relationship management capabilities of eSourcing suppliers



gestions of discrete contracts, parties in real-life dynamically interact, commit to, and reinterpret their agreements with one another to assure necessary flexibility. Further, depending upon the complexity of the contract, anticipating all future events and covering them by making them present is impossible (Macneil, 1974).

ii. **Structure:** IOR theory offers a lens for examining the structural dimension of an eSourcing relationship. Buyer-supplier relationships entail a set of structural properties such as, size, centralization, specialization and configuration (Hakansson & Snehota, 1995). In outsourcing several individuals from different functional areas, at different levels in hierarchy, and fulfilling different roles generally become involved (Kern & Willcocks, 2001). Therefore, the interface points of the supplier and customer should be clearly defined. For the supplier interface roles of SLA management, leadership and business understanding are critical for coordinating, developing and facilitating the relationship (Kern & Willcocks, 2001).

iii. **Knowledge:** IOR theory says that exchange is the dominant process underpinning interorganizational relations (Kern & Willcocks, 2001). Exchange does not necessarily involve elements of economic value, but may also include services, information and knowledge. The knowledge dimension can be described in terms of sharing service related knowledge and industry best practices with the client.

iv. **Behavior:** Both RCT and IOR theories identify the major elements in representing behaviors in interorganizational relationships. Interactions among cooperating parties may cast a positive, neutral, or negative overtone on the relationship, influencing the parties' behaviors toward each other (Kern & Willcocks, 2001). The behavior dimension can be described in terms of taking ownership, supplier-client business goal alignment and a good working relationship.

Applying the Perspective of Psychological Contract

Psychological contract theory focuses on the contracting parties' mental beliefs and expectations. Using grounded theory approach Koh, Ang and Straub (2004) generated a list of customer-supplier obligations and identified six major components of what clients' believe are supplier obligations (see Table 1).

The supplier obligations were drawn from the customer sources and they point out precisely '**what the customers expects**' from their suppliers. If the supplier is able to fulfill these obligations it is more likely to lead to customer satisfaction. This would in turn help in adding business value. Next, we map the supplier obligations with the relationship management capabilities required to fulfill these obligations (see Table 2).

Table 1. Supplier obligations (psychological contract dimension)

	Supplier Obligations (Psychological Contract Dimension)
1.	**Project Scoping:** Clear definition of the nature and range of the services covered in the contract and flexibility in handling clients' requests for changes in the scope of the services
2.	**Clear Authority Structures:** Delineation of the decision-making rights and reporting structures in the project, in terms of the roles and responsibilities of all the parties involved.
3.	**Dedicated Project Staffing:** Assignment of high quality staff to work on the project, and minimization of staff turnover during the project.
4.	**Effective Knowledge Transfer:** Educating clients in terms of the necessary skills, knowledge, and expertise associated with using the outsourced system or service.
5.	**Taking Charge:** Completing the job and solving problems independently, with minimal customer involvement.
6.	**Building effective interorganizational teams:** Investing time and effort to foster a good working relationship among the team of customer and supplier staff working on the project

Table 2. Mapping relationship management capabilities with supplier obligations

Relationship Management Capability	Supplier Obligation(Psychological Contract Dimension)
1. Contract	1. Project Scoping & Flexibility
2. Structure	2. Clear Authority Structures 3. Dedicated Project Staffing
3. Knowledge	4. Effective Knowledge Sharing & Transfer
4. Behavior	5. Taking Charge 6. Building Effective Interorganizational Teams

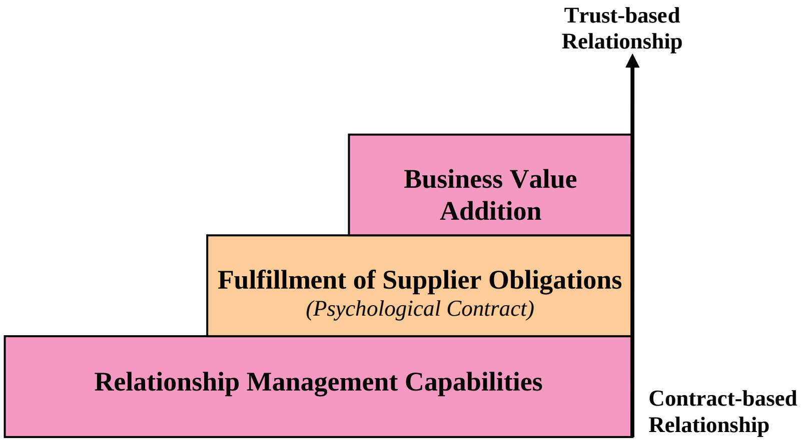
Contract capability is required to fulfill project scoping and flexibility obligation. Structure capability is required to fulfill clear authority structures and dedicated project staffing obligations. Knowledge capability is required to fulfill effective knowledge sharing and transfer obligation. Finally, behavior capability is required to fulfill taking charge and building effective interorganizational team obligations.

Relationship Step Model for eSourcing Suppliers

After combining the relational capabilities and psychological contract dimensions we posit that eSourcing suppliers possessing relationship management capabilities (input) are more likely to fulfill supplier obligations (intermediate outcome). As a result, the service provider will be more likely to achieve business value addition (final outcome). Figure 3 displays the relationship step model for eSourcing suppliers.

The first step is the achievement of relationship management capabilities. These relationship management capabilities would help the service provider to proceed to the second step of the model, which is the fulfillment of supplier obligations (intermediate outcome). After fulfilling the supplier obligations, the service provider ascends to the third step of the model, which is the achievement of business value addition (final outcome). As we move up in the vertical axis, the level of relationship also increases from a contract-based relationship to a trust-based relationship between the service provider and the client.

Figure 3. Relationship step model for eSourcing suppliers



METHODOLOGY

Case study research method was adopted for this study to carry out two exploratory case studies. Case study has been a common and widely accepted research strategy in psychology, sociology, political science, social work (Gilgun, 1994) and business (Ghauri & Gronhaug, 2002; Yin, 2003). Yin defines case study as an empirical inquiry to investigate a contemporary phenomenon within its real life context. Following Yin's (2003) approach, we included all the five components of research design:

i. Research Questions (RQ)
  RQ1: How do the relationship management capabilities help in fulfilling the supplier obligations (psychological contract dimension)?
  RQ2: How does the fulfillment of supplier obligations help in adding business value for the suppliers?
ii. Research Propositions (RP)
  RP1: eSourcing suppliers who possess relationship management capabilities are more likely to fulfill supplier obligations.
  RP2: eSourcing suppliers who fulfill supplier obligations are more likely to achieve business value addition.
iii. *Unit of Analysis*: a relationship/engagement between the supplier and the client
iv. *Logical linking of data collected with the propositions*: pattern matching
v. *Criteria for interpreting the findings*- logic model for analyzing case study evidence

DATA COLLECTION

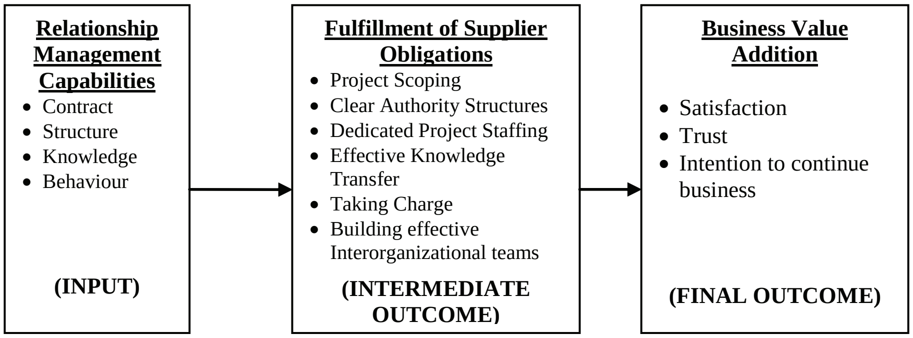
In the last decade, the information technology and business process outsourcing industries have seen substantial offshoring. Two eSourcing suppliers were selected from India for the purpose of data collection. India has established itself as a popular outsourcing destination as it offers and delivers the best 'bundle' of benefits sought from global sourcing (NASSCOM, 2006; Yadav, Bhardwaj & Saxena, 2006). India has successfully leveraged its advantages of abundant talent, a keen focus on quality and low costs coupled with an enabling business environment to attain leadership position in the global sourcing space ((NASSCOM, 2006). According to NASSCOM's report India accounts for 65 per cent of the global industry in offshore IT and 46 per cent of the global Business Process Offshoring (BPO) industry. Given trends in globalization and the increasing prevalence of offshore outsourcing (Carmel & Agarwal, 2002) and the relative dearth of eSourcing research outside the United States and selected parts of Europe (Barthelemy & Geyer, 2001; Koh, Ang & Straub, 2004), we believe that this dataset is useful in helping the Information Systems (IS) community understand eSourcing practices in other countries like India.

The two organizations selected for the study are well-established eSourcing suppliers based around the National Capital Region of India. Both service different domains- one provides knowledge-intensive eSourcing services in the Telecom domain and the other provides operational eSourcing services in the Travel Services domain. Their clients are located in USA. Due to high level of confidentiality and legal clauses involved in offshore outsourcing contracts the names of the organizations have been disguised in the paper. Hence in the rest of this paper Travel Services supplier will be addressed as *TravelWiz* and Telecom Services supplier will be addressed as *TeleWiz*.

We conducted interviews with the senior level managers from operations, finance, and business development; and middle-level project managers. Two members from the research team (one of the authors and one research assistant) took extensive field notes at the interview session to make the transcripts as complete as possible. During the interviews, the first author focused on conducting the interview using an interview script, which was transcribed from interview notes the same day. The interview questions (see Appendix 1) of the script were guided by our research propositions. Our research propositions provided the theoretical orientation to guide our case study analysis. Secondary data from sources such as company documentations, company press releases, presentations, official websites, news articles etc were also collected. Notes from informal observation were also taken during the site visits. All relevant information was stored as softcopies and hardcopies to create a case study database.

The case study evidence was analyzed using the 'logic models' data analysis technique. The use of logic models as an analytic technique consists of matching empirically observed events to theoretically predicted events. The events are staged in a repeated cause-effect-cause-effect pattern (Figure 4), whereby a dependent variable (event) at an earlier stage becomes the independent variable (causal event) for the next stage (Yin 2003). Thus according to our relationship step model (Figure 3), the presence of relationship management capabilities (input) leads to fulfillment of supplier obligations (intermediate outcome) and eventually to business value addition (final outcome).

Figure 4. Case analysis model

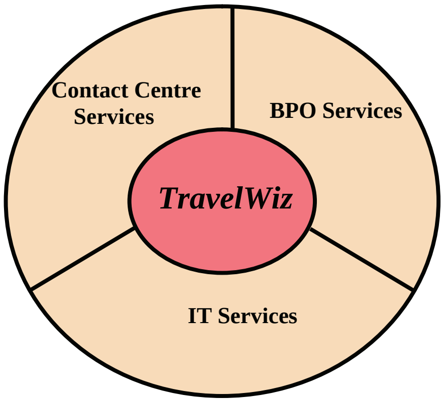


Case Study- TravelWiz

TravelWiz is a fully owned subsidiary, set up in India in 2001, of world's leading Travel and Real Estate Corporation based in USA. The parent company is listed among the fortune 500 companies and has clients in over 100 countries around the world. The offshore eSourcing unit in India provides a myriad range of services to its parent company. It operates as a niche player in the eSourcing arena and provides end-to-end solutions in the travel vertical.

The outsourcing services provided by TravelWiz fell under three categories: Contact Centre Services, IT Services and BPO Services in the travel domain (Figure 5). The Contact Centre Services included customer-facing (pre and post sales) services. Customer support was provided via email and phone in the caller's native language, e.g., calls from France would be routed to the agent in India handling French calls. IT Services included web design development and maintenance. This included support for enterprise management packages; website content management system; and ticketing engine used by the company and its clients. BPO Services covered back office administrative services and financial services. TravelWiz provided seamless integration of all these three services. Thus providing end-to-end travel domain specialized services which would help in achieving higher revenues and savings.

Figure 5. Services provided by TravelWiz



TravelWiz had a multicultural staff of over 1500 people with about 12% of them being Europeans. The expatriate staff was from 9 different countries in Europe. This offered unique opportunity to the Indian as well as expatriate staff to indulge in cross-cultural knowledge sharing. The expatriate staff was recruited and trained by TravelWiz clients from their native countries through advertisements posted on websites and employee referrals. During the span of six years TravelWiz had developed a robust multi-lingual support model to service voice and non-voice processes.

TravelWiz had signed detailed contracts with its client which allowed minimum flexibility related to scope changes. The process to be handled and the services to be provided by TravelWiz were defined in a very structured manner. The client and TravelWiz identified the interfaces in their relationships even before the project started. A formal organizational structure of their outsourcing value chain was drawn up to track the flow of the project. TravelWiz worked in a 24/7 mode and staffing was based upon seating capacity of their unit. For every project people were assigned based upon the required expertise and availability. The roles and responsibilities were clearly explained to the staff and were also documented in the company manuals. There were in-house ad-hoc training programs for new staff that joined in the middle of a project when there were situations of staff turnover or changes in the project scope. The services provided by TravelWiz were operational in nature and there were formally documented standards for every process and its delivery methodology.

TravelWiz had a formal relationship management team assigned to the eSourcing project. They interacted with the client on a regular basis via various modes- online chat, email, and videoconferencing. Scheduled face-to-face client meetings were also planned to report progress to the client and handle any project-related issues. This team was responsible to oversee any bottlenecks that would occur during the project and acted as a link between the client team and supplier team.

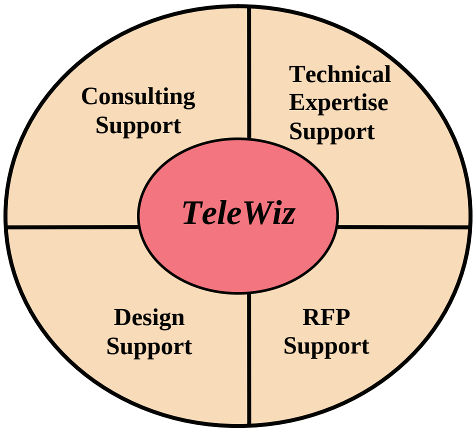
Case Study- TeleWiz

TeleWiz was a 60 percent owned subsidiary, in India, of a leading Telecom Corporation based in USA. TeleWiz was setup in the year 2002 as a technology and consulting group to provide pre-sales support on new technology to its parent company and business partners. The parent company was a global leader in communication systems, applications, and services. They designed, built, deployed and managed networks for enterprises. Customers ranged from small businesses and nonprofit agencies to the FORTUNE 500 companies, and the government.

TeleWiz provided knowledge-intensive eCommunication services to its parent company which included consulting support, technical expertise support, design support and request for proposal (RFP) support (see Figure 6). These services fell under the pre-sales category. TeleWiz provided these specialized services through a team of area specialists.

TeleWiz signed contracts with its client on basis of the nature of services and the range of services required. As a result, flexibility in contract scope changes was allowed to a great extent. The client team and TeleWiz team had clearly identified the interface structure for every project. Staff assignment for outsourcing projects was based upon the required expertise and availability of human resources. This was more critical in this case as the task at hand was highly complex and required expertise of specialized people. Communication skills of the team members were also considered as an important factor in staff assignment. The roles and responsibilities were clearly defined and documented in the company manuals. In-house extensive training programs for new staff were conducted for every project. People with prior experience in such projects were used as trainers in such programs. They motivated people to invest time in documentation by offering awards and prizes for building documentations during and after the projects.

Figure 6. Services provided by TeleWiz

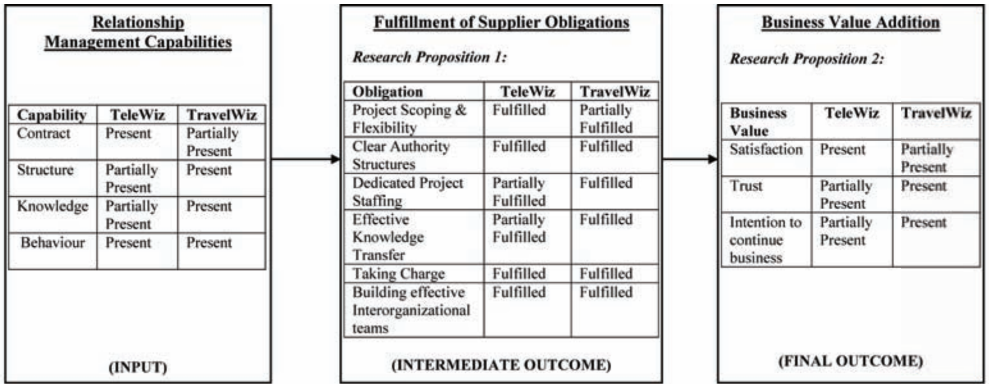


TeleWiz did not have a formal relationship management team assigned to the projects. But their team leads interacted with the client on a regular basis via various modes- email, teleconferencing and videoconferencing. Scheduled face-to-face client meetings were planned by senior project managers to report progress to the client and handle any project-related issues. Thus the structure of the relationship management team was defined as ‘informal in nature’ by TeleWiz. They informally spent time in educating the project team regarding the client’s business goals and work culture. This was conducted during project meetings which were attended by team members, team leads and project managers. They emphasized that the service being provided by them was highly specialized in nature and there were no industry best practices available.

RESULTS

Data analysis was guided by our case analysis model (Figure 4). The summary of the results for

Figure 7. Results summary



Relationship Management Capabilities

Capability	TeleWiz	TravelWiz
Contract	Present	Partially Present
Structure	Partially Present	Present
Knowledge	Partially Present	Present
Behaviour	Present	Present

(INPUT)

Fulfillment of Supplier Obligations

Research Proposition 1:

Obligation	TeleWiz	TravelWiz
Project Scoping & Flexibility	Fulfilled	Partially Fulfilled
Clear Authority Structures	Fulfilled	Fulfilled
Dedicated Project Staffing	Partially Fulfilled	Fulfilled
Effective Knowledge Transfer	Partially Fulfilled	Fulfilled
Taking Charge	Fulfilled	Fulfilled
Building effective Interorganizational teams	Fulfilled	Fulfilled

(INTERMEDIATE OUTCOME)

Business Value Addition

Research Proposition 2:

Business Value	TeleWiz	TravelWiz
Satisfaction	Present	Partially Present
Trust	Partially Present	Present
Intention to continue business	Partially Present	Present

(FINAL OUTCOME)

each research proposition are outlined in Figure 7 and explained as follows:

RP1a: eSourcing suppliers who possess 'contract' capability' are more likely to fulfill 'scoping & flexibility' obligations

Both the eSourcing suppliers believed that the project scope in the contracts should be clearly defined covering the nature and range of the services to be provided. They both also believed that some amount of flexibility should also be present in the outsourcing contracts. TeleWiz believed in signing very flexible contracts to the extent that project monitoring was loosely stated as per mutually agreed processes in the contract whereas TravelWiz believed in lesser amount of flexibility and greater amount of formality in the contracts. Both the suppliers had signed long term contracts which were reviewed on a yearly basis. Greater flexibility in the TeleWiz case can be attributed to the fact that the nature of the job was complex and was difficult to state explicitly beforehand whereas the TravelWiz case was more operational in nature that required lesser amount of flexibility.

Thus the presence of contract capability in the case of TeleWiz helped in the fulfillment of project scoping and flexibility obligations whereas the partial presence of contract capability in the case of TravelWiz resulted in partial fulfillment of the project scoping and flexibility obligations.

RP1b: eSourcing suppliers who possess 'structure' capability are more likely to fulfill 'clear authority structure & staffing' obligations

Both the suppliers assigned dedicated staff with the required expertise to the projects. An interesting finding was that even in highly technical roles, as in the case of TeleWiz, it was mandatory to possess good communication skills apart from having the required technical expertise. People were kept on-bench to mitigate the risk of staff turnover in the projects. Additionally, both companies had good HR practices consisting of a good salary structure and a healthy work environment. The interface points and roles and responsibilities were clearly defined for both the companies. But only TravelWiz had a dedicated relationship management team. The presence of structure capability in the case of TravelWiz helped in the fulfillment of clear authority structure & staffing obligations whereas the partial presence of structure capability in the case of TeleWiz resulted in partial fulfillment of clear authority structure & staffing obligations.

RP1c: eSourcing suppliers who possess 'knowledge' capability are more likely to fulfill 'effective knowledge sharing & transfer' obligation

The level of service related knowledge sharing with the client was high for both the companies. TeleWiz also offered awards for documentation and building content on service related knowledge. Industry best practices were shared by TravelWiz with its client (parent company). But TeleWiz shared none as they believed that there were no industry best practices in such a specialized domain. The services of TravelWiz were delivered with comprehensive and complete documentation whereas the services of the TeleWiz were delivered with brief and to-the-point documentation. It can be attributed to the fact that they were providing highly customized services and building extensive documentation separately every time could have cost implications in terms of time and effort. On the other hand TravelWiz tasks were mainly operational and repetitive in nature. This brought in a great amount of standardization and easy documentation for TravelWiz. Hence the presence of knowledge capability in the case of TravelWiz helped in the fulfillment of effective knowledge sharing & transfer obligations whereas the partial presence of knowledge capability in the case of TeleWiz resulted in partial fulfillment of effective knowledge sharing & transfer obligations.

RP1d: eSourcing suppliers who possess 'behavior' capability are more likely to fulfill 'taking charge & building effective interorganizational teams' obligation

Both the companies scored high on this dimension and believed in taking ownership of the project by completing the job and solving problems independently, with minimal client involvement. Also, both the companies invested time and effort to develop business understanding and a good working relationship. The team members working on the project were also given informal training on client-supplier goal alignment. Thus the presence of behavior capability in the case of TravelWiz as well as TeleWiz helped in the fulfillment of taking charge & building effective interorganizational teams obligations.

RP2: eSourcing suppliers who fulfill supplier obligations are more likely to achieve business value addition.

Fulfillment of most of the obligations for both the companies illustrated high level of satisfaction in the relationship with their respective clients. Also, both believed that the business with their client is likely to grow in future. The level of trust at the time of commencement of the eSourcing relationship was low in both the cases and was mainly contract–based. In the case of TeleWiz there were negative feelings about the project's success initially. The level of trust had risen in both the cases and was rated as very high in the present scenario by TravelWiz. This research proposition is strongly supported in the case of TravelWiz and partially supported in the case of TeleWiz. It is important to bear in mind that TravelWiz was a 100 percent owned subsidiary engaged in the relationship for the past six years whereas TeleWiz was a 60 percent owned subsidiary engaged in the relationship for the past five years. Trust had grown in both the cases but with varying levels. The ownership structure could have also impacted the level of trust.

DISCUSSION

Overall our exploratory results show considerable agreement in terms of our research model and propositions. They also highlight that the levels of the capability dimensions may vary from case-to-case. Researchers such as Poppo (2002) and Sabherwal (1999) stress on the importance of formal (contractual) as well as informal (interpersonal) aspects of the relationships. Our research model adds an interesting element of psychological contract to the informal aspect of the relationships. Further, our study revealed that communication skills of employees involved plays a major role in building relationship management capability.

Our results support Koh, Ang and Straub's (2004) view of psychological contract in outsourcing arrangements. Our research is advancement in this regard as it has moved beyond IT outsourcing and has studied the psychological contract perspective in eSourcing arrangements. Another important contribution of this study is that using the unique lens of psychological contract we were able to explore the gap between possession of a capability and achievement of business value for the firm.

In literature outsourcing value proposition in terms of vendor's own capabilities was stressed by Goles (2001) and Saunders et al. (1997). Our findings clearly indicate that relationship management capability of suppliers is an important factor shaping the outsourcing value proposition. The suppliers possessing these capabilities are more likely to fulfill the supplier obligations and hence are more likely to develop trust-based relationships with their clients. This study provides practical contributions to the outsourcing industry by recommending a comprehensive, yet easy to apply, relationship step model. The model can act as a relationship-checklist for the contracting process starting from planning for eSourcing contracts to post-contract management.

LIMITATIONS

Like most qualitative studies, this research has some limitations. Firstly, the study tries to derive results from two exploratory case studies. Yin (2003, pp. 10) clearly highlights a question posed frequently for case study research - "How can you generalize from a single case?" The answer, as argued by Yin (2003, pp. 10), is that "case studies like experiments are generalizable to theoretical propositions and not to populations or universes". We adopt Yin's viewpoint and try to generalize our results to our theoretical propositions and not to the population in general. Hence the results of this exploratory study should be considered as probable indicators for the phenomenon under study. Secondly, due to time constraints for the interview sessions, the authors had to focus their questions strictly around the theoretical propositions. As a result, other dynamic and static perspectives of eSourcing relationships could not be explored. We would like to put forward this as a future research direction for researchers examining sourcing relationships.

Thirdly, the research is purely from a supplier's perspective. Hence results from this study should be treated with caution. An ideal condition would be to study the client-supplier dyad. However, we would like to state that since this is one of the initial steps in this direction, insights from the supplier perspective are also important. The insights from this research can be taken forward to study the client's perspective to get the complete picture. Finally, the case studies were of successful eSourcing suppliers. An alternate viewpoint is also essential for progress of research. The case studies do not highlight negative examples of eSourcing relationships. Future research in this area can explore such dimensions as well.

FUTURE RESEARCH DIRECTIONS

The outsourcing industry is posed for phenomenal growth and this area has high potential for research. Future research in this area can involve further validation of the proposed relationship step model by undertaking case studies of third party eSourcing suppliers in India. Additionally, the framework proposed in this paper can be used by other researchers to carry out empirical research from the vendor perspective in other popular service provider countries, like China. An ideal endeavor would be to have client-supplier dyads as the unit of analysis.

An alternative viewpoint for looking at our research model (Figure 3) can be by viewing it in the reverse direction. In other words, what are the likely consequences of moving down the steps of the relationship step model? In what situations can this occur? A probable situation can be a case where projects do not reach their intended targets. Simulating such an example, a client and supplier start an outsourcing venture on a high note but due to high attrition at the supplier's end a large pool of team members engaged in the project leave in the middle of the project. With the urgency to meet deadlines the supplier hires a new talent pool. The new employees are unfamiliar with the current project and hence take more time in understanding the process and completing the project deliverables. As a result the supplier organization is unable to fulfill some of the supplier obligations which instigate dissatisfaction within the client team. In such situations, does a trust-based relationship collapse? Does it result in a stricter contract–based relationship? Or there exists a middle path. How can suppliers ensure that they move up the steps and not down the steps of the relationship step model?

An interesting extension of our research would be to compare and contrast our case studies with companies that have failed in outsourcing ventures using the relationship step model. Additionally, comparison between companies in a more variegated spectrum of industries can be carried out. Further, longitudinal studies can be carried out to establish causality effects in the proposed model. Future research can also explore other obligations that are important from the service provider perspective. Also, whether the supplier obligations evolve or change over time can be examined. Additionally, the impact of communication skills on relationship building can be studied by researchers.

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APPENDIX 1. CASE STUDY QUESTIONNAIRE

Research Dimension	**Interview Questions**
Capability Dimensions	
Contract	o Why did the client decide to outsource? o What is covered in the contract?
Structure	o What is the governance structure? o What is your outsourcing team structure?
Knowledge	o How critical is the process to the client's business? o How do you deliver services to the clients? o What kind of knowledge transfer takes places?
Behaviour	o How do you manage the relationship with your client? o How much client involvement do you require/expect during the project? o How does the client hope to benefit from the arrangement? o How do you, as a service provider, hope to provide benefits to the client?
Obligation Dimensions	
Project Scoping	o How do you define the contract scope for an outsourcing project? o How much flexibility do you incorporate into the contract to accommodate contract scope changes?
Clear Authority Structures	o How do you define roles and responsibilities for the team members? o How are the interfaces points for the project defined between the client organization and your organization?
Dedicated Project Staffing	o How do you assign staff for a project? o How do you deal with staff turnover, for example, situations where people have left in-between projects?
Effective Knowledge Transfer & Sharing	o How do you share service related knowledge with your client? o Do you share industry best practices with your client? How do you share them? o How do you educate the client in terms of the necessary skills, knowledge, and expertise associated with using the outsourced system or service?
Taking Charge	o How do you tackle problems encountered during the projects? o How involved is the client in the project functioning in terms of: ▪ Monitoring ability ▪ Monitoring frequency ▪ Task observability ▪ Outcome measures
Building effective Inter-organizational teams	o Do you spend time in understanding the client's business? o What steps do you take to understand your client's business? o Do you share the details of your client's business with the team members involved in the project? How does this take place?
Value Addition Dimensions	
Satisfaction	o How has been your sourcing experience with the client?
Trust	o How would you describe the level of trust between you and your client at the time of signing the contract? o How would you describe the level of trust between you and your client now?
Intention to Continue Business	o How do you foresee your business with the existing client? o How long is the relationship expected to last?

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Chapter 7.6

A Strategic Framework for Managing Failure in JIT Supply Chains

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ABSTRACT

Supply chains can be disrupted at both local and global levels. Just-In-Time (JIT) companies should be particularly interested in managing supply chain failure risk as they often have very little inventory to buffer themselves when their upstream supply chain fails. We develop previous research further and present a strategic framework to manage supply chain failure in JIT supply chains. We identify two dimensions along which the risks of failure can be categorized: location and unpredictability. We go on to identify strategies which companies can use either before (proactive) or after (reactive) the failure to manage supply chain failure. We support our framework with examples of actual responses to supply chain failures in JIT companies. It is also hoped that our strategic framework will be validated empirically in the future leading to specific guidance for managers.

INTRODUCTION

Just-in-time (JIT) manufacturing, with its focus on continuous improvement through waste reduction and problem solving, has been widely hailed as a philosophy that improves organizational performance. JIT principles include only having required inventory; improving quality; trimming lead time by reducing setup time, queue length, and lot sizes; and reducing costs in the process (Cox & Blackstone, 2002). The philosophy offers organizations some significant cost and quality benefits (e.g., Funk, 1995; Duguay, Landry, & Pasin, 1997; Claycomb, Germain, & Droge, 1999), so it is not surprising that large numbers of organizations around the world have implemented or are in the process of implementing JIT manufacturing.

However, there are several disadvantages and implementation difficulties associated with JIT (Im, Hartman, & Bondi, 1994; Inman & Mehra, 1989), including supply chain failure (Altenburg, Griscom, Hart, Smith, & Wohler, 1999; Zsidisin, Ragatz, & Melnyk, 2005; Kleindorfer & Saad, 2005; Craighead, Blackhurst, Rungtusanatham, & Handfield, 2007). The risk of supply chain failure refers to the combination of the probability that an element of the supply chain will fail, and the magnitude of the disruption caused by the failure throughout the remainder of the chain. A recent McKinsey survey found that managers face increasing supply chain risk (Krishnan & Shulman, 2007). Understanding supply chain failure is particularly important for JIT organizations because companies using JIT are especially susceptible to failures in their upstream supply chain as they have limited inventory to protect them if the parts do not arrive on time.

Tang (2006) categorizes supply chain risk as operational or disruptional. Operational risk refers to inherent uncertainties such as uncertain customer demand, uncertain supply, and uncertain cost. Disruption risks relate to natural and man-made disasters or economic crises. This article focuses on the disruptional risk aspect of JIT supply chains since, as Tang points out, the impact of disruptional risk is far greater than that of operational risk.

We begin by briefly outlining research on risk within supply chains, and on the particular challenges facing managers within JIT supply chains. We then go on to develop two dimensions of supply chain failure based on our inference from industry practice reported in the literature: (1) the location, and (2) the unpredictability of the supply chain failure (or unpredictability in recovering from failure). While others have focused on dimensions of supply chain failure such as controllability of the risk or severity of impact, we extend these treatments by emphasizing the location of the supply chain failure: whether the risk of supply chain failure is internal to the firm, external to the firm but internal to the supply chain, or whether it is systemic within an industry/region external to the supply chain. We illustrate the framework by categorizing some of the proactive and reactive processes used by companies to mitigate JIT supply chain failure. We conclude with a discussion of the implications of our framework for research on supply chain failure and JIT, and for practitioners. Our location-based view provides managers with an additional lens with which to view JIT supply chain risk, and an organizing framework to generate potential strategic risk management options.

It is hoped that this exploratory framework will lead to future studies using empirical approaches such as case-based research to validate the proposed framework. Case-based research (Miles & Huberman, 1994; Yin, 1994) can be used to explore in depth the use of different risk management approaches, among others. This type of in-depth research will allow the development of specific guidelines that managers can use to address supply chain risk within the enterprise.

SUPPLY CHAIN FAILURE AND JIT SYSTEMS

Sudden or catastrophic supply chain failure in JIT environments can have serious organizational impacts. The most common response has been to reduce or stop production until systems were operational again. The September 11, 2001 (9/11) terrorist attacks which delayed goods flowing between the United States and Canada, (Keenan, 2001), the 1995 stoppage of commercial traffic on the Rhine River in Germany due to flooding, the August 2003 power outage in the Northeastern and Midwest United States and Ontario, Canada, and the aftermath of the Kobe earthquake are examples.

Mitchell (1995) would categorize these examples as "performance loss" or "time loss" due to supply chain failure. However, the impact of supply chain failure does not end with merely immediate performance and time losses; they can extend to "financial loss" due to lost orders or the operational cost of remedying the failure, "physical loss" of facilities or supplies in cases of fire or flood, and even to "social loss" of the firm's reputation for reliability or "psychological loss" due to the stress of coping with the failure or damage to the organization's self-perception. It is therefore crucial that we better understand supply chain failure, and develop robust supply chain mechanisms and structures to cope with actual or potential failure.

Research on the supply chain design implications of following a JIT manufacturing strategy has tended to focus on "single sourcing, close supplier location, long-term relationships, schedule coordination and sharing, frequent deliveries of small lot sizes and stable supply-chain pipelines" (Das & Handfield, 1997, p. 246). Technical modeling on, for example, lead time uncertainty (e.g., Schwartz & Weng, 2000) has been complemented by survey-based research on the perceived cost reductions from implementing JIT purchasing and logistics (e.g., Dong, Carter, & Dresner, 2001). While some of these studies make passing reference to the risk of supply chain failure, research on JIT supply chains has contradictory messages on managing such risk. On the one hand, some JIT supply chain characteristics such as schedule coordination and long-term relationships encourage repeated interactions, trust, and increased information sharing, hence decreasing the likelihood of supply chain failure over time. On the other, increased strategic risk, or over-reliance on a single or limited number of suppliers (Sadgrove, 1996), can magnify the impact or outcome of any potential upstream supply chain failure since the JIT firm may have fewer alternative sourcing options.

Thus managerial recommendations for designing supply chains to handle failures are often complex or even contradictory. Mechanisms and structures to manage supply chain failure differ in their scope and timing. To take some examples from a recent list by Elkins, Handfield, Blackhurst, and Craighead (2005), some design strategies are implemented within a focal organization (e.g., training employees, including expected costs of failures in the total cost equation), some are implemented across the entire supply chain (e.g., enhancing system-wide visibility and supply chain intelligence by using near-real-time databases), and others require the involvement of supply chain members within particular industries or regions (e.g., gathering intelligence and monitoring critical supply-base locations). Similarly, some strategies are implemented before a failure (e.g., creating early warning systems to discover critical events outside normal planning parameters), and others are designed in response to a failure (e.g., conducting a detailed incident report and analysis following a major disruption). Further complicating the intervention suggestions is that some risks are much more unpredictable than others, and so need relatively more or less intensive monitoring and management.

Given the complexity of supply chain risk, many authors have developed two-dimensional frameworks for risk management. For example Meitz and Castleman (1975), Kraljic (1983), and Sheffi and Rice (2005) incorporate the probability that an element of the supply chain will fail and the magnitude of the disruption caused by the failure throughout the remainder of the chain as dimensions. Chopra and Sodhi (2004) examine 'level of risk' and 'cost of mitigating reserve' as dimensions in order to suggest risk mitigation strategies. Cavinato (2004) examines risk on the 'risk/uniqueness' and 'value/profit potential' dimensions. Kleindorfer and Saad (2005) examine supply chain risk management from a 'cost of disruption' vs. 'cost of risk mitigation' perspective. Thus the various two-dimensional frameworks have proved useful lenses for managers attempting to manage supply chain risk.

Recent treatments of supply risk also recognize the importance of both the source and outcome of the risk of failure (Zsidisin, 2003), and explicitly recognize that the source of supply chain failure can occur further away than the immediate buyer-supplier dyad (Zsidisin, 2003b; Spekman & Davis, 2004). Natural disasters, strikes, or fires can affect not only the first tier, but also second- or third-tier suppliers that are integrated within the JIT manufacturing system. Supply chain failures arising from apparently remote disruptions can have significant impact on an integrated supply chain, particularly within an increasingly uncertain, post-9/11 global environment (Spekman & Davis, 2004; Barry, 2004). Our framework will assist decision makers to develop appropriate responses to apparently distant supply failure risks by focusing on the location of the risk.

An important aspect of managing supply chain failure is to understand how and why supply chain disruptions occur. Chopra and Sodhi (2004) emphasize the importance of understanding the drivers of risk (labor disputes, inadequate capacity, and weather are some examples) and categorize them to help develop effective risk mitigation strategies. Kleindorfer and Saad (2005) suggest 10 principles to help understand and mitigate supply chain failure. Craighead et al. (2007) identify network density, network complexity, and node criticality as drivers of supply chain failure risk, and recovery and warning as drivers of supply chain failure mitigation.

While these are useful starting points for understanding the risk of failure in JIT systems, a framework is needed which helps managers deal with the complexity of risks arising in distant supply locations both before (proactive) and after (reactive) the failure. The research in *proactive* planning in supply chain disruption risk has paid insufficient attention to risk mitigation strategies based on location of the risk (i.e., whether the disruption risk is internal to the firm, external to the firm but internal to the supply chain, or external to the supply chain). This is an important oversight in our current understanding of the proactive management of supply chain failure since risks internal to the firm may be most controllable while disruption risk external to the supply chain may be least controllable. While focusing on the location of supply chain failure, our framework echoes previous research, which includes the unpredictability of the risk. We suggest that the proactive approach to JIT supply chain risk mitigation can be understood better if analyzed on the 'location of failure' and 'unpredictability of failure' dimensions.

In addition, while many articles discuss avoidance of disruption by upfront planning, only a few (Lee, 2004; Sinha et al., 2004; Zsidisin, Melnyk, & Ragatz, 2005a; Zsidisin, Ragatz, & Melnyk 2005b; Tang, 2006; Craighead et al., 2007) discuss *reactive* recovery in the case of supply chain failure. Since supply chain failures will take place occasionally even with the best of proactive planning, we should also address the reactive management of supply chain failure. We suggest that the recovery from JIT supply chain failure (reactive approach) can be usefully analyzed along the same two dimensions of location and unpredictability.

LOCATION AND UNPREDICTABILITY AS DIMENSIONS OF SUPPLY CHAIN FAILURE

While the risk of supply chain failure is influenced by many factors, we focus on two primary dimensions: location and unpredictability. To consider location first, supply chain failures may be classified as: internal to the organization, external to the firm but internal to the supply chain, or external to the supply chain. Internal organizational failures include strikes or chaos arising from internal reorganization. It is important to note that a focal firm's internal failures could affect other supply chain members (for the other members the risk is external to the firm but internal to supply chain situation). Conversely, suppliers might suffer performance loss due to their own internal reorganization or financial difficulties, but this could affect the focal firm and so is categorized as external to the firm but internal to the supply chain. External to supply chain failures are generally due to acts of God such as weather or natural disasters, or acts of human aggression such as terrorism, sabotage, or arson (though these could apply to the other two categories also).

Location as a dimension of supply chain failure is related with controllability to the extent that failures arising further from the firm are less controllable than the focal firm. The advantage of location over controllability is that if managers can understand the location of a given risk, then they are better equipped to find a proactive plan or reactive response based on the location. Highly uncontrollable risks have the implication of managerial impotence. However, as we argue below, risks in distant locations encourage managers to think of mitigation actions matched with the location.

Our second dimension, unpredictability, captures the extent to which the probabilities of a failure and its impacts are ambiguous. This extends from traditional notions of risk (where probabilities and variables are known) and uncertainty (where variables are known, but probabilities are not), to an extreme form of unpredictability where neither the variables nor probabilities associated with supply chain failures are known (Hall & Vredenburg, 2005). Thus highly predictable failures can be understood with traditional risk measurement and management techniques, whereas highly unpredictable failures can usually only be identified after the fact.

The location of supply chain failure is often correlated with unpredictability of occurrence (or the unpredictability of recovering from a failure), since in general, the nearer the failure is to the focal organization, the more information the focal firm may have of the variables or probabilities of failure. Usually, an organization has little visibility of external failures even though it still has to deal with the failure. Sometimes, there may be an indication that the failure will occur such as in the case of an impending hurricane, but at other times there may be no warning. However, even some potential failures internal to the firm are unpredictable, and other external failures may be predictable. Therefore our framework maps location against unpredictability in an orthogonal two-dimensional space, including the entire conceptual set of failures from internal to external and from high predictability to low.

Examples of external failures which have high unpredictability include natural disasters, which can have very far-ranging effects, like floods and earthquakes. In these instances, an entire geographic locale is affected, usually including transportation arteries and local suppliers. Major parts of the global supply chain can be affected for all companies, whether JIT or not, such as with the 1995 earthquake in Kobe, Japan (Forman, Williams, & Sapsford, 1995), the ice storm and resulting power outage of 1998 that produced chaotic conditions in eastern Canada (Chipello, 1998), the 9/11 terrorist attack (Ip, 2001), and the SARS epidemic in Asia (Young, 2003).

Supply chain failure internal to the chain can arise due to actions taken or occurring within the supply chain. Consequently, for the most part they have at least some predictability and can be prevented by better supply chain practices. However, when the supply chain fails due to a strike at the logistics provider, for example, the effect can often be widespread. In the United States, the United Parcel Service (UPS) strike greatly affected its customers, especially those who used UPS as their sole "rush goods" transporter. During the strike, because UPS handled such a large portion of the U.S. market (63% of all rapid deliveries and 80% of all ground deliveries), other companies like Federal Express and the U.S. Postal Service were not able to pick up all the slack. The competition also placed a number of restrictions on customers due to increased volume (Coleman & Jennings, 1998). Nonetheless, since everyone in the U.S. was dealing with the impact of the strike, customers had to be more understanding. Another example of a high-impact strike is when the major trade unions strike, such as the 2002 longshoremen strike on the U.S. West Coast (Cavinato, 2004).

Examples of predictable failures within the firm would be reorganization, including mergers and acquisitions, plant expansions, major supply chain software installations, and the like. When Union Pacific acquired Southern Pacific Rail Corporation, poor integration of the scheduling systems resulted in more than 10,000 rail cars a day stalled due to a shortage of locomotives, crew members, and track space. Union Pacific's customers, whether JIT or not, had to work around the supply chain failure (WSJ, 1997). Problems with an Enterprise Resource System (ERP) software installation resulted in shipment delays and incomplete order shipments at the Hershey Company (Stedman, 1999). While the company kept producing, the software implementation glitches resulted in chocolate piling up in warehouses instead of being shipped.

A less predictable failure within the supply chain would be if a supplier goes bankrupt or encounters financial difficulties, which can result in the work being stopped quickly. This can be a particularly serious failure, since there is a focus on single sourcing and small lot deliveries in JIT. Land Rover in the UK faced this difficulty when its only chassis supplier UPF-Thomson faced financial difficulties in 2001 (Meczes, 2004).

Sometimes, what starts as an internal failure can have far-ranging effects. Natural disasters can impact locally, as when a fire guts a building, though the impact may be significant when that building houses the sole supply for another organization, as in the case of a lightning-bolt-based fire at a Philips semiconductor plant that supplied Nokia and Ericsson (Latour, 2001) and at Aisin, a supplier of Toyota (Reitman, 1997).

Thus location and unpredictability of failure appear to be dimensions that warrant investigation. In the following sections we elaborate on the strategic issues in the proactive and reactive management of supply chain failure in JIT systems. As mentioned earlier it is hoped that this discussion will lead to future empirical research into this topic, leading to more specific management suggestions.

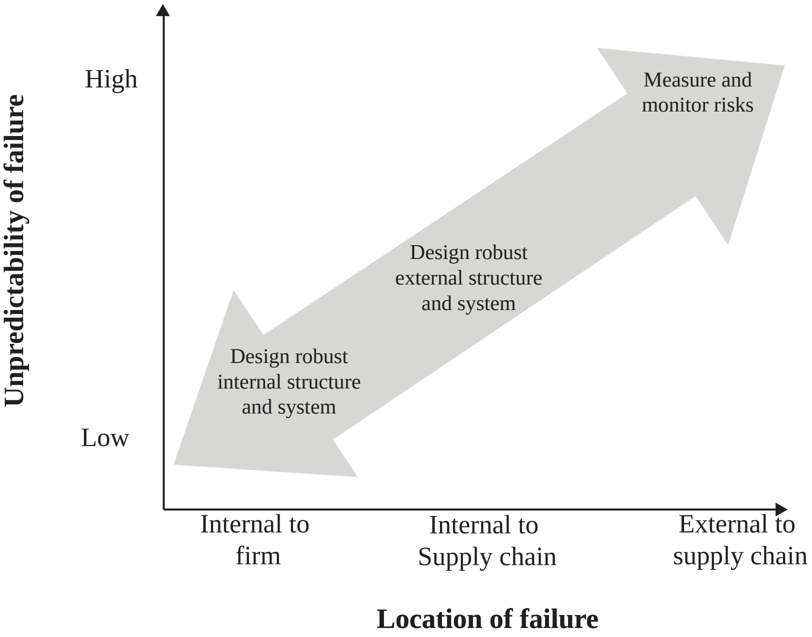
PROACTIVE MANAGEMENT OF SUPPLY CHAIN FAILURE

How can firms anticipate, avoid, or minimize supply chain failure before it occurs? In Figure 1 we map proactive risk mitigation strategies in our location/unpredictability framework (see Kelindorfer & Saad, 2004; Chopra & Sodhi, 2004; Lee, 2004; Johnson, 2001; Sinha et al., 2001). Based on examples of strategies and tactics that firms have adopted, and suggestions of strategies from the literature, we derive three main proactive options for firms along the shaded arrow depending on the location and unpredictability of the failure. These range from: (1) designing a robust internal structure and system, through (2) designing a robust external structure and system, to (3) measuring and monitoring risks in the external environment.

Robust Internal Structures and Systems

To manage highly predictable (i.e., low unpredictability) and internal potential failures, firms *design robust internal structures and systems.*

Figure 1. Proactive management of supply chain failure



For example, when companies believe that a supply chain failure may be coming, they may have a policy of stockpiling parts; that is, they implement failure anticipation inventory (Chopra & Sodhi, 2004; Sheffi & Rice, 2005). When GM speculated that its unions might go on strike, it tried to prevent supply chain failure; it stockpiled in advance, had contingency plans, and maintained backup data from the suppliers on the components of their products (Becker, 1998).

Another aspect of internal system design is business continuity planning (Zsidisin, Ragatz, & Melnyk, 2005; Zsidisin, Melnyk, & Ragatz, 2005; Sinha et al., 2004; Kleindorfer & Saad, 2004; Chopra & Sodhi, 2004). Steps such as risk analysis, contingency plans, logic charts and tabletop exercises, and failure modes and effect analysis (FMEA) would be useful in planning to deal with supply chain failure. This type of system planning becomes even more important when the company knows that the probability of a failure occurring may be higher than usual. For example, locations that suffer snowstorms, hurricanes, and the like with known probabilities can plan for disaster recovery within certain tolerances. Internally, if a strike is expected or if a labor contract is coming up for renewal, the company can choose to make "just in case" plans.

Lee (2004) emphasizes the great importance of agility, adaptability, and alignment in building robust supply chains (he calls it the Triple-A supply chain). Honda is a leader in flexible assembly plants, producing more than one model on the same line, and the same model at more than one plant. The Honda plant in Ontario, Canada, can build the Odyssey van and two types of SUVs on the same assembly line, while the Honda plant in Alabama can also produce the Odyssey (Keenan, 2003). While this increases Honda's flexibility from a competitive viewpoint, it also protects against supply chain failures. In case of a supply chain failure in Ontario, production at Alabama could be ramped up. Similarly Toyota is following a strategy of spreading out the location of its plants in North America to reduce what it teams as "geographic risk" (Shirouzu, 2005).

Another strategy is to minimize variability, that is, increase the ability to manage the process consistently. An example of variability would be the breakdown in machinery that might delay a shipment. Variance reduction and process improvement allow the organization to become better at supply chain management, which can result in fewer supply chain failures. If waste and variability can be removed (the JIT philosophy), the chain becomes more robust and it becomes easier to prevent problems from occurring. For example, the JIT practice of small batch sizes and reduced lead times helps reduce variability, or risk, in supply (Lee, Padmanabhan, & Whang, 1997). This could help avoid spikes in the supply chain that often creates a domino effect leading to supply chain failure.

Reducing the size of the product line through rationalization and the use of modularity will help duplicate production capacity (Kleindorfer & Saad, 2004; Chopra & Sodhi, 2004). This will allow production shifts in the case of supply chain failures. For instance, in 1999 Unilever made plans to trim away 1,000 of its 1,600 brands to focus on global/regional brands instead of local/national brands. The primary focus would become 400 brands that account for almost 90% of its annual revenue (Beck, 1999). Part of the rationale was to simplify the supply chain, which should make it more robust. When there are fewer products, it is also easier to duplicate production. Producing the same product at multiple locations allows the company to shift production when the supply chain fails at one facility. Even if a product is not duplicated, standardized components (modular design) and processes make it easier to locate an alternate source when the chain fails, as compared to totally customized components. An auto manufacturer was caught short recently because it failed to do this. It had a single supplier for rubber radiator gaskets that used unique machinery to produce these gaskets. When a fire destroyed the gasket supplier's machines, the only option left was to remanufacture the machines with much cost and time delay, as no alternative supplier could be found due to the uniqueness of the machines (Martha & Subbakrishna, 2002). In contrast, Toyota made use of the Aisin fire to improve its system by launching a project to increase parts standardization. In the case of the Philips fire, among its customers, Nokia was able to recover more quickly since it could find alternate sources of supply because its phone was more modularly designed than that of another customer, Ericsson (Tang, 2006).

Firms can also design their internal systems to manage product design and product portfolio for supply chain robustness. Innovative product manufacturers often use flexibility or postponement to deal with rapid changes in demand (Lee, 2004). Dell is able to circumvent the negative effects of components partially, by offering promotions and price discounts for other products for which components are available. Thus operations continue as normally as possible and the standardized modular components are being used rather than being left to accumulate dust and cost in inventory.

Other aspects of internal system design can include analyzing risk early in the product lifecycle. Teradyne Inc. incorporates supply chain analysis at the product design stage (Atkinson, 2003). The company tries to identify potential failures early in product design. The goal is to create a product sourcing plan that becomes a roadmap that anticipates and generates mitigation plans for every risk identified. Risks could relate to technology, suppliers, and parts. Naturally, suppliers should be involved in the product design stage to maximize the flexibility in the design for supply chain robustness (i.e., *external structure and system,* which is discussed later).

Designing a robust internal system can be helped by a formalized process (Hauser, 2003). Companies can seek to optimize supply chain performance by analyzing supply chain risk and making sound business decisions based on this analysis. This helps companies identify, quantify, and prioritize risks (sometimes hidden) in their supply chain and take proactive action to mitigate these risks. Hauser's model involves the following steps: (1) identifying risks, (2) understanding which risks can lead to significant supply chain disruption, (3) quantifying the economic impact, (4) determining the organization's desired risk profile, (5) conducting simulations and identifying key performance measures, (6) developing risk mitigation initiatives along with timing and sequences, and (7) measuring and monitoring performance. A similar process is used in business continuity planning (Barnes, 2001; Zsidisin, Ragatz, & Melnyk, 2005; Zsidisin, Melnyk, & Ragatz, 2005). A utility in the Midwestern United States was able to recover from the effects of a very major storm much better than other utilities in the same area because it had a plan in place that outlined what suppliers were to do in the event of a storm. While other utilities struggled to get power back to customers within four weeks, this utility was able to get power back to all its customers within two weeks. Other strategies to prevent supply chain failure could involve carrying critical parts at strategic locations (Atkinson, 2003; Aichlmayr, 2001).

Robust External Structures and Systems

The best defense when risk of failure is outside the firm but in the supply chain, and the risk is fairly predictable, is to *design robust external structures and systems* (Johnson, 2001; Kleindorfer & Saad, 2004; Chopra & Sodhi, 2004). This might include alternate sources of supply and distribution. A comparison of Japanese and American auto manufacturers in 1990 showed that while Japanese companies in Japan had about a third of the suppliers per assembly plant compared to their American counterparts, they only had 12% of their parts single-sourced compared to 69% for the Americans (Womack, Jones, & Roos, 1990, p. 157). This is confirmed by a study by Shin, Collier, and Wilson (2001) that found that dual or multiple sourcing was common. Increased globalization in the logistics industry and information technology is making it more feasible to find alternate sources of supply; not only are there more logistics providers, these providers are also global. This increases the chances of locating a supplier worldwide who is able to supply the affected facility.

Craighead et al. (2007) discuss the effect of supply chain density, supply chain complexity, and node criticality on the possibility of disruptions. Thus when one designs the supply chain structure, these factors must be analyzed in order to come up with a resilient design. Sinha et al. (2004) and Tang (2006) address external supply chain structure from a risk perspective.

Another example of a robust structure is the use of collaborative planning, forecasting, and replenishment (CPFR), which these days involves supply chain management (SCM) software and can help avoid problems (Tang, 2006). Greater visibility in the supply chain can be a successful mechanism to prevent disruptions (Christopher & Lee, 2001). If a supplier or one of its partners goes through a merger, acquisition, plant expansion, or software installation, operational planning with the supplier is critical. Texas Instruments uses CPFR to manage items on a JIT basis (Roberts, 2004). If disruptions do occur, real-time information available in SCM software also allows quick what-if analysis. This will help the organization make alternate plans to combat the disruption, whether it is alternate suppliers, routes, or logistics providers. Technologies like Internet marketplaces allow for quick identification of alternate sources of supply, while technologies such as Geographical Positioning Systems (GPSs) and Radio Frequency Identification (RFID) will allow companies to monitor the location of inventory within the supply chain, an important requirement in a JIT system where there is no excess inventory.

It is important to select supply chain partners carefully and strategically when structuring the supply chain based on their capability (Johnson, 2001). The partners in the supply chain, whether suppliers or customers, will have an impact on the chain. When their part of the chain fails, the whole supply chain is affected. Thus, the primary selection criteria should be their capability to maintain supply and their ability to respond in case of supply chain failure. For instance, it is important to examine a potential supplier's financial viability. In addition their plans in case of supply chain disruption should be examined. The example of the utility in the Midwest is a good illustration of this. When power fails, manufacturing will be significantly affected. Thus even the capability of utility partners within the supply chain is important.

Measurement and Monitoring

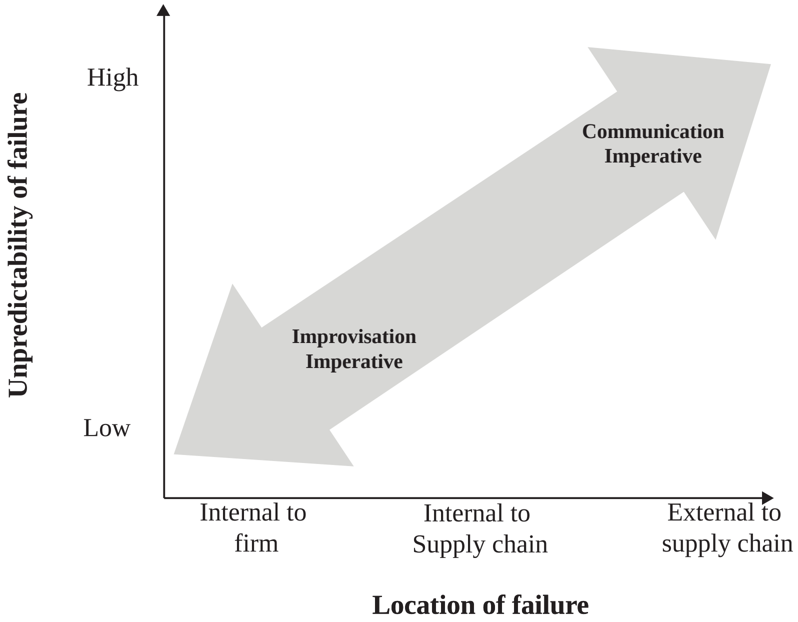
Prescription from the literature is weakest on how to deal with highly unpredictable events, especially those events external to the supply chain. Perhaps the best solution for highly unpredictable failures is consistent *measurement and monitoring.* Authors such as Hauser (2001), Zsidisin, Ellram, Cater, and Cavinato (2004), and Sinha (2004) include monitoring as part of their risk management process. In highly unpredictable situations this takes on added importance since it is difficult to plan ahead for something that is not known. Such monitoring can include early warning systems to discover internal system operations that exceed normal planning parameters (for internal to the firm); screening and regularly monitoring current suppliers for possible supply chain risks (for external to the firm, but internal to the supply chain situations); and scanning the external environment possibly through the use of scenario analysis (for external to the supply chain situations). The most recent literature in this area has begun to develop prescriptions on how to manage highly unpredictable failures (e.g., Rice & Caniato, 2003; Zsidisin, Ragatz, & Melnyk, 2005; Zsidisin, Melnyk, & Ragatz, 2005; Sinha et al., 2004; Craighead et al., 2007). The emphasis in these prescriptions is on upfront planning and monitoring so that the firm is in a good position to improvise if the unpredictable does occur. For example, one company seeing the potential for disruption in the supply chain leased additional transportation equipment, just in case (Craighead et al., 2007). While the inability to predict or take proactive action may be frustrating, it is important to note that highly unpredictable failures such as weather, acts of war, and other natural causes are likely to be more widespread with wide-ranging effects. So partners in the supply chain as well as customers themselves may be affected and are more likely to be understanding. In this situation the focus moves to reactive options in the post-failure stage outlined below, where it is important to be able to respond quickly to restore the supply chain.

Planning and buffering can be useful in managing failure. Though it is easier to buffer when the unpredictability is low, it has been used in highly unpredictable situations if the situation warrants it. During the Y2K warnings, the Cap Gemini Group commissioned a survey; it found that about 40% of the U.S. companies surveyed planned to stockpile inventory. Xerox Corp. built up a month's supply of raw materials (about four times the usual amount) and made sure suppliers were Y2K compliant (Aeppel, 1999). Similarly, when Toyota expects major demand changes within the year, it knows that its supply chain needs to be more responsive than usual. It sets the load of the machine at half of its future capacity; each worker operates several machines. This gives the capacity flexibility and buffer.

REACTIVE MANAGEMENT OF SUPPLY CHAIN FAILURE

What can companies do in the immediate aftermath of the failure to mitigate the damage? We suggest that it should vary according to the location and unpredictability of the recovery from failure (see Figure 2). The two core strategies

Figure 2. Reactive management of supply chain failure



suggested are communication and improvisation. Companies can also use a combination of these two core strategies.

The appropriateness of each strategy depends on the location of the failure. In Figure 2 as the location of the failure moves closer to being internal to the supply chain and unpredictability is lower, customers may feel that the failure could have been predicted and so be less forgiving. Thus they would expect the company experiencing the failure to act quickly to fix the problem (an 'improvisation imperative'). On the other hand for failures that are more external to supply chain and are more unpredictable, customers would be more willing to accept slower improvisation, but will expect communication on progress toward normalization (a 'communication imperative').

Consider two examples of internal failure discussed earlier. In the case of failure due to new software implementation, customers might expect that those problems were predictable (as there are many cases of firms experiencing this type of disruption). So they expect the company to have done some proactive planning to prevent such failures and to have recovery plans. In this situation, firms need to improvise quickly to fix the software problem. On the other hand if the failure was due to a factory fire resulting from a freak lightning strike, customers may be more forgiving and be satisfied with immediate communication and later improvisation.

The Communication Imperative

A example of the *communication* imperative situation due to freak events was experienced by Mitel Corp. (a semiconductor manufacturer) in 1998 during the ice storm. Mitel had to rent generators to produce electricity; even so, it could not recover lost time, as it was a 24-hour-a-day operation. So, Mitel communicated with its customers daily on the telephone to update them on the situation, and rescheduled production and shipment carefully to satisfy their customers as much as possible (Chipello, 1998). Kleindorfer and Saad (2004) and Craighead et al. (2007) also emphasize communication and information sharing in these circumstances.

Communicating with downstream customers helps alleviate the customer's anxieties, and they may be more likely to be willing to accept delays. If there is no communication, then their supply chain could also be severely disrupted, giving rise to strained relationships with their customers. Customers understand that supply chains do not always run smoothly and thus are going to be more forgiving if they are kept informed rather than if they are left in the dark. This communication strategy is particularly effective when the failure has its origins external to the supply chain. Customers may be more understanding if the whole system is down due to events external to the supply chain such as a flood, earthquake, or Teamsters Union strike, since many companies in the industry would be affected.

The Improvisation Imperative

As mentioned, when the failure is more predictable, the core strategy is to *improvise*. This relates to the business continuity planning (BCP) process discussed in Zsidisin, Ragatz, and Melnyk as well as Zsidisin, Melnyk, and Ragatz (2005, 2005). Sometimes companies will find room for additional capacity through improvement within the current system (*internal improvisation*). Tri-City Heat Treat Co. is a tier-two automobile supplier of heat-treated wheel nuts. To satisfy its customers' needs, it agreed to increase production, but the ordered equipment became delayed. Tri-City did its best to cope; besides asking customers with less pressing orders to wait, it worked round the clock to generate ideas to increase capacity. It used process improvement to eliminate gaps in a production line, turning the batch process into a continuous process (Petzinger, 1995). Similarly, Nishin Kogyo, a minor supplier of valves to Toyota, found a way to increase its efficiency permanently by 30% during the Toyota-Aisin crisis (Reitman, 1997).

Alternatively, companies can increase capacity by increasing labor hours (a type of *internal improvisation*). Many JIT plants tend to have excess capacity (Knod & Schonberger, 2001; Korgoankar, 1992), which allows time for activities such as maintenance, process improvement, and employee training. So if a crisis hits, it is possible to use this as a temporary alternate source to make the required parts or to increase production after the failure is rectified. This can be done by using a third shift, by working overtime, or by hiring temporary workers.

Another option to improvise internally is to not waste existing capacity. Such improvisation might include producing incomplete units. For example, when Johnson Controls went through a strike, it produced seats with management and temporary workers to maintain production. Multifunctional workers also help manage supply chain failure since production may be shifted to other products when one product's supply chain has failed. Demand shifts from one model to another can be influenced through the use of promotions and price incentives, as was done by Dell during a parts shortage (Martha & Subbakrishna, 2002).

Alternately a firm can *improvise externally* around the failure. One way to do this is to find an alternate source of supply and delivery. Although this may be more costly than the normal source, it still can be less expensive than the chain not functioning. This may include shifting sourcing locations, finding alternate routes, and using alternate modes of transportation (Aichlmayer, 2001). Naturally, this would have to involve the cooperation of the logistics provider. After the Kobe earthquake, some companies considered altering their supply routes. Nissan Motor Co. and others investigated costly new alternate routes to avoid supply bottlenecks. Seven-Eleven Japan Co. considered using helicopters to supply convenience stores in the region (Shirouzu, Williams, Sapsford, & Reitman, 1995). If the failure is likely to delay the shipment enough that it will miss a crucial deadline, one may have to find faster alternatives. For example, when a shipment of Sony PlayStations being transported by sea got delayed at the Suez Canal, the company chartered Russian cargo aircraft in order to deliver to customers on time for the crucial Christmas season (Maitland, 2005).

EXTENSIONS AND CONCLUSION

In the past two decades many organizations have embraced JIT and faced challenges of operations protection during supply chain failure since there is little inventory buffer. We presented an organizing framework for some of the structural designs and mechanisms that companies have used to prevent supply chain failure, and to mitigate the effects when the supply chain has broken. We have illustrated that many successful strategies and tactics used by firms, together with several risk mitigation strategies from the literature, can be usefully mapped on a two-dimensional framework anchored on the location and unpredictability of the failure. Since companies plan to persist with JIT even with the possibility of supply chain failure, we hope that our framework will be useful in positioning risks of failure and mitigation options.

While we have initially separated proactive from reactive responses, these may be dynamically connected over time. Firms may learn based on reactive experience. Gulliver (1987) discusses British Petroleum's appraisal of the management of the completed projects so that the lessons can be applied to future projects. The same principle could be applied in the case of supply chain failure. Through reactive improvisation, firms could learn which types of improvisation were effective, and use this to improve the proactive tactics in the future.

Similarly, it is important to note that the ability to reactively manage the supply chain failure is contingent on proactive planning. For example the ability to rely on suppliers to improvise depends on the relationships built within the supply chain. If the company's supply chain structure was not built on long-term strategic relationships, the ability to rely on suppliers to react may be diminished. Within the company, the ability to improvise may be improved by ensuring that employees are trained in process improvement and critical analysis skills, and if crisis planning is done up front.

Even after the fire at the Aisin plant, Toyota plans to keep its policy of single-source suppliers for certain parts despite the dependency, or strategic risk, to which this exposes them. However, the company is building fail-safe mechanisms such as improving the ability of the supplier to shift production to another site if a disaster strikes (Reitman, 1997). Hajime Ohba, general manager of the Toyota Supplier Support Center in Kentucky, publicly responded with Toyota's rationale for JIT after the fire. He said that a better solution is to keep the company's resources at a consistently low cost level, and then rely on the cooperative relationships in the supply network if anything does go wrong (Ohba, 1997). In fact JIT also helps maintain supply chain flexibility when deployed properly. Toyota believes that small lot production allows for flexibility to meet changes in demand, regardless of the cause. This flexibility develops the capability of the supplier to rapidly respond to any crisis (Ohba, 1997).

The evidence points to the fact that over the long term, the benefits of reduced waste and variability through JIT more than offset the disadvantages of being caught without inventory in the unlikely event of a supply chain failure. Accordingly, consultants such as Mercer Management Consulting still advise clients to carry on with JIT since it is estimated that in the auto industry alone, companies are saving $1 billion in carrying costs due to JIT policies (Aichlmayer, 2001). What is required is to make the appropriate adjustments for any unreliability in supply that cannot be avoided. Even from an insurance perspective, implementing JIT systems can have benefits. While some premiums may increase due to increased risks such as that of non-conformance in a supply contract and the increase in road accidents due to more frequent deliveries, the philosophy of focusing on perfection can reduce the premiums related to the risk of product liability and warranty claims (McGillivray, 2000). Also the lack of inventory means lower losses in the case of disasters such as fires.

Given the fact that JIT is likely to be a popular philosophy in the foreseeable future, it is important to provide guidance to organizations using JIT to manage the risk of failure in their supply chains effectively. The proposed framework should help companies manage the risk in JIT-based supply chains. We suggest that managing supply chain failure within JIT systems involves a two-pronged approach. Before the event, JIT involves making the production system as foolproof as possible and forming close relationships with capable suppliers. We have argued that a variety of structures and mechanisms can be used to mitigate the low-to-medium unpredictability events at the firm, supply chain, and external locations. However, some highly unpredictable events can occur despite a well-functioning JIT system. Before the event, firms can monitor and measure events in their internal system, supply chain, and external environment. After a failure occurs the options are more limited to a combination of improvisation and communication with the supply chain. In the ideal case, a well-designed JIT supply chain can use its high visibility, communication, and group problem-solving approach to cooperate to quickly find solutions to supply chain failure. In this article we have illustrated the framework using company experiences and previous supply chain risk research. Further research could attempt empirical validation of the proposed framework.

In the meantime, we hope that our strategic framework encourages managers to consider the location and unpredictability of supply chain failure as they devise strategies to cope with this crucial decision arena in JIT systems. We also hope that researchers will explore the framework using empirical research to validate it, and provide specific guidance to managers regarding the management of location and unpredictability issues in JIT supply chain failure.

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Chapter 7.7

Towards Stable Model Bases for Causal Strategic Decision Support Systems

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ABSTRACT

Most decision support systems (DSS) based on causal models fail to analyze the empirical validity of the underlying cause-and-effect hypotheses, but instead concentrate on numerous analysis techniques within the method base. However, the soundness of these cause-and-effect-relations as well as the knowledge of the approximate shape of the functional dependencies underlying these associations turns out to be the biggest issue for the quality of the results of decision supporting procedures. Therefore this article strives towards an approach to prove the causality of nomologic cause-and-effect-hypotheses by empirical evidence as a prerequisite for the approximation of the mostly unknown causal functions. Since the latter very often show non-linear influences, it is necessary to employ universal function approximators for this purpose: consequently the proposed approach adopts artificial neural networks (ANN) as an inductive method to learn a calculational model of cause-and-effect functions from empirical time series.

INTRODUCTION

One critical challenge in planning and implementing corporate strategies is deriving appropriate decisions and measures from an uncertain and diffuse informational background. Therefore, a crucial requirement for any application supporting this type of decisions is necessary to tackle at least two elementary issues. First, the decision maker has to be supplied with appropriate data about the underlying relevant key figures and business drivers as well as environmental information related to the market or competitors. This first function of data support as outlined before is the main focus of so-called management information systems (MIS). These tools usually employ powerful techniques to gather the necessary figures as a basis for strategic planning efforts.

Second, this raw data has to be arranged within decision models in order to reduce the variety and complexity coming with it. One characteristic of a complex strategic decision that is it is influenced by an immense set of business variables which have to be analyzed in this context. As a consequence, data supporting tools do not provide appropriate aids for this type of entrepreneurial function. It is to reduce the complexity emerging from this amount of data which becomes the principal task of decision support systems (DSS). Hence it can be observed that the architecture of any arbitrary DSS is highly dependent of the managerial approach it is designed to support. It necessarily incorporates the notion of a mental model underlying the respective decision theory as well as techniques to derive decisions from these assumptions. Sprague & Carlson (1982) specify these two core components of a DSS as model base and method base, respectively. The former defines the structure of the decision model, which arranges the raw data provided by a data support component, whereas the latter encompasses decision theoretic methods specifically designed to operate on the given decision model. According to the type of the model base, analytic techniques, like optimization as well as statistical methods or stochastic approaches, like simulation, are used to draw decisions from the raw data organized in the decision model.

A considerable number of recent approaches within the domain of strategic decision making propose to organize business indicators in the form of causal models. The main task of these models is to visualize the cause-and-effect relations which the decision maker assumes to exist between the given variables and/or goals (Hillbrand & Karagiannis, 2002a).

One well-known example for this type of strategic decision methodologies is the balanced scorecard approach (Kaplan & Norton, 1992): The main idea behind this concept is that short-term goals of financial nature like the improvement of profitability measures are usually influenced by long-term objectives of non-financial type. Therefore Kaplan and Norton (1992) postulate a balanced selection of strategic goals out of (at least) four distinct dimensions: financial-, customer-, process- and, development-specific perspectives should be included in the strategic process. Between the goals and measures of these dimensions the decision maker has to make hypotheses about the underlying cause-and-effect relations. Subsequently they can be used to disaggregate main strategic goals into tactical objectives and measures.

Similar principles are encompassed by the French tableau de board methodology (Mendoza et al., 2002) as well as by cybernetic management principles as proposed for example by Vester (1988) in his biocybernetic approach, whose main concepts are reused in the St. Gallen management model (Gomez & Probst, 1999; Schwaninger, 2001; Spickers, 2003).

Although these managerial approaches for strategic decision support provide some practical approaches for the reduction of complexity coming with a sense-making process the implementations of these ideas in the form of DSS are rather weak. It can be observed that software tools supporting such approaches are focused on techniques out of the method base in order to draw conclusions from a hypothetically assumed cause-and-effect model as outlined before (Hillbrand & Karagiannis, 2002a, p. 368). Therefore most DSS of this type provide simulation techniques as well as how-to-achieve- and what-if-analyses. However, the model base usually remains unproven with respect to the empirical evidence of the hypothetically assumed cause-and-effect relations between the business variables. As a logical consequence, the overall quality of the decision support provided by such a system is directly related to the completeness and soundness of the underlying causal hypotheses. Moreover, these techniques are not able to provide quantitative forecasts for future impacts of an analyzed strategic scenario. The reason for this lack of approaches for causal proof and quantitative techniques for managerial cause-and-effect models can be traced back to a proposition of Kaplan and Norton (1996): In their book, they recommend "correlational studies" in order to infer causal knowledge from time series of business variables in the course of double loop learning. This postulate caused an intense discussion about the admissibility of such techniques with respect to the purpose as mentioned before: As for example Weber and Schäffer (2000) conjecture, the "basic problem of an analytic derivation of the `correct` cause-and-effect relations cannot be solved in this way" (p. 8). Horvàth & Partner (2001) come to a similar conclusion:

> *Cause-and-effect relations [...] do not describe arithmetical logics for example in the form of the known ROI-scheme [...]. The goals and for this reason also the measures are causally associated in a logical but not in a calculative sense. If the value of one goal changes, the impacts on another variable of the same system cannot be predicted exactly. (p. 44f.)*

Other authors only refer to the need for further research in this area (Probst, 2001, p. 81). However, this discussion and its limitation to the construct of correlation lead to a rather dogmatic conception that managerial cause-and-effect models must not be evaluated in a quantitative way, which is typical for the relevant managerial literature. According to Schneiderman (1999) this is one of the major reasons for the failure of balanced scorecard projects:

> *We all know that correlation does not mean causality. But try explaining these data to someone who has been only reluctantly convinced that the non-financial scorecard metrics are a leading indicator of future financial success.*(p. 10)

However, if we abandon the restriction to correlation as a concept for the proof of causality and a measure of association, it seems to be possible to infer further causal knowledge from empirical data and therefore improve the quality of the model base significantly. Hence, this article proposes an approach to automatically prove managerial cause-and-effect relations and to approximate the unknown causal function underlying these associations.

The rest of the article is organized as follows: section 2 provides a brief overview of causality concepts as proposed within the appropriate philosophic literature. Consequently, specific causality criteria are defined on this basis. This definition is employed in section 3 in order to establish an approach for the automated proof of nomothetic cause-and-effect hypotheses. Since every single of these proven causal relations are characterized by an arbitrary unknown cause-and-effect function, this function has to be approximated in order to build a quantitative model base for DSSs. Therefore, this article discusses appropriate approximation techniques in section 4 and proposes a nonparametric approach for the universal approximation of arbitrary cause-and-effect functions by the means of ANNs. This article is concluded by the presentation of experimental results in section 5.

CAUSALITY CONCEPTS

Since one main objective of this article is to provide an approach to proof hypothetically assumed cause-and-effect relations between managerial variables, it is necessary to define necessary and sufficient conditions for the concept of causality in this environment. As it has been outlined in the introduction, the mere correlation of two variables seems to be insufficient for this purpose. Moreover, causality per se cannot be observed or tested by objective means. According to Kant, it is a synthetic judgment a priori (Schnell et al., 1999,

p. 56). Causality must therefore be regarded as an assumption about the connection between cause and effect made by the human mind and based on a variety of experiences rather than some kind of natural phenomenon which can be observed in an objective manner.

The Notion of Causality within the Philosophy of Science

As a consequence of the lack of observability of causal relations, there has been a broad scientific dispute within the philosophy of science about the concept of causality. The beginning of this discussion can be traced back to the Humean regularity theory (Sondhauss, 1998). This notion of causality is founded mainly on the two concepts of contiguity and temporal succession (Hume, 1748), that is, two events always have to occur within temporal and or spacial limits and the effect *must* follow the cause in time. Although this theory does not seem to be fully sufficient to explain the concept of causality[1], it introduces an important property that is part of almost every causality theory. Causal relations are usually regarded as asymmetric associations of two events.

However, there are (at least) two objections regarding this basic theory of causation.

Firstly, representatives of probabilistic causality theories bring forward the argument that the deterministic association between cause and effect as an integral part of the regulatory theory represents a too rigorous characteristic. According to their notion, the occurrence of a cause only raises the probability of an effect but does not necessarily imply it.

Secondly, the Humean regulatory theory is criticized because of temporal precedence being the only characteristic to establish the necessary asymmetric property of a causal relation as for example Brady (2002) explains:

The Humean theory does even less well with the asymmetrical feature of the causal relationship because it provides no way to determine asymmetry except temporal precedence. [...] Causes not only typically precede their effects, but they also can be used to explain effects or to manipulate effects while effects cannot be used to explain causes or to manipulate them. (p. 18)

Approaches to overcome these shortcomings lead to the notion of causality as it is proposed by interventionistic theories. The central ideas of these theories are driven by human action as the definition of Gasking (1955) shows:

The notion of causation is essentially connected with our manipulative techniques for producing results. (p. 483)

According to this perception, a causal relation can only be verified in experimental settings where a response can be observed after a cause has been manipulated and the system can be isolated from other (unknown) influences. This is necessary because there exists situations where the essential for defining causation, and it is mere observation of cause and effect misleadingly suggest causality between two events where there is none. For example, the influence of an exogenous third variable U on two endogenous variables C and E can lead to correlation as well as to a temporal precedence relation between C and E although they are not causing each other. This example demonstrates the inability of mere temporal precedence to explain the asymmetry in causal relations quite graphically.

The restriction of interventionistic approaches to analyze the concept of causality only experimentally is the main reason for their failure to explain many real-life problems as it is also the case for managerial cause-and-effect relations: In an enterprise there is hardly any situation where an experiment-like situation can be created because the trial-and-error manner of these settings usually would inflict losses for the business and the response time of basic cause-and-effect relations can be rather long. As a consequence it seems to be too costly to prove causality in this way.

A Synthetic Concept of Causality between Business Variables

Applied to managerial cause-and-effect relations, an appropriate concept of causality must restrict itself to observational studies in terms of empirical data as a consequence. Therefore, we can summarize the previously mentioned disquisition of definitions for causality as follows: A cause should provide information which can be used to (partly) explain its effects. In case of linear cause-and-effect relations this property of informational redundancy is also known as correlation or covariance. However, as it has been shown in the introduction these concepts do not succeed to fully explain causality. According to Hume, there has to be a temporal precedence relation between a cause and its effects additionally to informational redundancy as for example Pearl and Verma (1991) state:

Temporal precedence is normally assumed essential for defining causation, an it is undoubtedly one of the most important clues that people use to distinguish causal from other types of associations.(p. 442)

Regardless of the ability of these two necessary properties to fully explain many causal relations there still remains the problem of an exogenous common cause to induce spurious associations between presumably causal variables. Therefore, the definition of causality has to be enhanced by the postulate to control for this type of association. This leads to a notion similar to the one of Suppes (1970):

X and Y must covary, X must precede Y, and other causes of Y must be controlled.

Based on these foundations the following definition of an appropriate concept of causality to analyze associations between managerial variables can be derived:

Theorem 1 (managerial causal relation): *A causal relation between variables of a managerial system exists if and only if there exist appropriate nomothetic (i.e., unproven) cause-and-effect hypotheses based on causal a priori knowledge where the following conditions are fulfilled:*

- The empirical observations of a potential cause provide informational redundancy regarding its potential effect.
- The variation within the time series of the potential cause must always precede the response of this variation within the time series of the potential effect.
- The three causality properties as defined above (causal a priori knowledge, informational redundancy and temporal precedence) must not originate from the influence of a known or unknown cause, common to the potential cause and the potential effect.

□

As seen in theorem 1, the underlying notion of causality follows the logic of logical empirism, which regards a hypothesis as true as long as it cannot be falsified. Therefore, it is the task of a causality proof to rule out non-causal associations according to the criteria from a given strategy model consisting of nomothetic cause-and-effect hypotheses. The next section develops an appropriate approach for the automated proof of causality.

AN EMPIRICAL VALIDATION APPROACH FOR CAUSAL STRATEGY MODELS

As the previous section provides a homogeneous notion of causality, it remains to identify an approach to apply this definition to the causal knowledge of an enterprise in order to distinguish between genuine and spurious cause-and-effect relations. The conceptual basis for the construction of proven causal models for strategic decision support is therefore represented by the necessary and sufficient properties of causality as previously defined.

Modeling Nomologic Cause-and-Effect Hypotheses

The starting point for this approach is the compilation of causal knowledge in the form of implicit mental models or corresponding data into an explicit model of nomologic cause-and-effect hypotheses. The latter are contained in a rudimentary cause-and-effect model which has to be given by strategic decision makers and represents the first necessary causal property of a priori knowledge.

One possible approach to model causal strategy maps has been proposed by Hillbrand and Karagiannis (2002b, p. 53). The meta-model of their modeling framework consists of indicators which can be of crisp or fuzzy type and two types of associations which connect a pair of indicators:

- *Defined influence relations represent causal associations between variables which can be fully explained by decision makers. Usually the target variable of this type of relation is some kind of synthetic ratio which has been axiomatically devised by a formula consisting of several input parameters. A well-established example for influence relations are profitability measures like ROI, ROCE, and so forth. As a consequence defined influences can only be modeled between crisp indicators where the values of the result variable can be fully explained by some algebraic function of input indicators.*
- *All remaining potentially causal associations between either crisp or fuzzy variables which do not fulfill both conditions for a defined influence relation are called undefined. For this type of relation it is not possible to assume causality a priori as in the preceding case. Rather, the decision makers are forced to rely on nomothetic cause-and-effect hypotheses. However, the empirical knowledge of past time-series enables managers to scrutinize the causal content of the interjacent potential cause-and-effect relation.*

Consequently, it is the focus of this section to provide appropriate methods in order to analyze the hypothetically defined model base of a strategic DSS with respect to its causal validity. This task of the proposed approach is to detect so-called α-errors[2] of nomothetic cause-and-effect hypotheses between variables. Therefore the starting point for the reconstruction of a proven causal model is a rather over defined rudimentary model as described above.

Identification of Temporally Lagged Informational Redundancy

The second necessary condition for causality—as defined in the previous section—is informational redundancy between a potential cause and its potential effect. As a consequence the time series of the dependent variable as the output of an unknown causal function associated with the respective relation must also reflect patterns or variations of independent time series. Very often these patterns are transformed by the underlying causal function and superposed by the influences of other exogenous or endogenous variables.

Therefore, they cannot always be detected a prima facie. If the causal function which transforms the values of a set of independent variables into the value of a dependent value is of linear type, the concept of correlation can be used as a measure for informational redundancy. In all other cases, one has to find other techniques to analyze whether two time series are informationally redundant or not. For the purpose of this approach it seems to be suitable to restrict to the linear case because the causality proof per se does not build the model base but is used to select variables for the following approximation of a nonlinear causal function. Therefore, it is not necessary to rule out all possibilities of α-errors because the ANNs—assigned to perform the causal approximation task—are supposed to detect the non existing influence of marginally spurious associations. The admissibility of this theory for different types of causal functions has been shown by Hillbrand (2003, pp. 299ff.).

When considering the third necessary condition for causality of temporal precedence of cause and effect, the inadequacy of the concept of correlation alone to prove cause-and-effect relations becomes obvious: The correlation of two time series would show that the variations of a independent and a dependent variable are similar and that they take place contemporaneously.

As this is mutually contradictory to the notion of causality as defined in the previous section, the concept of correlation has to be adopted to measure temporally lagged responses of the variation of an independent factor within the time series of the dependent variable. Therefore, cross-correlation $\rho_{X,Y}(\Delta t)$ implies a time lag (Δt) between a cause X and an effect Y in the following form:

$$\rho_{X,Y}(\Delta t) = \frac{\dfrac{\sum_{t=1}^{T}\left(y_t - \overline{Y}\right)\left(x_{t-\Delta t} - \overline{X}\right)}{T}}{\sigma_X \cdot \sigma_Y} \qquad (1)$$

Where y_t and x_t stand for the values of the variables Y and X at time t, $\overline{X}$ and $\overline{Y}$ stand for the average values and σ_X as well as σ_Y for the standard deviation of the respective time series. As it is evident from the previous expression, the upper part of the fraction is derived from the construct of covariance.

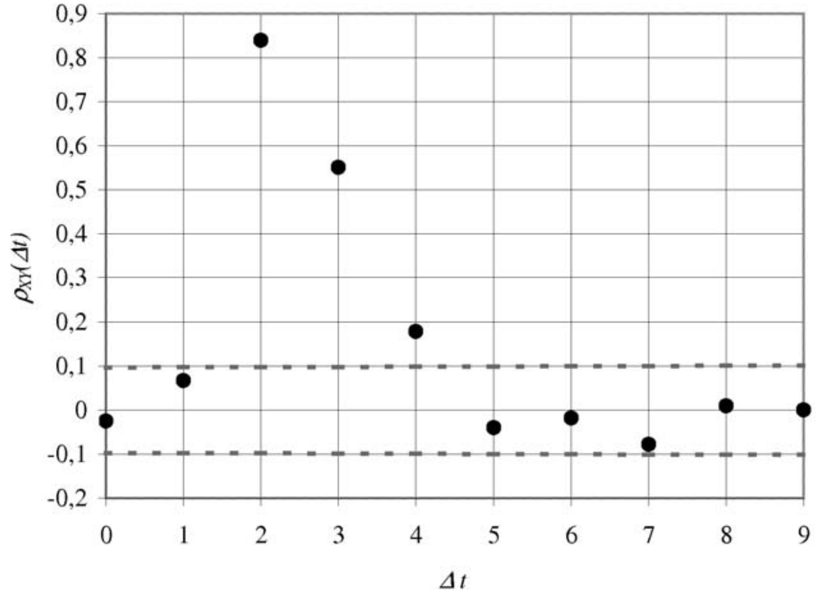
As a consequence, this approach employs this concept to identify the two causality conditions of informational redundancy and temporal precedence. By calculating the cross correlations for varying time lags it is possible to identify a window of impact between an independent and a dependent variable. This window of impact is characterized by a minimum time lag and a number of subsequent effects (i.e., the length of the window of impact). For this purpose it is necessary to identify the significance of a cross correlation at a given time lag. Therefore, this approach uses Bartlett's significance test (Bartlett, 1955) following the suggestions of the appropriate literature in this area (Levich & Rizzo, 1997; Makridakis & Wheelwright, 1978): The null hypothesis of this test is formed by the assumption that two given time series at a certain time lag are independent if their cross correlation shows a value of zero. This hypothesis has to be accepted if the cross correlation lies within the boundaries which are given by the standard deviation of the cross correlation. If it exceeds this critical value, the null hypothesis is rejected and it is said to be significant. Since the standard deviation of the cross correlation is usually not known a priori the critical test value is replaced by the following estimate (Bartlett, 1955):

$$\sigma_{\rho_{X,Y}(\Delta t)} = \frac{1}{\sqrt{n - |\Delta t|}} \qquad (2)$$

Where n stands for the number of samples in the time series of X and Y, respectively.

By increasing the time lag Δt by discrete steps beginning at a lag of zero time periods, it is possible to identify the minimum time lag by recording the first significant cross correlation between the time series.

Figure 1. Correlogram between two time series



This approach is illustrated in Figure 1 for the following synthetically generated time series:

$$x_t = \varepsilon_{U(0;\,1)}$$
$$y_t = 0.2y_{t-1} + 0.5x_{t-2} + 0.2x_{t-3}\ \varepsilon_{U(0;\,1)} \qquad (3)$$

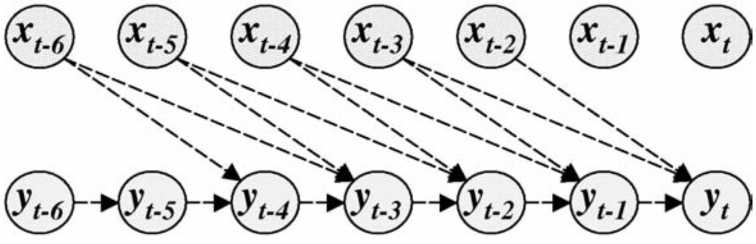
Where $\varepsilon_{U(0;\,1)}$ is a random variable, uniformly distributed between zero and one.

As it is obvious from the above equations, the time series y_t of the independent variable Y incorporates past values of the time series x_t with a time lag of two and three time periods, respectively. Therefore the correct window of impact is [2,3].

Figure 1 shows the cross correlations computed from the artificial time series x_t and y_t for the time lags $\Delta t = 0, ..., 9$ as well as the bandwidth of their standard deviation which lies between the dotted lines. The clear consequence which can be drawn from this correlogram is that the first significant correlation starting from zero occurs at a time lag of $\Delta t = 2$, which corresponds exactly to the generating function of y_t as stated above. Therefore, the minimum time lag for this potentially causal relation is $b = 2$ time periods. This means that the variation of the independent variable X is first repeated within the time series of the dependent variable Y after two time periods.

The first attempt to determine the appropriate length of the window of impact using the correlogram in Figure 1 yields time lags between $\Delta t = 2$ and $\Delta t = 4$ because the last significant cross correlation occurs with a time lag of four time periods. As this is not correct with respect to the generating function, one has to take the autocorrelation of the two variables into account. It can be shown that significant autocorrelation of the independent time series leads to the so-called echo effect (Hillbrand & Karagiannis, 2002b; p. 74), which describes the indirect effects of independent values prior to the window of impact through an autocorrelated dependent time series. In the example of Figure 1, this effect becomes evident when scrutinizing the generating function of the time series y_t. This function includes the term "… $0.2y_{t-1}$ …," which means that the actual value of the variable Y reflects also a fraction the preceding value y_{t-1}. As this in turn is influenced by the independent values x_{t-3} and x_{t-4} it becomes evident that the latter is reflected in y_t with the weight $0.2 \cdot 0.2 = 0.04$ (Figure 2). As the autocorrelation of the dependent variable can be regarded

Figure 2. Echo effect



as an infinite series, it can lead to putative random patterns for the echo effect.

Therefore, it is crucial for a correct identification of the impact window to eliminate any autocorrelation within the time series to be analyzed. This preprocessing of the time series is known as prewhitening in the appropriate literature (Makridakis & Wheelwright, 1978; pp. 382f.). As a prerequisite for this task, the order of autocorrelation for independent and dependent variables has to be determined by the use of the autocorrelation coefficient[3]. Thus this approach analyzes the autocorrelation coefficients for ascending orders which exceed the critical value of the Bartlett test (for details see above) and consequently are denoted as significant. This approach comes to reliable results for the analysis of independent time series. However, it does not perform well for result variables as a further disturbance effect can be observed in this context: Influences with a significant number of subsequent effects (i.e., the window of impact is larger than one time period) tend to induce an autocorrelation-like pattern in the dependent time series although there is no significant autocorrelation from the generating process of y_t. As a consequence, it seems to be necessary to identify the appropriate window of impact before analyzing the autocorrelation of the dependent time series. Therefore, a circular dilemma occurs because the autocorrelation of the dependent variable is a prerequisite for the prewhitening process, which is in turn necessary to avoid echo effects and to identify the appropriate size of the window of impact consequently.

Approaches for this dilemma include the solution of separated autoregressive generating processes for each time series, as well as iterative approximation techniques. The separated generating processes as mentioned previously are characterized by partial autocorrelation coefficients. The combination of partial autocorrelations of dependent and independent time series, as well as the cross correlation between the two of them, result in the specific cross-correlation pattern observable in the correlogram (Figure 1). Since the relevant literature knows solutions for this problem which are far from trivial, this article employs an approach which is based on an iterative approximation of an appropriate length for the window of impact:

1. Prewhitening of independent variables:
   a. Determine orders of significant autocorrelation within the time series of every independent variable X_t.
   b. For every order o of significant autocorrelation for every independent variable X_t determine the respective autoregression coefficient $\beta_{X,o}$.
   c. For every value $x_{i,t}$ of an autocorrelated independent variable X_t subtract past values of the same time series weighted by the appropriate autoregression coefficient in the following form: $x'_{i,t} = x_{i,t} - \sum_{\forall o} \left(\beta_{X_{i,o}} \cdot x_{i,t-o} \right)$.
2. Determine significant cross correlations between every prewhitened independent timeseries $x'_{i,t}$ and the dependent time series y_t for different time lags Δt.

3. Identify the windows of impact – determined by the minimum time lag b_i and the following effects s_i – from the the correlograms between every prewhitened independent variable X_i' and the dependent variable Y.
4. Determine the regression coefficients $\beta_{X'_{i,\Delta t}}$ between any independent variable X_i' and the dependent element Y for time lags Δt with a significant cross correlation.
5. Eliminate all impacts of independent variables on the dependent variable by subtracting the respective past values of the independent time series $x'_{i,t-\Delta t}$ weighted by the appropriate regression coefficient $\beta_{X'_{i,\Delta t}}$ according to the prewhitening procedure as described in step 1c.
6. The isolated dependent time series y_t^* resulting from the previous step is tested for significant autocorrelation.
    a. If no significant autocorrelation can be identified within the time series of y_t^*, the procedure terminates. Therefore the windows of impact for each independent variable X_i are given as determined in step 3.
    b. If the time series y_t^* is significantly autocorrelated, the raw time series y_t is prewhitened according to steps 1b and 1c. The procedure resumes with a new iteration at step 2 using the prewhitened dependent time series y_t'.

Having an appropriate algorithm to test the second and third necessary condition of causality (informational redundancy and temporal precedence) non-causal or spurious relations can be identified by the absence of an empirically significant window of impact.

Controlling for Third Variable Effects

The remaining potentially causal relations, which comply with the first three causality criteria, are subject to a further analysis of common causation by third variables. For this purpose Pearl and Verma (1991) propose an approach to distinguish spurious associations induced by a common cause from genuine causation:

Theorem 2 (Controlling for third variables): *One can assume a relation $X \rightarrow Y$ to be causal if and only if the time series of the potential effect Y incorporates not only patterns of its potential cause X but also those of the predecessors P (i.e., causes) of X in the cause-and-effect model. If X and Y as well as P and X are informationally redundant but P and Y are not, an unknown third variable U rather than a causal relation must be assumed to induce the informational redundancy between X and Y.*

□

As a consequence the patterns of P are reflected within the time series of X, but they are not passed on to Y due to the absence of a genuine cause-and-effect relation $X \rightarrow Y$.

A basic tool for the analysis of these assumptions within causal graphs is the concept of conditional independence: Two variables A and B are conditionally independent given a set of variables S_{AB} – written as $(A \perp B \mid S_{AB})$ – if A and B are informationally redundant but if the impacts of S_{AB} on B are eliminated, this property vanishes. Therefore S_{AB} is said to "block" the causal path between A and B.

Applying this concept to the previously mentioned theory, spurious associations between a potential cause X and a potential effect Y can be ruled out by the following observations:

- There exists a minimal set of blocking variables S_{PY} causing conditional independence between any predecessor P of X and the effect Y, denoted as $(P \perp Y \mid S_{PY})$.
- X is part of the set S_{PY}.

The theory to detect third variable effects as outlined in this paper is implemented by the

IC^4-Algorithm. For reasons of lucidity, this paper dispenses with a detailed discussion of these procedures but refers to the appropriate literature (Hillbrand, 2003, p. 198; Pearl & Verma, 1991).

Summarizing this approach, the mapping of nomothetic cause-and-effect hypotheses, by decision makers represents a prerequisite for their proof as well as the first causality criterion. The second and third condition for causality—informational redundancy and temporal sequence—are tested by analyzing the cross correlations between the prewhitened time series of the respective variables connected by a cause-and-effect hypothesis. To rule out a third variable inducing informational redundancy between two lagged variables, this analysis is completed by the application of the IC-Algorithm as outlined above. Only relations which pass all these tests satisfy the necessary causality conditions and are therefore said to be genuinely causal.

APPROXIMATION OF UNKNOWN CAUSAL FUNCTIONS

The proof of causality, as proposed in the previous section, is the main prerequisite for the approximation of the unknown causal function affecting the values of any arbitrary business variable within a cause-and-effect structure. This provides the necessary numeric properties for the causal model base of a DSS to run simulations as well as how-to-achieve or what-if analyses. One crucial issue of this task is that the form of these cause-and-effect functions cannot be assessed a priori. Therefore, three alternative approaches are to be considered in this context:

First, the base functions for the approximated associations have to be predetermined (e.g., linear, logarithmic, logistic, exponential, etc.). With this assumption, it is possible to approximate the unknown function by estimating the parameters of an appropriate regression model.

Second, a function can be locally approximated by developing an appropriate polynomial. This principle is used for the Taylor or Fourier series expansion. A disadvantage of these techniques is that their approximation is only accurate within local limits of the function.

Third, unknown functions can also be reconstructed without prior knowledge of their shape by so-called universal approximators (Tikk et al., 2001). Hence these techniques are able to learn a function from mere empirical observations without the need to narrow down some base function. This characteristic becomes increasingly important whenever the unknown function to be approximated is of nonlinear type. As it can be shown by numerous examples, microeconomic functions which usually underlie strategic reasoning are almost never of linear type (Hillbrand, 2003, pp. 201ff.). The reasons for this observation are manifold. Saturation as well as scale effects or resource limitations are only a few causes for the nonlinearity of relations between business variables. One well known example is the association between the market price and the customer demand for a certain product. Raising prices will not linearly result in an increasing demand. Rather it is likely that there is some maximum price level the customer is willing to pay, which therefore provides a limit for the demand. As an example Allen (1964) supposes demand functions to follow some S-shaped—also known as sigmoidal or logistic—pattern.

For these reasons it is essential to abandon all restrictions regarding a priori assumptions about the unknown function underlying a cause-and-effect relation. This postulate leads to the necessity to employ universal function approximators in order to identify the functional form of the causally proven associations. Therefore this approach studies the potential and limitations of artificial neural networks (ANNs) for universal causal function approximation. The theoretic foundations of this property of ANNs is the result of the endeavors to approximate an unknown mapping by the combination of known functions. The central theory in this area has been proposed by Kolmogorov (1957) who argued that any arbitrary unknown function *f* can be approximated by two nested known functions ϕ and ψ. This theory is usually regarded as the central concept for universal function approximation in the relevant literature (Tikk et al., 2001, p. 2):

Theorem 3 (Kolmogorov's superposition theorem): *For all $n \geq 2$, and for any continuous real function f of n variables on the domain [0, 1], $f: [0,1]^n \rightarrow \mathbb{R}$, there exist $n(2n+1)$ continuous, monotone increasing univariate functions on [0, 1], by which f can be reconstructed according to the following equation*

$$f\left(x_1, \ldots x_n\right) = \sum_{q=1}^{2n} \phi_q \left(\sum_{p=1}^{n} \psi_{pq}\left(x_p\right) \right) \square$$

Further enhancements of Kolmogorov's superposition theory are developed by several authors which lead to the notion of ANNs as universal function approximators (De Figueiredo, 1980; Hecht-Nielsen, 1987). Since the inner function of Kolmogorv's theorem can be highly nonsmooth it has to be weighted with a factor λ in order to use specific continuous functions (squashing functions) for this purpose. Therefore the resulting function can be represented by a multi-layer perceptron (MLP).

Separating Causal Function Kernels from Causal Strategy Models

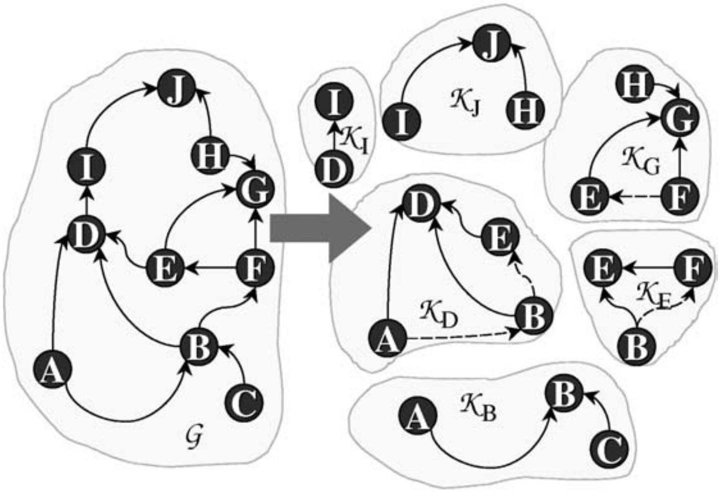
Since the universal approximation property has been proved for numerous types of ANNs, this approach focuses on the construction of MLPs out of empirically proven cause-and-effect hypotheses. Therefore the causal strategy model has to be separated into causal function kernels (CFK). The latter describe a set of variables and interjacent cause-and-effect relations, each of which consists of a dependent element and its direct predecessors. Therefore, the number of CFKs derived from a causal strategy model corresponds to the number of contained variables, which show an empirically significant influence by other elements. Following the theory underlying this approach, the total cause-and-effect relations within a causal function kernel represent the unknown causal function determining the values of the dependent variable. Taking the previous discussion into account, this function can be approximated sufficiently accurate by an MLP with the appropriate time series of the independent variables as input and those of the dependent element as output node.

Due to the possible existence of indirect associations between independent and dependent variables within a CFK it is likely that the overall effect between such two elements has to be separated in order to obtain the direct share of influence. This effect is called multicollinearity in the appropriate statistical literature and perturbs the approximation quality if it remains unsolved. Hence, it is necessary to extend the causal function kernels for cause-and-effect relations which directly and or indirectly link two independent variables $X_1 \rightarrow X_2$ and consequently induce an indirect effect between X_1 and the dependent variable *Y*. These auxiliary cause-and-effect relations accounting for multicollinearity can be discovered by analyzing the transitive closure[5] of each independent variable within the global causal system: For every pair of independent variables X_i and X_j within a causal function kernel K_Y there exists an auxiliary cause-and-effect relation $X_i \dashrightarrow X_j$ if and only if X_j is contained in the transitive closure of X_i according to the global model G. The procedure to construct extended causal function kernels (eCFK) from a causally proven global strategy model G is shown in Figure 3.

Temporal Disaggregation of Causal Function Kernels

Since an unknown causal function to be approximated does not exist between variables but rather

Figure 3. Separation of (extended) causal function kernels



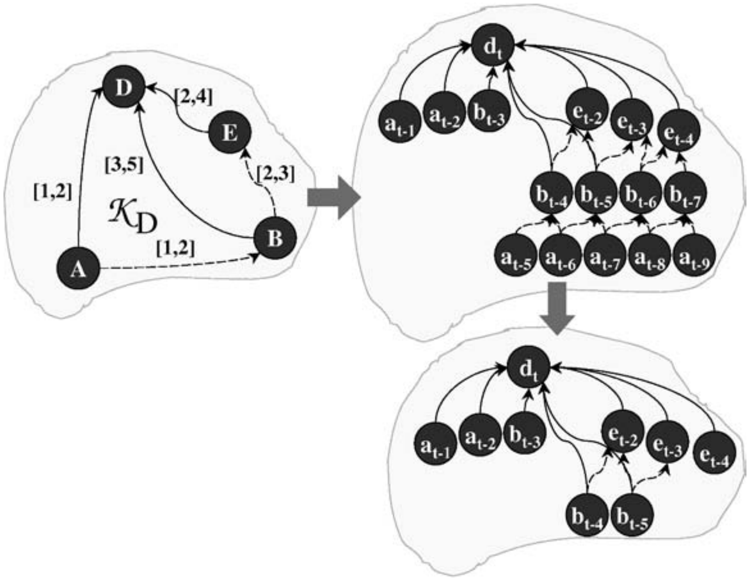
between their lagged time series, the eCFKs have to be temporally disaggregated. Therefore, this approach uses the window of impact as identified by the causal proof procedure (see section 3): While the dependent variable Y is represented by its instantaneous time series y_t as an output node, each independent variable leads to a number of input nodes corresponding to the length of the appropriate window of impact. These input nodes each represent one lagged independent time series within the window of impact. As far as eCFKs are concerned, it is necessary to introduce a second input layer which accounts for auxiliary cause-and-effect relations. The time series of the second layer are derived by the same procedure as described above taking the influenced indirect time series of the auxiliary association as output node and the influencing element as input node. Second input layer elements which affect first layer time series and the output node directly are of specific interest because they combine direct and indirect influence, as it is shown in Figure 4, for the extended causal function kernel K_D. All other second layer input elements where this overlap does not exist can be eliminated from the temporally disaggregated causal function kernel (dCFK) since they are already encompassed by another (d)CFK.

As temporal disaggregation delivers the appropriate input and output nodes for a neural function approximator in the form of temporally lagged time series there remains the issue to complete the model selection of the ANN. This includes an adequate dimensioning of the hidden layer(s) as well as the selection of input and transfer functions for all ANN-nodes.

Since the universal approximation property postulates a limitation of the inner function of Kolmogorov's theorem, it is necessary to use transfer functions which map the input values to a certain output interval. This class of so-called squashing functions encompasses sigmoid as well as logistic sine or heaviside functions (Hillbrand, 2003, p. 214). For practical reasons the use of an additive input function for hidden and output neurons is recommended.

The selection of an appropriate number of hidden neurons is directly related to the generalization ability of the ANN (i.e., to learn a certain function instead of memorizing input-output mappings). As this specific model selection task depends on a variety of influences which cannot be fully assessed a priori, it is necessary to rely on heuristics (for details see Hillbrand, 2003, pp. 226–230) and validate the prediction accuracy of the ANN by using a validation data set[6].

Figure 4. Temporal disaggregation of (e)CFKs



As it follows from the temporal disaggregation of eCFKs, the resulting auxiliary cause-and-effect relations between second-level and first-level time series have to be incorporated into the neural function approximator in order to account for indirect effects. Therefore, auxiliary sub-MLPs are introduced as symbolized by dotted connectors in the example of Figure 5.

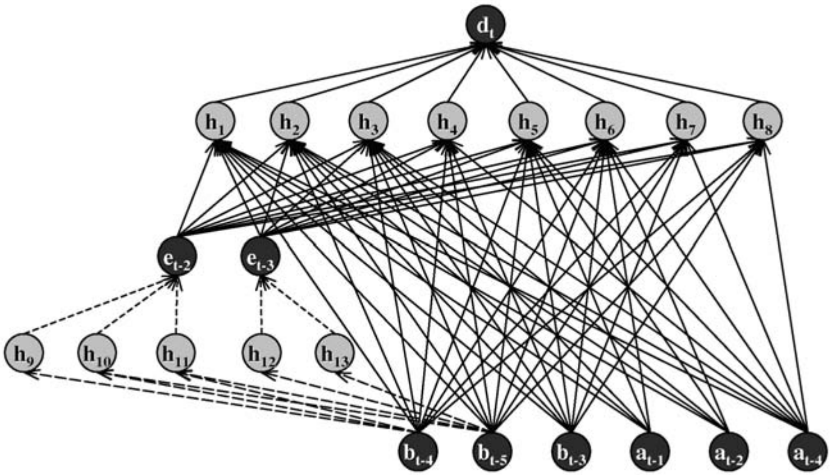
Before the training of the overall causal function approximator it is necessary to learn these correcting functions each of which has one first-level time series (e.g., e_{t-2} and e_{t-3}) as output node and one or more second-level time series as input nodes. The hidden layer of a correcting ANN is dimensioned by the same heuristics like the main function approximator. After the training of all correcting ANNs, their weights are kept fixed and included in the main neuron model. For the overall training of the causal function approximator it is necessary to equip first-level nodes with a specific input function since they are input and hidden nodes in the same way. Consequently, the input function of a first level node calculates the weighted output sum of all preceding nodes plus the respective input value of the node itself[7]. The ratio between these two shares of cumulative input is needed for training purposes when employing an error backpropagating algorithm. The same portion by which the overall input for a first-level node consists values from a lower network layer is used to distribute the output error—backpropagated from higher network levels (e.g., $h_1 – h_8$) —among lower level neurons (e.g., $h_9 – h_{13}$).

Since all further characteristics regarding layout and training of neural causal function approximators correspond with those of MLPs they are not discussed in further detail but referred to the relevant literature (e.g., Hillbrand, 2003).

EXPERIMENTAL RESULTS AND PROOF OF CONCEPT

The concepts to validate corporate cause-and-effect hypotheses and to approximate the underlying causal function from empirical evidence as proposed in this article have been implemented in

Figure 5. Neural function approximator for (e)CFKs



the form of a research prototype (Hillbrand, 2003, pp. 288–319). The latter has been implemented based on a modeling environment as described in section 3 provided by the metamodeling platform ADONIS (Karagiannis & Kühn, 2002). This provides the basis for an in-depth investigation about the admissibility of the proposed approach for real-world strategic scenarios as well as about its limitations with respect to several problem classes. Therefore, this proof of concept employs a causal system consisting of five variables each of which is described by artificially generated time series. According to the characteristics of these time series the respective CFKs are assigned to specific problem classes. Starting from a completely interlinked causal strategy model it has to be tested, if all spuriously inserted associations are detected and eliminated from the model. Furthermore the correct windows of impact have to be identified. Based on this reconstructed model the approach should construct appropriate causal function approximators which are trained subsequently. The superior prediction quality of the trained function approximator is then tested in comparison with similar techniques.

A Generating Causal System for the Proof of Concept

The causal system in Figure 6 is implicitly represented by the following functional associations:

$$as_t = \varepsilon_{N(1;\,0.50)}$$
$$rm_t = \varepsilon_{N(1;\,0.50)}$$

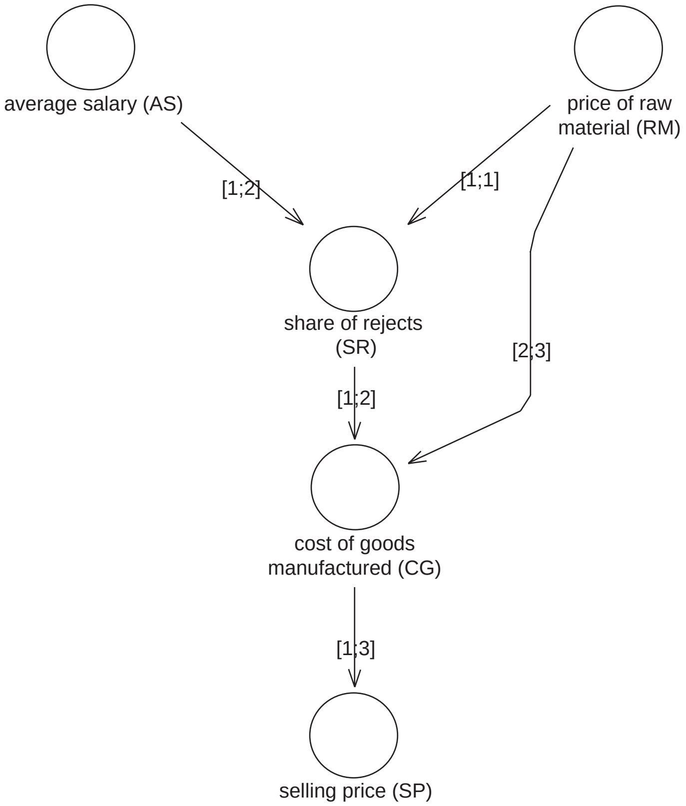
$$sr_t = 0.95 + \frac{1}{30 \cdot as_{t-1} - 23.5} + \frac{1}{6.66 \cdot as_{t-2} - 5} - \frac{7 \cdot as_{t-1} - 6}{8} + \varepsilon_{U(-0.15,+0.15)}$$

$$cg_t = -2.5 + 0.25\,(4 - \sin(4+5rs_{t-1}) + 0.2\,(4 - \sin(2 + 7rs_{t-2})) + 1.1rn_{t-2} + 0.8rn_{t-3}\,\varepsilon_{U(-.3;\,0.3)}$$

$$sp_t = \frac{\sum_{\Delta t=1}^{3} cg_{t-\Delta t}}{3} + \varepsilon_{U(-0.15,+0.15)} \qquad (4)$$

Where as_t, rm_t, sr_t, cg_t and sp_t stand for the values of the variables *average salary*, *price of raw material*, *share of rejects*, *cost of goods manufactured* and *selling price* in period *t*, respectively. The term $\varepsilon_{U(-0.15,+0.15)}$ stands for uniformly distributed random number within the interval [-0.15,+0.15]

Figure 6. Generating causal system



and $\varepsilon_{N\ (1;0.05)}$ represents a normally distributed random number with expectated value of 1 and a standard deviation of *0.05*.

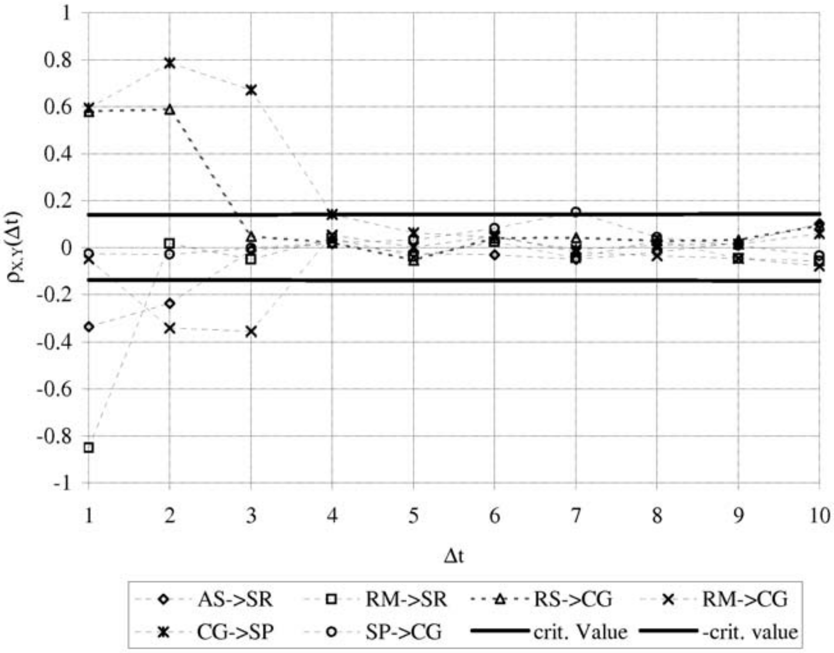
Identification of Spuriously Inserted Cause-and-Effect Hypotheses

Since the generating system of causally related time series does not exist explicitly in real-world scenarios, it is the aim of this approach to reconstruct the structure of the causal model as shown in Figure 6, to identify the appropriate time lags and to approximate the functional dependencies. The basis for the application of this approach is a rudimentary causal strategy model which comprises the nomologic cause-and-effect hypotheses as assumed a priori by decision makers. For this purpose, the functional proof of concept starts with a fully interlinked causal system consisting of the five variables already mentioned.

In order to rule out spurious associations according to the second and third causality criterion (informational redundancy and temporal precedence) the proposed approach analyzes the cross correlations for every link in the maximal strategic system model for different time lags. Since fourteen associations do not show a significant cross correlation at any Δt, they are marked as spurious. The remaining six potentially causal relations according to the second and third causality criterion yield cross correlation patterns as shown in Figure 7.

As it is obvious from this correlogram, the proposed proof of causality identifies the correct windows of impact of the five causal relations implicitly included in the generating system. However, this algorithm untruly identifies a sixth association ($SP \rightarrow CG$) to be potentially causal according to the second and third causality criterion because its cross correlation at a time lag of seven periods seems to be significant:

Figure 7. Cross correlations resulting from the verification algorithm



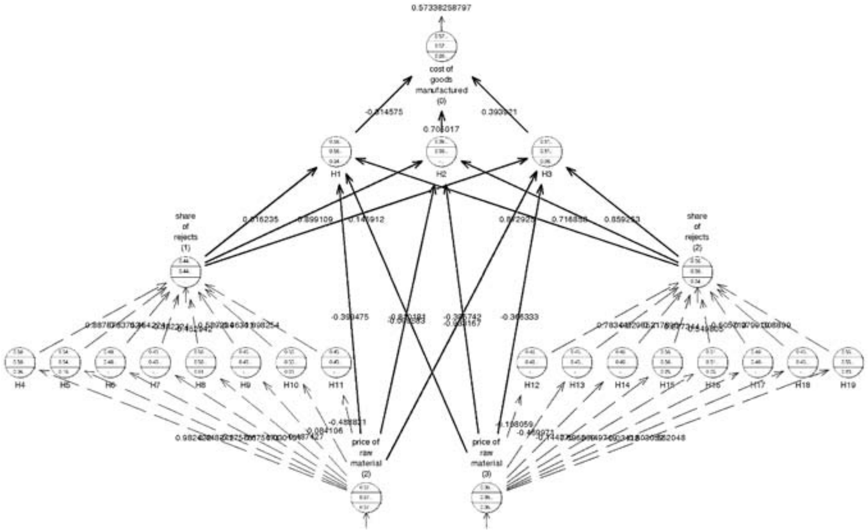
$$\rho_{SP,\,G}(7) = 0.1458 > \sigma_{\rho_{SP,\,G}} = 0.1411. \qquad (5)$$

The test for exogenous third variables inducing a spurious correlation between two elements of the causal system is performed by the principles as proposed in section 3 of this article. Since the variations of both, the variable *average salary* and *price of raw material* are not only reflected in the timeseries of their direct successor but also in those of the remaining elements it can be concluded that the potentially causal relations *SR* → *CG* as well as *CG* → *SP* are genuinely causal. As the latter proves that the direction of this relation is unambiguous, the potentially causal relation *SP* → *CG* is marked as spurious association.

Approximating Causal Functions

The next step, according to the proposed approach, is to approximate the unknown causal functions for each causal function kernel which consists of a positive number of proven causal relations. Therefore, this approach derives three multi-layer perceptrons (MLP) from the identified causal strategy model. For the K*SR* this neural network consists of the output node sr_t as well as of an input layer consisting of as_{t-1}, as_{t-2} and rm_{t-1} and a four-element hidden layer being dimensioned using a heuristic proposed by Baum and Haussler (1988). Another MLP—approximating the causal function of K_{SP}—is established with the time series cg_{t-1}, cg_{t-2} and cg_{t-3} forming the input nodes and sp_t as an output node. The input and output nodes of the causal function approximator for K_{CG} are derived analogously: The time series sr_{t-1}, cg_{t-2}, rm_{t-2} and rm_{t-3} representing the input layer and cg_t as output node. However, since this CFK contains the influence relation *RM* → *SR,* which causes multicollinearity, it is necessary to distinguish between first and second level input nodes and connect them with correcting function approximators. Therefore, the temporal disaggregation algorithm introduces two correcting MLPs. One of them contains sr_{t-1} as output and rm_{t-2} as input

Figure 8. Causal function approximator for K_{CG}



node and the other receives input values from rm_{t-3} and has sr_{t-2} as output element. The resulting MLP is shown in Figure 8, where dashed arcs represent auxiliary correcting MLPs accounting for the relation $RM \rightarrow SR$ and solid links are part of the main function approximator.

After deriving the three neural function approximators as shown in Figure 8, the latter have to be trained in order to inductively learn the unknown causal function from the empirical data. Therefore, the time series associated with each input and output nodes are split into a training and a validation set. If an MLP incorporates correcting function approximators, the latter have to be trained independently first. After reaching a global error minimum for these correcting ANNs, their weights are kept fixed and are included in the main function approximator as specified in section 4 including the special input functions for first level input nodes as well as its inverse function for error backpropagation purposes.

The training of these MLPs leads to an approximation of the causal function determining the values of the dependent variable of each causal function kernel. With the approximate knowledge of its functional dependencies in the form of the trained ANN, the causal strategy models can be enhanced by a prediction model which allows numerical analyses on future impacts of strategic scenarios. Since ANNs are known for their universal approximation properties in the relevant literature (cf. section 4), they are expected to yield better approximation results than other techniques. A comparison with linear forecasting models like multiple linear regression analysis shows a predominantly clear picture.

As it is shown in Table 1, the proposed approach enables decision makers to approximate a

Table 1. Prediction quality of linear regression vs. connectionist approximator

CFK	$MSE_{lin.}$	MSE_{ANN}	significant
K_{SR}	0.0048	0.0015	yes
K_{CG}	0.0143	0.0056	yes
K_{SP}	0.0022	0.0020	no

more precise causal function compared to linear regression in all cases. As the latter does not account for nonlinear functions, indirect effects, autocorrelation or noisy time series, it yields significantly[8] higher Mean Squared Errors (MSE) for the validation set than the connectionist approach especially for these problem classes. The only exception of this observation is CFK K_{SP}, which is not included in any of the problem classes: Only for these—strictly linear—functions, given the absence of other disturbances, it is not possible to achieve significantly better predictive results using the connectionist approach.

CONCLUSION

This article proposes a new approach to validate causal strategy models consisting of nomologic managerial cause-and-effect hypotheses as a prerequisite for the approximation of the unknown underlying functions: Therefore this paper focuses on artificial neural network models due to their universal approximation properties which explicitly dispenses with a priori assessments about the functional form of these associations. Therefore, this article presents techniques for the separation causal function kernels from causal models and their temporal disaggregation into multi-layer perceptrons. The article concludes with a functional review of the prototypical implementation based on these concepts. The main findings show that the assumption of linear causal function for model selection purposes within the stage of causal proof is admissible to a large extent. Merely the high noise level of one variable leads to the acceptance of a spurious cause-and-effect hypothesis for an intermediary result. However, this source of error will be one issue for future research: As Bartlett's significance test does not account for the noise level of a dependent variable this technique has to be enhanced in order to provide improved significance boundaries which are sensitive with respect to the predictive uncertainty.

In order to integrate this approach into a DSS it seems to be necessary to extend this approach for analytic techniques based on this improved model base like simulation, what-if- or how-to-achieve-analyses. These applications allow the quantitative anticipation and prediction of future impacts of strategic scenarios.

Another field of interest is the transfer of the approach—as proposed here—to other scientific areas. Basically, these techniques could be employed for every decision theoretic problem based on causal networks such as economic theories, medical diagnostics, etc.

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ENDNOTES

[1] If the two Humean properties of causality would be sufficient to explain causal structures, a bad weather forecast would be the regarded as the cause for bad weather.

[2] An α -error or type-1-error denotes a cause-and-effect relation between two variables in a causal strategy model although the corresponding time-series are not causal. On the contrary the term β- or type-2-error is used if there exists a causal relation in reality (i.e., between the time-series of two variables but it is not represented in the causal strategy model).

[3] The computation of the autocorrelation of a variable X and a given order n corresponds to the one of the cross correlation $\rho_{x,x}(n)$. Hence it will be abbreviated by the symbol $\rho_x(n)$ for the rest of this article.

[4] IC = Inductive Causation

[5] The transitive closure is the set of all direct and indirect successors of a node within a directed graph (e.g., a causal strategy model).

[6] A validation data set is a subset of the empirical data which is not used to train the ANN

[7] e.g., $net_{e_{t-2}} = in_{e_{t-2}} + \sum_{i=9}^{11} w_{h_i, e_{t-2}} \cdot out_{h_i}$

[8] The statistical significance of this statement has been validated by testing the group average of the squared errors for both techniques using variance analysis.

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Chapter 7.8

Decision Support–Related Resource Presence and Availability Awareness for DSS in Pervasive Computing Environments

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ABSTRACT

Over the last 10 years, pervasive computing environments and mobile networks have become extremely popular. Despite the many end user benefits of pervasive computing, the intrinsic instability and context ambiguities of these environments pose impediments to data-oriented decision support systems. In pervasive computing environments where users, systems, and computing resources are distributed or mobile, the online or "available" state of decision support-related resources may be intermittent or delayed. Awareness or knowledge of these resources' online presence and availability can affect the decision making process. This article discusses issues related to data-driven decision support systems (DSS) in pervasive computing environments (PCE) and demonstrates that a decision maker's awareness of online status and availability can improve decision outcomes. A model for extending DSS resource presence and availability awareness to decision makers is presented and the impact of this knowledge on decision outcomes is evaluated using a management problem simulation.

INTRODUCTION

Technologies such as data mining and business analytics have seen explosive growth over the last 5 years in both research and industry. At the same time, advances in 3rd generation networks and communication have made the promise of pervasive computing environments a reality. With the convergence of pervasive computing environments and business analytics, now more than ever, greater volumes of data are available to decision support systems and subsequently decision-makers. One effect is the increase in data usage for both analysis and justification in decision making. In this context, the data is frequently assumed to be completely accurate and available. Moreover, it is also assumed that a decision support system would be available to assist with filtering, processing, analysis and other decision making tasks.

Despite the advances in technology, the fundamental characteristics of business decision making have not changed. Many business decision opportunities are time limited, and the phases of Simon's (1960) decision-making model still apply to business decision-makers. What has changed is industry's dependence on and related faith in data. There is an implicit belief that data is generally correct and that decision support systems can provide correct deterministic answers to decision problems. The data are used, not only as the basis to derive decision advice, but also to provide supporting justification. As evidence of this change, consider the North American business analytics market. Frost and Sullivan estimate that the enterprise analytics market generated $2.22B in revenue for 2005 and should increase at a Compound Annual Growth Rate (CAGR) of 10.8% from 2006 to 2012, reaching approximately $4.54B in 2012. Business intelligence (BI) is the largest single segment in this market, with $961.4M in revenues, which should reach $1.92B in 2012 at a CAGR of 10.4% (Frost & Sullivan, 2006).

The availability of decision support systems is integrally tied to industry's dependence on data. Gartner estimates that wireless voice and data will continue to displace wireline services, with voice and data services growing at a 6% CAGR - making wireless the fastest-growing segment of the communications services market (Flewelling, 2007). This demand for communication-enabling and data analysis products is clear evidence of businesses' interest and commitment to data-driven decision support and pervasive computing.

While data-oriented decision support and ubiquitous computing capabilities deliver many benefits to decision makers, in real world situations the availability of decision-related resources and support systems is not guaranteed. Moreover, data can be generally considered just one decision-related resource. Other types of computing resources, such as storage or processors must also be considered. What good is data without storage to hold it or a processor to process it? A great deal of research has been conducted to make systems highly available in pervasive computing environments (PCE) through redundant power and communications, data distribution and caching, and dynamic storage solutions. Much of the prior research has sought to address hardware limitations and ensure that computing resources are always available. In practice however, it is difficult, if not impossible, to ensure 100% availability. The telecommunications industry has a concept known as five nines (99.999% up time), which refers to system reliability of a copper-based telephone network. Five nines historically characterized the expected level of service availability that users could expect from a provider's communications network. With the advance of technologies such as digital subscriber lines (DSL), wireless, and packet-based voice communications, users are willing to accept increasingly lower standards of network quality (Lynch, 2002).

This acceptance of ambiguity in network and system availability conflicts with the increasing dependency on systems and data for decision making. Connectivity in pervasive computing environments is classically known to be intermittent and unstable. Intermittent and unstable communications and their underlying networks can have a significant impact on decision support systems, decision making, and decision outcomes. Moreover, time sensitive decisions, which often characterize business decision opportunities, can be even more susceptible to issues of availability. Extending knowledge of system and data availability to decision makers, who expect computer-aided support in these environments, may reduce uncertainty about the level of support available. This in turn, may improve the overall utility of decision support systems.

The relevance of research on resource and system availability becomes increasingly important as the popularity and availability of pervasive computing environments intensifies. However, little attention has been paid to the effects of data and system availability on decision making and decision outcomes. This article examines how decision maker's knowledge of decision support-related resources' or systems' online status (presence awareness) and readiness (availability awareness) can improve decision outcomes.

Following this introduction, the next section provides a discussion of prior work and background on presence and availability awareness. The third section illustrates presence and availability awareness in a decision making context and presents a model that incorporates these concepts in a traditional decision making support system. The third section is followed by the details of an experiment to evaluate the effects of availability awareness on decision making in a pervasive computing environment. The fifth section presents the results of this experiment, followed by a discussion of the implications for decision support systems. The article concludes with a summary and discussion of future work.

BACKGROUND AND PREVIOUS WORK

There is a significant amount of work on data and system availability. Much of this work focuses on hardware related issues. For example, Imielinski and Badrinath (1994) examined the challenges in data management for mobile computing. Their research identified several issues including bandwidth, location management, and power management. Imielinski and Badrinath's research has been supported by more recent efforts that provide solutions in each of these areas. Recent research has seen improvements in mobile power management that claim upwards of 35% improvement in battery lifetimes (Chakraborty, Yau, Lui, & Dong, 2006; Rahmati & Zhong, 2007) and redundant power has become a standard for data centers and servers (Bartlett & Spainhower, 2004). The concept of redundancy has also been applied to data storage (Muthian, Vijayan, Andrea, & Remzi, 2005).

Storage redundancy has implications for location management from the perspective of locating data closer to its users, thereby making it more available (Andreas, Alan, & Peter, 2005; Ruay-Shiung, Jih-Sheng, & Shin-Yi, 2007). Redundant storage can be very effective for local access, but the introduction of a network introduces other points of failure or interruption. Network latency is often a direct indicator of network congestion and problems (Shahram, Shyam, & Bhaskar, 2006). Roughan et al. (2004) propose how combining routing and traffic data can be used to detect network anomalies. Russello et al. (2007) provide a comprehensive hardware solution for managing network-distributed data that is policy based. Their approach allows application developers to specify availability requirements for data tuples, while an underlying middleware evaluates various distribution and replication policies to select the one that best meets the developer's requirements.

Research focusing on system and network hardware solutions provides a good practical foundation for addressing data availability in decision support systems. From the perspective of pervasive computing environments, extensive research has been done utilizing location as a context for how, when, and what device is interacting with computing resources. For example, Milliard et al. (2005) used wireless sensors, infrared, and accelerometers coupled with a semantic model to provide information on where a user physically was, in order to adjust resources and preferences accordingly. Perich et al's (2004) work is similar in that it combines semantic expressions to describe users' context and location. However, Perich's work combines the sensors and semantics with a caching algorithm to aid data management as users move about the computing environment.

The vision of true pervasive computing environments requires that pervasive data availability is essential for pervasive computing (Satyanarayanan, 2001). While this prior research goes a long way towards realizing the vision and promise of pervasive computing, these hardware approaches are not perfect and none of these solutions provide 100% data availability. Additionally, the focus of this research tends to concentrate on the system, network, or system administrators rather than on the end users.

There have also been efforts to apply these concepts specifically to decision support. This research is most frequently found in applications of distributed decision support systems and is divided into two different categories: decentralized systems and systems that support decentralized users. Both of these areas emphasize hardware approaches and collaborative components. For example, Du and Jia (2003) developed an enterprise network environment for cooperative problem solving. Compared to traditional client/server approaches, Du and Jia sought to provide a more efficient and secure solution by reducing network traffic and protecting private information. Recent work by Adla (2007) proposed a framework for a distributed cooperative intelligent decision support system. Adla's framework extends Soubie (1998) work for cooperative knowledge-based systems. The framework described components that effectively decomposed decision tasks and enabled collaboration amongst distributed decision-makers. Adla introduced innovation in his framework by including the concept of decision roles such as facilitator and considered the paradigm of distributed decision-support systems, in which several decision-makers who deal with partial, uncertain, and possibly exclusive information must reach a common decision.

In contrast to this other research, much of the work addressing data availability has focused on its psychological impact on decision-makers. Most significantly, data availability has been shown to be related to ambiguity, uncertainty, and risk (Kentel & Aral, 2007). The concepts of ambiguity, uncertainty, and risk should be considered as related, yet discrete concepts that may not necessarily be causal. For the purposes of this article, ambiguity is considered in the context of available data that has the capacity to reduce doubt regarding decision variables. Most of this work has studied user-centric perspectives of ambiguity in decision making, such as ambiguity tolerance. There have been several studies examining the effects of ambiguity (Boiney, 1993; Hogarth, 1989; Owen & Sweeney 2000; Shaffer, Hendrick, Regula, & Freconna, 1973) and ways to reduce ambiguity (Geweke, 1992; Hu & Antony, 2007; Pezzulo & Couyoumdjian, 2006) in decision making. This research has shown that a decision-maker's reactions to ambiguity are likely to be situation-dependent. Potentially relevant factors include not only the degree of ambiguity but also the size of the payoffs and the perceived role of individuals other than the decision-maker (e.g., the decision-maker's boss or spouse) (Winkler, 1997). Moreover, ambiguity may often be interpreted as risk and reduces a decision-maker's confidence (Ellsberg, 2001; Ghosh & Ray, 1997). In managerial contexts, the presence of risk and ambiguity may lead to suboptimal decision outcomes.

Some work has been done specifically examining the effects on decision making with and without having a DSS available for use. These efforts have evaluated the benefits of using decision support systems through simulations (Bricconi, Nitto, Fuggetta, & Tracanella, 2000; Forgionne & Russell, 2007), case studies (Alter, 2004; Keen & Scott-Morton, 1978), and empirical field studies (Holsapple & Sena, 2005; Sharda, Barr, & McDonnell, 1988). Unlike the work described in this article, these prior efforts examined the efficacy of decision support systems, themselves concentrating on the benefits resulting from the use of the system. Generally these studies have examined availability in absolute terms, either with or without a DSS; not the case where the system is intermittently available.

Unlike these previous efforts, the emphasis in this article is not on improving system/resource reliability or minimizing psychological effects of ambiguity resulting from data or system unavailability. In a pervasive computing environment, it is expected that reliability will be less than 100% and there will be occasions when data or systems are unavailable. The motivation behind the work in this article is to determine the effects of providing contextual details regarding when or if decision support-related resources will be available.

Context Aware Computing

Because the concepts behind presence and availability awareness are not new and have been applied in other domains, some attention must be given to the research conducted on these topics. It is important to begin with a definition, a**s** it is difficult to define presence awareness or characterize pervasive computing environment systems without some discussion of context. To be effective, PCE-based systems require some context aware components (Want et al., 1995). From a user's perspective, concepts that fall under context awareness include changes in a user's physical state and location, workflow, preferences, or resource interests. Context-awareness also includes environmental conditions. In recent years, there has been a significant amount of work on context aware computing. In this domain, research has been conducted examining aspects of users' physical environment (Yau & Joy, 2006), usability (Ho & Intille, 2005), system adaptation based on context (Baldauf, Dustdar, & Rosenberg, 2007), location modeling (Becker & Dürr, 2005; Satoh, 2005), personalization (Krause, Smailagic, & Siewiorek, 2006; Yang, Mahon, Williams, & Pfeifer, 2006), and presence (Brok, Kumar, Meeuwissen, & Batteram, 2006; Khan, Zia, Daudpota, Hussain, & Taimoor, 2006; Raento, Oulasvirta, Petit, & Toivonen, 2005; Sur, Arsanjani, & Ramanthan, 2007; Wegdam, 2005).

Within the broad domain of context aware computing, the concepts of presence and availability awareness can be grounded in location awareness research. Much of the research in location awareness concentrates on collaboration (Griswold, Boyer, Brown, & Truong, 2003; Holmquist, J.Wigstrom, & Falk, 1998) and commerce/service provisioning (Crow, Pan, Kam, & Davenport, 2003; Zeidler & Fiege, 2003). Knowing where a user or system is located and whether they are available for interaction can be particularly useful for these activities. While proximity is not a direct issue for availability awareness, it can allude to the quality of a resources' connectivity. Similarly, knowing the location of a user or resource can suggest when a resource will be available for interaction and it also implies its online state or presence.

Previous research in context and location computing provides a sound foundation for hardware and software approaches to capture and utilize information about where and how users use computing devices. However, the primary distinction between previous research in context awareness and that described in this article is that most of the previous solutions capture context information and utilize it within the system, rather than provide it directly to the end user. The solutions that do provide context information to the end user only provide presence (binary online/offline) status and not details about the likelihood of when resources will be available. Moreover, little of this research examined how availability contexts impact decision outcomes, either directly or indirectly.

Presence and Availability Awareness

This article does not address all of the issues with context awareness; instead, the focus is on presence and availability awareness, in terms of both data and system resources. A working definition of presence awareness in this article is: knowledge of whether data/system resources are online or connected for communication. Presence awareness provides knowledge of a resource's state, in terms of connectivity. Presence awareness is the basis for availability awareness, since knowing if a resource is online is the first step in determining availability for use. Succinctly, availability awareness is knowledge of a resource's readiness to be used.

Presence awareness has gained a great deal of popularity in real-time communication applications such as instant messaging (IM). All IM clients incorporate a form of presence awareness so that users can be made aware of when a potential communication partner, or "buddy," is online. Many of these clients also include availability awareness using techniques such as keyboard and screen saver monitoring. From a research standpoint, most of the studies on IM have been on its utility as a communications medium (Griss, Letsinger, Cowan, VanHilst, & Kessler, 2002; Kwon, Shin, & Kim, 2006; Wang et al., 2004).

Jesus Favela's research differs from the main body of instant messaging communication research. Favela's group embraces the concept of pervasive computing and has investigated using instant messaging, as a presence and availability awareness tool in agent-based systems. Favela (2002) created AIDA, an instant messaging and presence awareness client for handheld devices running PalmOS. Using this client, Favela created a pervasive computing communication application called DoMo. What is unique about Favela's efforts is his treatment of network resources, such as scanners and printers, as presence aware items. By extending the notion of presence to documents and other resources, AIDA offers new opportunities for casual encounters in a community of co-authors. For instance, when a user notices that a document has been locked, he/she might send a relevant message or even join his/her colleague in a synchronous collaborative authoring session.

Favela's work, while innovative and unique, did not focus on decision making. His application of presence awareness was much more practical in nature and concentrated on location contexts (i.e. proximity to resources and basic online-offline status of resources). His work did not examine how knowledge of presence and availability would affect users; rather his group studied the implications of a hybrid software-hardware architecture supporting document management and collaboration in a PCE. Particularly in a PCE, the implications of including presence and availability awareness of data in a decision support system can lead to improved outcomes for users and organizations. In contrast to Favela's work, the research described in this article differentiates itself by examining how a decision maker's knowledge of data's availability can affect decision outcomes.

PRESENCE AND AVAILABILITY AWARENESS FOR DECISION SUPPORT SYSTEMS

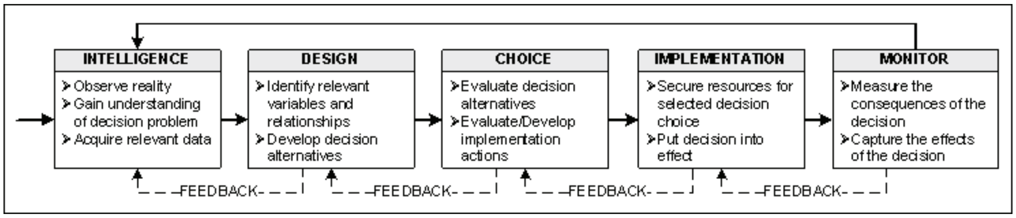
As data-driven decision support technologies become increasingly popular, the availability or knowledge of data's availability will become increasingly important. Even in situations where a model exists, the data for the model may often come from several systems. Pervasive computing environments will aggravate problems with data availability. Knowledge of when, or if, data will be available can impact the efficacy of a decision making support system that relies on data, particularly when the data come from multiple sources. If a decision support system requires data from external systems and the data from these systems were delayed or completely unavailable, the decision-maker would have to work around the lack of data, and the assistance provided by the system may be limited. Decision timing further complicates the effects of data availability. Depending on the time constraints for the decision, the data may not become available in a timely manner.

Figure 1 shows the phases and activities of the decision making process, adapted from Simon's (1960) model. If the decision opportunity has a time limit, then the intelligence, design, choice and implementation phases are also bounded by time constraints that must cumulatively be less than or equal to the opportunity time limit. Interruptions or delays occurring at any phase can affect any subsequent phases, constricting the time available for that phase. This constriction of time can have significant implications for the decision-maker, particularly if the causal delay is unknown. If the decision-maker does not have any understanding the delay duration, then he or she is left to either wait (possibly too long), skip that phase's tasks (no-wait), or improvise to accommodate the activities in the delayed phase. Decisions made under high pressure time constraints encourage a decision-maker to rely on heuristics and historical approaches that may not be appropriate for the current decision problem (Gonzalez, 2005; Ordonez & Benson, 1997). Moreover, these cascading effects can lead to reduced DSS effectiveness and sub-optimal decision outcomes.

In a pervasive computing environment, data may come from a variety of sources and are likely to be outside of the functional DSS itself. Environmental factors and the number of data sources required for the decision opportunity may have a direct impact on inputs, which then can affect processing and subsequent advice output. Moreover, in complex computing environments, the processing and output components may be distributed or physically separate from the other components. This consideration is particularly significant in a PCE because the DSS itself, users, or decision support-related resources may be mobile, have sessions interrupted, or have inconsistent network bandwidth.

When there is uncertainty about the availability of decision support-related data or the DSS itself, it introduces an additional decision within the core decision making process. Consider a simple example where someone wants to purchase a digital video disc (DVD) player and their only consideration for the decision is price. However, they want to use it to play a movie for some guests who will be arriving at their home in the next 90 minutes. The decision maker might use a DSS, which has a resource on the Internet that would identify the lowest price DVD available for local purchase. Now, what if the decision maker's Internet connection is down? The decision maker has an additional decision to make that stems from the original decision process. The decision

Figure 1. Decision making process steps



maker could wait for the connection to come back up and hope it comes back with sufficient time to identify a DVD and travel to make the purchase. The decision maker could try to get connectivity using another medium, such as an Internet-capable cell phone; or alternatively, the decision maker could forgo support altogether and drive to a local brick and mortar store and choose from the on hand selection of DVD players.

Figure 2 shows what happens to the traditional decision making process when availability is unknown at whatever step of the decision process. At each step in the primary decision process (shown as shaded boxes with dark arrows), there exists the possibility to spawn a secondary decision process (shown as lighter boxes and dashed arrows), due to uncertainty regarding the availability of resources necessary at that step. Moreover, these secondary decision processes may be terminal or create their own additional processes. To illustrate the effect of availability awareness and expand the previous example: what if the decision maker knew or was informed that the Internet connection would be available 10 minutes from the time the decision maker was made aware of the outage? The decision maker could make an informed decision about how to proceed and could weigh the previous alternatives with additional certainty.

Awareness information does not necessarily have to be limited to whether or not a resource is online/offline or when it will be available; it could also include probabilistic information as well. For example, the decision maker purchasing a DVD player could have been provided a probability that the Internet connection would be available within a certain amount of time and the likelihood that the connection will stay up, once it returns. To support the dynamic nature of pervasive computing environments, a DSS should incorporate interfaces that are capable of providing insight into components' and resources' online status and availability. Additionally, the DSS itself should provide status and availability information interactively directly to the decision-maker.

In order to meet these requirements in PCEs, a typical DSS architecture is adapted by considering resource characteristics that can cause delays (such as network bandwidth capacity and quality, storage failures, or extended processing loads). Figure 3 shows an architecture extending the typical DSS with an added layer of presence/availability awareness. The awareness layer delivers information and feedback from the functional DSS elements through the user interface and the dialog management directly to the decision-maker.

Examining this architecture from the inputs' perspective, the DSS would have information about the databases or data warehouses online status. Should the data or inputs not be online, the availability awareness layer would deliver details about when the data may be available. Similarly from the processing perspective, the decision-maker would have information about processor loading and subsequent task processing delays. Unlike architectures where the decision-maker has no knowledge of the DSS and its resources' availability, the decision-maker is provided the necessary information to evaluate the wait/no-wait, accommodate, or abandon secondary decisions resulting from system/resource delays or interruptions.

Figure 2. Decision making process with no presence and availability awareness

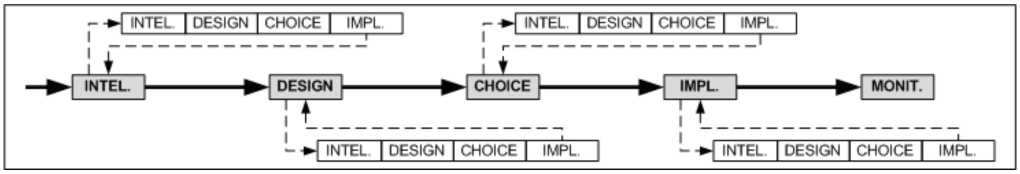
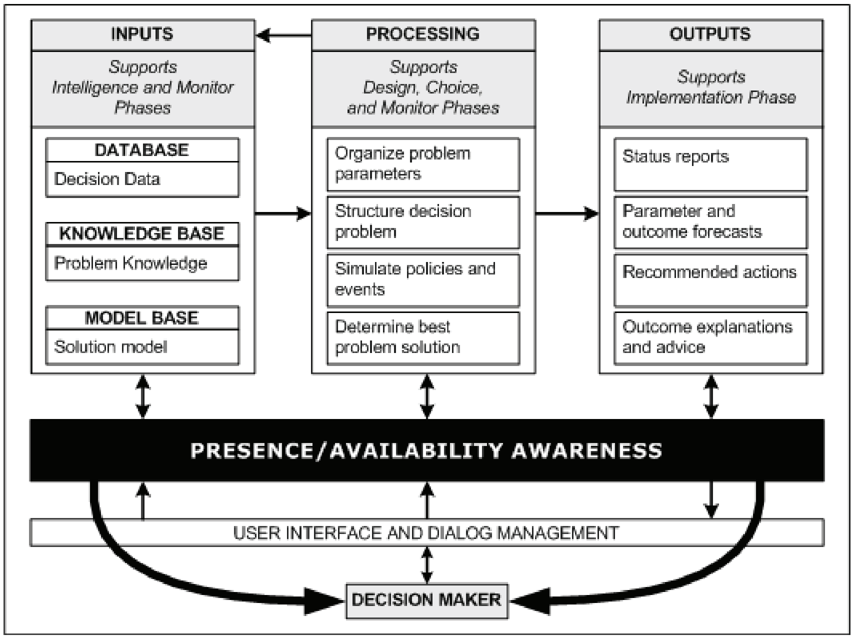


Figure 3. Typical DSS with awareness layer added

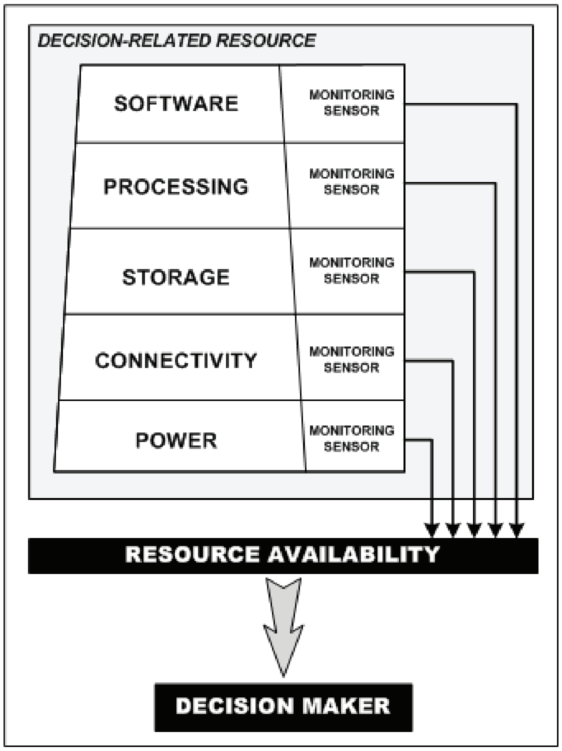


While shown as a monolithic layer in Figure 3 and centralized management of presence and awareness information is necessary, portions of the presence and availability awareness layer could exist within each functional DSS resource, e.g. as part of the database, as a process monitor, or as a function of a printer driver. If the DSS resources, including the DSS itself, are generalized they can be considered a hierarchical set of functions that are independent bottom up and dependent top down. Figure 4 illustrates a generalized hierarchy. While every level may not be necessary for every resource, the level dependencies are evident. Consider an example where a DSS provides guidance by presenting information on a graphical map, e.g. a spatial DSS. This DSS may require data from a remote website that converts street addresses to latitude and longitude. This remote website/data would be considered a resource. This resource depends on a hierarchy of dependent functions to be able to serve its purpose. Examining Figure 4, without power/electricity, there is no connectivity or anything else above power. Without connectivity the data in storage cannot be delivered. Without storage, processing cannot occur; there is nothing to process. Without processing, the software cannot operate, and if the software (web server, address-to-lat/long converter, or host operating system) fails, the resource cannot respond to the DSS's request. There is an implicit dependency from top to bottom but not the other way. It is possible to not have connectivity, yet have power and so on.

Each level has a sensor to monitor its own functions and the total availability of these individual levels comprises the resource's availability. The monitoring sensor at each level may take different forms as appropriate for that level. For example, the power monitoring sensor may be a hardware device that feeds data back to the DSS directly. In contrast, the software monitoring sensor may be software itself that monitors how well a service responds to requests, i.e. doesn't crash or stop running.

The obvious question is: *how might details about decision support-related resources' availability be obtained and quantified*? The hardware and software technology already exists to enable

Figure 4. Decision resource hierarchy



both new and existing DSS with presence and availability awareness. Hardware that monitors loading, power, outages, and interruptions have become standard in high availability environments. Research in high availability computing has already identified methods to evaluate, quantify, and monitor hardware related statuses such as power (Rahmati & Zhong, 2007), network characteristics (Shahram et al., 2006), computer components (Weatherspoon, Chun, So, & Kubiatowicz, 2005), processing/computing load (Zhoujun, Zhigang, & Zhenhua, 2007), and storage (Blake & Rodrigues, 2003).

Software presence and awareness solutions are broadly available and can be commonly found in server monitoring, instant messaging, and web service software. Moreover, research in the area of web service composition and quality of service (QoS) can provide solutions delivering awareness knowledge for general software-based resources. There is a significant amount of research studying applications using QoS monitoring for service level agreements, adaptation to changing system conditions, and web service composition (Ali, Rana, & Walker, 2004; Menasce, 2004; Thio & Karunasekera, 2005). Web service composition is a particularly active research area, rich with solutions for service availability, because of the critical nature of this information for process scheduling and execution planning (Peer, 2005; Pistore, Barbon, Bertoli, Shaparau, & Traverso, 2004).

These theoretical and accessible approaches provide a wide range of alternatives for implementing the collection, quantification, and monitoring of decision support-related resource presence and availability information. With regard to integrating resource presence and awareness in existing and future DSS, these technologies are well researched and readily available. The model discussed above maps presence and availability awareness information to decision support resources. This information can then be provided to decision makers. In theory, if presence and availability awareness is extended through a DSS to the decision maker, structured decision problems with deterministic outcomes should realize improved support. This theory suggests the following research question and hypotheses.

Research Question: Will decision support-related resource availability awareness improve decision outcomes?

- **Null Hypothesis**: Decision support-related resource availability awareness knowledge provided to decision makers will not improve decision outcomes.
- **Alternative Hypothesis**: Decision support-related resource availability awareness knowledge provided to decision makers will improve decision outcomes.

SIMULATION EXPERIMENT

To evaluate the above hypothesis a time constrained, deterministic, structured or semi-structured decision problem is desired. The experimental methodology consisted of two scenarios: one where the decision maker *is not* provided awareness information (control) and a second where the decision maker *is* provided this information (treatment). In order to isolate the effects of the resource awareness information, support from the DSS should provide specific and correct advice and the entire population of alternatives should be available to the decision maker whether the decision support-related resource is available or not. Figure 5 shows the control scenario and Figure 6 shows the treatment scenario; the decision maker is denoted as DM. The primary difference between Figure 5 and Figure 6 is the introduction of awareness information in the center of the flow diagram, where the DM has a choice to wait or not. To implement these scenarios a simulation experiment was created.

The simulation experiment utilized a complex semi-structured problem, frequently used in management training and evaluation and typically requiring decision making support (McLeod, 1986). This problem involves a market in which top management uses price, marketing, research and development, and plant investment to compete for a product's one-quarter total market potential. Demand for the organization's products will be influenced by: (1) management actions, (2) competitors' behavior, and (3) the economic environment. The decision objective is to plan a "next quarter" strategy that would generate as much total profit as possible. This profit is the deterministic quantitative result of the decision maker's choice.

Figure 5. Control experimental process

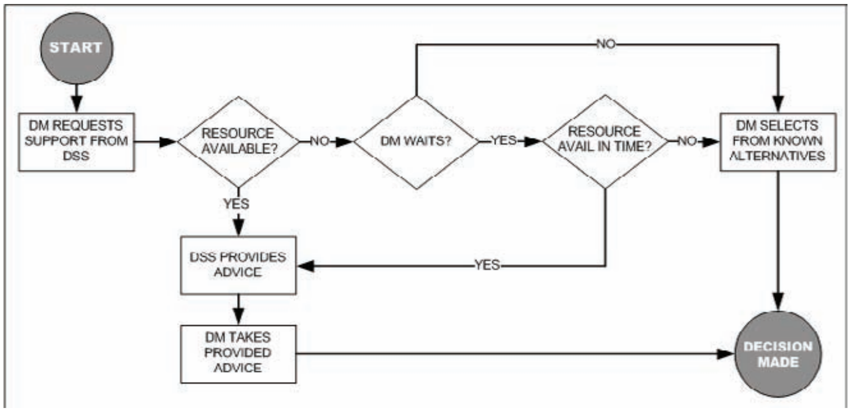
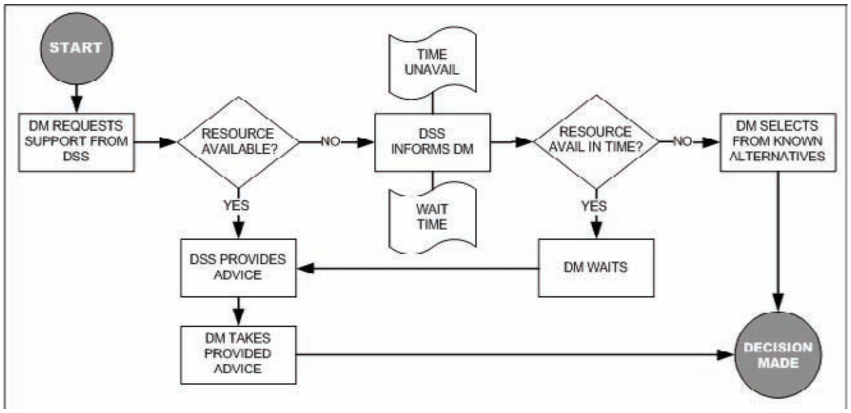


Figure 6. Treatment experimental process



Strategy making requires: (1) setting the product price, marketing budget, research and development expenditures, and plant investment and (2) forecasting the competitors' price, competitors' marketing budget, a seasonal sales index, and an index of general economic conditions. Twelve additional variables, including plant capacity, raw materials inventory, and administrative expenses, were calculated from the strategy. Initial values for these twelve variables form the alternatives for decision-making. These twenty (controllable, uncontrollable, and calculated) variables jointly influence the profitability of the organization. This profit value is used as the key measure for decision outcome.

This management problem formed the core decision opportunity for the simulation, as it provides an explicit quantifiable measure of the decision outcome: profit. While the actual management problem used is considerably more complex (as described above), to illustrate the simulation and experimental methodology in a simple manner, let profit (P) equal forecasted sales (S) multiplied by forecasted price (PR) minus forecasted production cost (PC).

$$P = S * PR - PC$$

The data for forecasted sales, production cost, and price would consist of several historical values for each variable and be supplied by an external system. The data comprising the historical values are considered the decision-support related resource, as is the DSS itself. However, these resources may or may not be available within the time allotted for the decision. Within the DSS, there exists a model that would suggest the appropriate values, from all available historical data, that would provide the maximum profit value. This is the provided advice.

In strategy making, it is the decision-maker's responsibility to select which forecasted values to use, within a 5 minute time limit. The simulated decision-maker takes 3 forms: 1) where the decision-maker always takes the advice provided by the DSS, 2) where the decision-maker takes the advice a random number of times, 3) where the decision-maker never takes the provided advice. Using the simplified management problem here are three example simulation scenarios:

1. **The forecasted data *is* provided within the time allotted for the decision.** The DSS identifies the price, sales, and production cost that result in a maximum profit. Decision-maker (DM) 1 accepts the advice. DM-2 may or may not take the advice (randomly); if DM-2 does not take the advice, DM-2 chooses his/her own values. DM-3 does not take the advice and chooses his/her own

values. For all three DMs, the values for *S*, *PR*, and *PC* are applied to the management problem resulting in a profit value for each DM.

2. **The forecasted data *is not* provided within the time allotted for the decision.** All three DM choose their own values that are applied to the management problem, resulting in a profit value for each.
3. **The forecasted data *is delayed* and may or may not be provided within the time allotted for the decision.** If the data will be available within the allotted time, the DSS identifies the values that will result in maximum profit. If the data becomes available and DM-1 decides to wait, then DM-1 takes the advice. If the data are not available *or* DM-1 does not decide to wait DM-1 chooses his/her own values. If the data are available *and* DM-2 decides to wait *and* DM-2 chooses to take the advice then the DSS supplied values are used. If the data are not available *or* DM-2 decides not to wait *or* DM-2 declines the advice, DM-2 chooses his/her own value. DM-3 chooses his/her own values. The values for each DM are applied to the management problem, resulting in a profit value for each.

The simulation had 5 scenario variables that determined the conditions of the scenario, as shown in Table 1. All of these values were randomly generated for each run of the simulation. It was assumed that each input value would follow a standard normal distribution with a mean of 0 and a standard deviation of 1.

To evaluate the effects of data availability on decision making, the simulation was run with and without awareness of the data's availability, according to Figures 5 and 6. In one case, the decision-maker will be provided knowledge of the availability of the data (treatment) and in a second, the decision-maker has no knowledge of when or if the data will be available (control). For experimental purposes, the two simulations were run with two additional conditions that affected how values were handled when the decision-maker did not use the DSS advice. The first condition simulated the decision-maker choosing values from the forecasted dataset which consisted of the DSS advice values and 50,000 additional, sub-optimal input values. The second condition simulated the decision-maker selecting values without the forecast data dataset. Table 2 summarizes the simulations and conditions.

The first condition (A) represents the situation where the decision-maker has access to the data but may not have access to the DSS advice. Under condition A, the simulated decision-maker's values were randomly selected from the forecasted data. Condition B represents the situation where the DSS is available, but the data source may not

Table 1. Simulation scenario variables

VARIABLE	FUNCTION
Take_Advice	This is a 1 or 0 value determining if the DM who randomly takes the DSS advice decides to take the advice. If 1 then the DM takes the advice, 0 DM doesn't.
Data_Avail	This is a 1 or 0 value determining if the data is immediately available. If 1 then the data is available, 0 it is not. If this is 0 then the DM-Wait and Delay_Amt values are used.
DM_Wait_YN	This is a 1 or 0 value determining if the DM waits for the data to become available or decides to choose a value before it becomes available. This variable only applies to the simulations where the availability is unknown.
DM_Wait	Decimal value between 0 and 5 minutes that determines how long the DM waits. This variable only applies to the simulations where the availability is unknown.
Delay_Amt	Decimal value between 0 and 10 minutes that determines how long the data will be unavailable.

Table 2. Simulation decision-maker input value conditions

SIMULATION	CONDITION	DECISION MAKER INPUT VALUES…	CONTROL / TREATMENT
Simulation 1	A	Are randomly selected from dataset	Availability is unknown
	A	Are randomly selected from dataset	Availability is known
Simulation 2	B	Are randomly selected	Availability is unknown
	B	Are randomly selected	Availability is known

be. Under condition (B), the decision-maker's values were selected randomly based on formulas developed to ensure that input values would fall within the management problem's permissible ranges, according to a normal probability distribution.

For all randomly generated variables, to incorporate the diversity of inputs from a population of users and scenario conditions, each variable was assumed to follow a standard normal distribution with a mean of 0 and a standard deviation of 1. The choice of a normal distribution was based on the Central Limit Theorem, which roughly states that all distributions approach normality as the number of observations grows large (Barron, 1986; Davidson, 2002).

A precise and explicit model of the decision problem and simulation was programmed in Matlab. This software provided a robust programming environment where the simulation could be created and evaluated. Once programmed, 50,000 runs were conducted for each simulation and condition (4 sets as defined in Table 2 of 50,000 runs each). For every run, the run's scenario variables and resulting profit (decision outcome) for each decision-maker were recorded.

SIMULATION RESULTS

The results of the profit generated by the simulations were analyzed using SPSS and the hypothesis was tested for each type of decision maker and each condition. In summary, the results show that the runs where availability information was known performed significantly better for the simulated decision maker who took the DSS advice (either always or randomly). The decision maker who never took the advice had the lowest profits of all of the simulations. As might be expected, the availability awareness had no effect on the decision maker who never took the DSS advice and the simulation condition where the DSS (but not the data) was intermittently unavailable yielded higher profits. Table 3 shows a summary of the mean profit for all of the simulations.

The runs where availability was known (had awareness) had the best decision outcomes or highest profits, except in the case where the decision maker did not ever take the advice. Availability awareness had the greatest impact on the simulated decision maker who always took the advice. To evaluate the hypothesis, each decision maker is compared between the control and treatment groups using a paired t-test. Tables 4 and 5 show the results of the t-tests. The awareness-enabled runs outperformed the "unaware" runs. However, in the case of the decision maker never taking the advice, the difference was not significant (.558 for data intermittently available and .170 for DSS intermittently available) and subsequently the null hypothesis for this case must be accepted. The other two cases, where the decision maker either always or randomly took the DSS advice, were significant with alpha's lower than .025, rejecting the null hypothesis.

IMPLICATIONS AND LIMITATIONS

As this simulation study illustrates, awareness of decision support-related resources' presence and availability can lead to different decision

Table 3. Decision maker's average profit values (dollars)

DSS Advice:	**Always Accept**		**Randomly Accept**		**Never Accept**	
Availability:	**Aware**	**Unaware**	**Aware**	**Unaware**	**Aware**	**Unaware**
Data Intermittently Available	3,165,699	1,767,831	421,594	-275,659	-2,361,590	-2,376,501
DSS Intermittently Available	4,090,788	3,383,296	2,690,010	2,338,166	1,341,965	1,299,331

Table 4. T-test results for data intermittently available simulation runs

	Paired Differences					**t**	**df**	**Sig. 2 tailed**
	Mean	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**				
				Upper	**Lower**			
ALWAYS Aware VS Unaware	1,397,867.823	4,543,970.936	20,321.256	1,358,037.942	1,437,697.704	68.788	49,999	0.000
RANDOM Aware VS Unaware	697,252.604	5,189,774.544	23,209.377	651,761.974	742,743.235	30.042	49,999	0.000
NEVER Aware VS Unaware	14,910.336	5,691,405.378	25,452.739	-34,977.307	64,797.979	0.586	49,999	0.558

Table 5. T-test results for DSS intermittently available simulation runs

	Paired Differences					**t**	**df**	**Sig. 2 tailed**
	Mean	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**				
				Upper	**Lower**			
ALWAYS Aware VS Unaware	707,491.906	4,441,803.454	19,864.349	668,557.568	746,426.245	35.616	49,999	0.000
RANDOM Aware VS Unaware	351,843.327	5,835,473.647	26,097.032	300,692.863	402,993.791	13.482	49,999	0.000
NEVER Aware VS Unaware	42,633.342	6,942,609.965	31,048.296	-18,221.654	103,488.337	1.373	49,999	0.170

outcomes. In addition to presenting a model that maps presence and availability awareness to decision support resources, this study examined the effect of this awareness on decision outcomes augmented by DSS. In the cases where the decision maker always took the advice, having availability information provided delivered an average increase in profit of 17-56%. While more research may be necessary, this is significant. The research findings indicate that given time constrained, structured or semi-structured, deterministic decision problems supported by a DSS, resource availability information can have a dramatic impact on decision outcomes. Because the necessary resources need to be known before presence and availability information can be provided the benefit of this knowledge may be limited to structured and semi-structured decision problems. However, if the decision maker is able to provide structure during the intelligence or design phases of the decision making process, the benefits demonstrated in this study should translate to unstructured problems.

The benefits of presence and availability awareness are integrally tied to the architecture of the DSS and the support it provides. Other types of decision making support systems may offer different forms of support and guidance, changing the advice depending on the evolving circumstances in the decision situation. This research suggests that even in these other cases benefits can be gained by providing resource availability information to decision makers. Moreover, the technology to obtain availability information is mature, reducing the barriers for adoption; making practical implementations of this research immediately feasible. By applying this mature technology to existing and future DSS, the challenges of limited bandwidth, overloaded systems, and general delays in settings such as PCEs can be minimized.

Resource availability in a PCE is seldomly 100% guaranteed and delays/interruptions are likely. This study examined awareness benefits given a time constrained decision opportunity under conditions where resource availability was intermittent or delayed. The benefits of extending awareness information to the decision maker may be limited if the decision opportunity has a broad time window or delays resulting from unavailability are minimal. The issues of delay are significant, but pervasive computing environments may suffer from complete outages and interruptions where the disruption goes beyond the time boundaries of the decision opportunity. In this case, awareness of resource availability would have a limited effect, essentially mirroring the simulated decision-maker who never accepts the DSS advice. Further study is necessary to evaluate the implications of resource availability awareness in extreme cases of delay.

The awareness-enhanced model presented here sought to address the issues evaluated in the simulation experiments. Results from any simulation are only as good as the assumptions used in the analyses. This study assumed that scenario conditions, acceptance rates, and input values would follow normal distributions. A variety of other distributions are possible, including the uniform, binomial and Gamma, distributions. Further studies, then, should examine the sensitivity of the results to changes in distributions. This study also assumed that the management problem was a reasonable representation of many organizations' strategic decision making problem. Different organizations, however, may utilize different management philosophies, accounting principles, and decision objectives. If so, the decision model should be changed to reflect the organization's practices, philosophies, objectives, and decision environments. In particular, the profit equation may be replaced with an alternative measure or measures of performance, some tangible and others intangible. Variables and relationships may be defined and measured differently. Additional environmental factors may be added to the equations. While such alterations would change the specific form of the simulation model, the general model and experimental methodology would still be applicable.

CONCLUSION

This study presented a model that maps presence and availability awareness to decision support-related resources for use by decision support systems. A simulation was conducted to evaluate the effects of awareness on a data-driven DSS supporting management decision making. The results of this study confirm that extending awareness knowledge to decision makers through a DSS improves decision making when compared to DSS without this capability. In addition, these results suggest that availability awareness is important whether it supports data inputs or DSS advice. Since the results are expressed in dollars of net profit, the findings provide an objective measure of determining the relative decision value of presence and availability awareness. Moreover, as a large-scale simulation that approaches a census study, the evaluation results should be generalizable to other applications of DSS that decision problems in distributed or dynamic environments.

The results in this study suggest that the benefits of presence and availability awareness are most significant in environments where the reliability and accessibility of decision support resources are not 100% guaranteed; extending the findings of this study to most DSS in pervasive computing environments. With the advances in wireless and mobile networks, most modern computing settings have characteristics of pervasive computing environments. As a result, the benefits of generally extending resource presence awareness information to decision makers will be of increasing importance. Additionally, distributed computing resources, another characteristic of PCEs are already common. The research in this study implies relevance and applicability for these applications as well. However, further study is necessary to operationalize the model proposed in this work.

Future work is planned to implement decision support-related resource presence and availability awareness in an operational DSS. This future study will incorporate existing awareness quantification and monitoring solutions such as those discussed in the third section and will expand this study, examining the limitations noted in the implications section.

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Chapter 7.9

Decision Support Systems and Representation Levels in the Decision Spine

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INTRODUCTION: DECISION-MAKING AS PROBLEM SOLVING

Problem solving has been defined as the complex interplay of cognitive, affective, and behavioural processes with the aim to adapt to external or internal demands or challenges (Heppner & Krauskopf, 1987). In the realm of organizational decision-making, Herbert Simon (1977) describes the problem-solving process as moving through three stages: intelligence, design, and choice. In this context, design focuses on "inventing, developing and analysing possible courses of action," where the design artefact being constructed for this purpose constitutes the "representation of the problem."

While a wide range of representation means and calculi have been proposed for decision problem solving purposes, practical implementations generally involve applying one or more of these means to develop the structure of the problem within one or more frames. Typically, these are future-scenario frames, multi-attributed preference frames, and rule base-frames (Chatjoulis & Humphreys, 2007). Simon (1977) characterized decision problems according to the degree of problem-structure that was pre-established (or taken for granted as "received wisdom," or "the truth about the situation that calls for a decision") at the time participants embark on the decision problem solving process. He placed such problems on a continuum ranging from routine (programmed, structured) problems with well-specified solutions to novel, complex (unprogrammed, unstructured) with ambiguous solutions.

System thinking and soft systems methodologies (Checkland, 1999) have provided ways of looking at problem solving as an integrated whole throughout this continuum by modelling the process within a problem definition cycle, moving from the awareness that a problem exists to the moment of choice. Central to these models is the specification of a sequence of stages that the decision-making group has to follow in order to reduce uncertainly and increase structure, in transforming an ill-defined problem into a well defined one (Humphreys, 1989; Phillips, 1992). A great number of decision support systems (DSS) have been produced with the goal of providing mechanisms to help decision makers get through such sequences in processing uncertain and ambiguous decisions (Silver, 1991). The majority of these DSS are intended to support decision makers by increasing the structure of decision problem representations situated in already semi structured decision situations (Keen, 1980). However, as Meredith (2006, p. 31) points out:

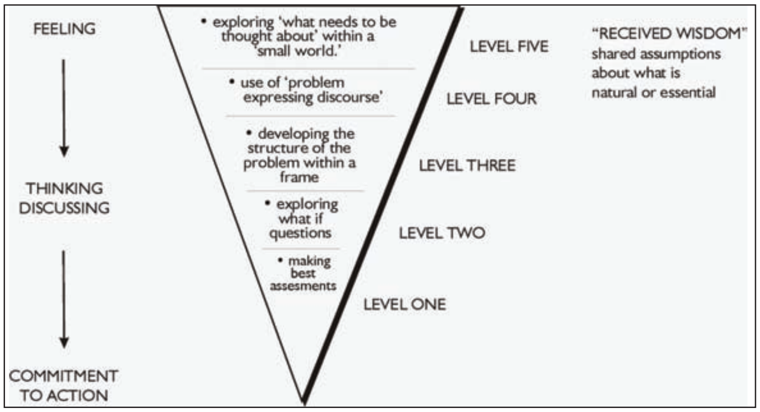
> *At the extremely unstructured end of the continuum sits a class of decision problems for which a pre-existing solution either does not exist or is inadequate. Such problems require creative decision-making. DSS designed to support decision makers with such a task face a dilemma: too much structure may stifle the creative process, while too little structure provides inadequate support.*

In such situations, participants embarking on the decision-making process can start out at the level of feeling, without being constrained (either explicitly or implicitly) by "received wisdom" about how the decision problem is already structured. Initially, participants have complete freedom and autonomy about how to think about translating this desire into action: all imaginable courses of action are candidates for implementation (Meredith, 2006). Conventional decision support methodologies, operating within the problem solving paradigm, intend to support a group process that aims at progressively strengthening the constraints on how the problem is represented at five qualitatively distinct levels, until only one course of action is prescribed: the one which should actually be embarked upon in the *real* (Humphreys & Jones, 2007).

LEVELS OF REPRESENTATION OF DECISION PROBLEMS

Each level of problem representation is associated with a different kind of discourse concerning how to structure the constraints at that level (Humphreys, 1998). The nature of the knowledge represented at each level and the cognitive operations involved in generating these knowledge

Figure 1. Five levels of constraint setting along the decision spine



representations has been discussed in detail elsewhere (Humphreys, 1984, 1989; Humphreys & Berkeley, 1986). These levels have been presented in a point-down triangle, or "decision spine" (Humphreys, 2007), as shown in Figure 1, indicating the progressive decrease in discretion in considering what knowledge can be included in the problem representation being developed as one moves downward from level 5 (exploring fantasy scenarios and dreams with conjecturality beyond formalization or structure) towards fixed structure (with all other knowledge now external to the representation of the problem), and zero discretion at level 1 (making "best assessments"). Three key formal properties of the 5-level scheme, taken as a whole, are as follows:

1. What is qualitatively different at each level are the cognitive operations carried out in thinking about the decision problem.
2. The results of the operations carried out on a particular level constrain the ways operations are carried out at all lower levels.
3. Any decision problem is represented at all levels, *doubled* in the symbolic/imaginary (where cognitive operations are carried out) and in the real (Deleuze & Guattari, 1988).

Therefore, we cannot treat levels like taxonomy, classifying decision problems as level 1, level 2, and so forth. We have to examine how each problem is handled at each level. In the actual decision making process, the sequence movement through the levels is not linear, but corresponds to a spiral through the circular logic of choice (Humphreys, 2007 ; Nappelbaum, 1997) to the point where a particular course of action is prescribed as the "true solution" to the decision problem. Decision conferencing methodologies essentially provide process designs to enable the decision making group to move efficiently and effectively through these levels within a general process which Phillips (1988, 1989) called "conferencing to consensus."

At Level 5

At the top level (level 5 in Figure 1), the roots of the decision problem are imagined through explorations carried out within a "small world" (Savage, 1955; Toda, 1976) whose bounds are defined by what each of the participants in the decision-making process is prepared to think about. However, small worlds complete with contents do not exist as complete entities pigeonholed away in a person's mind ready to be retrieved intact. From the outside, we infer the contents of the small world the person is using by looking at what he or she explores, and guessing its boundaries or possible holes within it by what he or she leaves out.

We are left with uncertainty concerning the actual boundaries of this structure in the same way cartographers of the physical world in the middle ages experienced uncertainty about where to draw bounds when they had access only to explorers' reports and guesswork to fill in the gaps. As they made the maps, they were, at the same time, exploring and creating a rhizome (Deleuze & Guattari, 1988; Humphreys & Jones, 2006).

From the standpoint of this analogy, though, the person doing the thinking is not the cartographer, but an explorer within the rhizome. Exploring alternative futures in a territory for which there are no maps except those made during the explorations and where there may be considerable uncertainty: not only about where the boundary limiting the explorations could be set, but also about what unforeseen successes—or terrors—lie along the route.

In decision making under conditions of uncertainty, at level 5, it is generally necessary to explore worst case scenarios, which can be an extremely frightening process when the worst case is unbounded: offering the possibility that in exploring it a participant could stumble upon all kinds of terrors which he or she otherwise succeeded in keeping out of consciousness. Hence explorations within these bounds are generally made within what Sandler and Sandler (1978) called "the background of safety,"[1] and are themselves beyond language (Lacan, 1977), which can only be used to describe the results of what is found during such exploration. These results constitute the contextual knowledge that is available in forming the content elements of problem representations that are manipulated in problem structuring at lower levels.

Attempts to improve or enrich this contextual knowledge, by persuading participants to explore beyond their background of safety can be highly distressing to them, and are usually countered with what others (who consider such exploration to be "safe") experience as *paranoid discourse* as described by Colby (1975): discourse aimed at preventing other participants from exploring in areas that the speaker considers could be "unsafe" for them. Hence effective decision support techniques, at level 5, should aim to extend the background of safety for all participants, creating an arena where communication can be innovative and creative rather than paranoid.

Techniques for doing this have been developed over many years in the field of drama. The role of the chorus in ancient Greek tragedies, providing ritualised, structured communication in unsafe areas where issues need to be resolved in coming to terms with tragedy, is one example; others involve improvisation techniques providing safe spaces for collectively acting out fantasies about alternative futures (Chatjoulis & Humphreys, 2007).

Humphreys and Jones (2006) describe how, within a flexible learning environment, a background of safety is created and maintained for participants through using dramatic techniques (construction and presentation of skits, enabling participants to explore future scenarios through the rhizome, enriching context, and allowing for more creative cognitive endeavours further down the decision spine).

At Level 4

At the next level down, (level 4 in Figure 1), problem-expressing discourse may be employed to make claims that particular elements of what was explored should (or should not) be included in the representation of the decision problem (Vari, Vecsenyi, & Paprika, 1986). This discourse determines the parts of the contextual knowledge, accessed by participants at level 5, which are expressed as "representatives in illocutionary acts" (Searle, 1979, following Austin, 1962) that will be proceduralised within the decision spine. This discourse is usually argumentative; *claims* about what aspects of context should be explicitly proceduralised. Claims are expressed by their advocates who support them with warrants and *backings* (Toulmin, 1958; van Eemeren, Grootendorst, Jackson, & Jacobs, 1997) in order to gain their acceptance by all participants in the decision making process.

The successful establishment of the claims of "what to include in the representation of the problem" is promoted and accepted through the use of *discourses of truth* (Foucault, 1981). These focus on establishing "unquestionable" or "natural" status for the backings for the claims made, in the minds of those participants in the decision making process who need to be persuaded to accept them. Thus problem-expressing discourse serves both to develop the proceduralised knowledge context within the decision spine and to define the constraints on what claims can be linked into frames so that their collective implications for potential prescriptions for action can be explored (Beach, 1990).

At Level 3

The claims thus established through problem expressing discourse need to be linked into frames so that their collective implications for the decision can be explored (Beach, 1990). Hence, at level 3, framing discourse is employed to develop the structure of the problem within a frame. Within "soft systems methodology" (Checkland, 1981; Checkland & Scholes, 1990; Humphreys, 1989), this process is described as "conceptual model building" and is located within proceduralised knowledge context established at level 4.

The problem structuring frames employed by participants developing problem structure within a decision spine usually fit into three principal categories (Chatjoulis & Humphreys, 2007). These are:

1. *Frames that structure future scenarios*, for example, through modelling act-event-sequences with decision trees. In this case, framing discourse serves to link imagined contingent acts and events in the future, forward through potential consequences of immediate acts, or backward from goals and imagined outcomes, with the aim of establishing course and action and investigating their potential consequences and side effects, usually under conditions of uncertainty.
2. *Frames that structure preferences between alternatives*, for example, through decomposition and recomposition within multi-attribute utility hierarchies. In this case, framing discourse seeks to identify value-laden attributes on alternative courses of action under consideration, (i.e., as explored within the other two categories of frames), and to make trade-offs (Keeney & Raiffa, 1976) or establish a dominance structure (Montgomery, 1983, 1989) between the alternatives to provide a rationale for "choice of the best alternative" (Berkeley, et al., 1991).
3. *Rule-based structures aimed at reducing the problem-solution search space*. In the extreme (bureaucratic) case, the framing discourse employed by participants tries to constrain possibilities for action by specifying a sufficient set of rules such that only one course of action is prescribed by the rule set, taken together.

Framing discourse is also employed to police the coherence of the material drawn from the proceduralised context into the frame until sufficient coherence is reached where it is possible to explore the structure so developed inside the frame.

Below Level 3

The result of the operations carried out at level 3 is a decision problem representation within one or more frames whose structure is conditionally fixed. Participants within the decision spine at this level no longer have any discretion over, say, which value-laden attributes may be considered within a preference structuring frame, but sensitivity analysis is possible within each frame, exploring what-if questions about the impact of changing values at nodes or reference points within structures developed at level 3. In this way it is possible to explore the decision problem within a frame. Hence at level 2, the content manipulated with the structured frames need not be represented as "facts" (where participants are expected to agree that there is a single "true" value), but as hypotheses (opinions, views, etc.). At this level, it is explicitly recognised, for example, that probabilities can vary according to individual participants' views on future states of the world and that utilities vary in reflecting the range of participants' interests and preferences.

Effective decision support systems, at this level, may employ "what-if" explorations to see the impact of changing the assessment of an element located at a particular node within the structure on the values of other nodes of interest within that structure. This kind of sensitivity analysis can discover points and areas within the frames where change of values across the range espoused by various participants makes very little impact on nodes of crucial interest, (e.g., those defining a choice between immediate courses of action) and so can be safely ignored. Conversely, where differences in espoused values are shown to have a crucial impact, a rationale is provided which could justify further effort in the *real* to refine participants' views on

At level 1, the only degree of discretion left for the participants in developing problem structure within the decision spine is to decide on how to make a "best assessment" of the of "the most likely value" at those points in the represented problem that have been represented as "uncertain" within the constructed decision-making frames, such that a particular course of action is prescribed.

If the resulting prescription is not acceptable to one or more stakeholders in the decision, this points to a re-examination of how the various higher- level constraints were set, to discover the level at which adjustment or negotiation is necessary, or for setting the constraints on how contextual knowledge is proceduralised in a new way, which will better reflect the interests of the parties to the decision.

DECISION SUPPORT WITHIN AND BEYOND THE DECISION SPINE:

From GDSS to GDACS

Figure 1 is not intended to indicate a prescriptive process model for decision-making (i.e., "start at level 5, establish constraints, then go down, one by one through the levels until action is prescribed at level 1"). All that can be established, *in general*, is that the employment, within the group decision-making process, of the discourses identified at each level in Figure 1 serves to constrain what can be explicitly considered, at the levels below it, in establishing the "truth about the decision situation" (Chatjoulis & Humphreys, 2007).

Group decision support systems (GDSS), following the approach instigated by the linear problem solving account of Herbert Simon, conventionally address the explicit modelling and support process at level 3 and below—working within one or more frames. What happens at levels 5 and 4 , in identifying what these frames might be and in proceduralising the context which specifies the material to be structured within the frames, is seen as something a *priori* and external to the decision-making process. The participants in the decision making process are expected to have shared assumptions about this (as "received wisdom"). Generation of "sufficient" alternatives (as can only be known with hindsight) is considered, within this paradigm, as a problem of creativity prior to the decision process itself, rather than intrinsic to it (Kleindorfer, Kunreuther, & Shoemaker, 1993; Meredith, 2006).

Elsewhere, Humphreys and Jones (2006) have proposed a fundamental evolution of the group decision support model from one that provides support at levels 3 and below, presuming a single, pre-existing proceduralised context (Brezillon & Zarate, 2007) to comprehensive group communication and decision support (GDACS) at all levels. GDACS supports creative decision-making at levels 5 and 4 through construction of narratives with the fundamental aim of enriching contextual knowledge within the *rhizome* (Deleuze & Guattari, 1988) which constitutes the body-without-organs of a *decision-hedgehog* (Humphreys, 2007). Localised processes within a plethora of decision spines, developing problem structure through the five levels described above with the aim of "pricking the real" at the tip of the spine, are rooted in this rhizome.

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ENDNOTE

[1] The "background of safety" is built up over time through play; that is, structured and guided exploration of ways of setting bounds or having bounds provided initially by one's parents and subsequently by significant others, whose authority one accepts and trusts.

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Chapter 7.10

Supporting Demand Supply Network Optimization with Petri Nets

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ABSTRACT

The present study implements a generic methodology for describing and analyzing demand supply networks, that is, networks from a company's suppliers to its customers. There can be many possible demand supply networks with different logistics costs for a product. Therefore, we introduce a Petri Net-based formalism, and a reachability analysis based algorithm that finds the optimum demand supply network for a user-specified product structure. The method has been implemented and is currently in production use inside all Nokia business groups. It is used in demand supply planning of both network elements and handsets. An example of the method's application to a concrete Nokia product is included.

INTRODUCTION

Logistics refers to the flow of materials, information, and money between the suppliers and customers. A *demand supply network* refers to the manner in which components flow from suppliers to the manufacturer's plants, and finally to the end customers. The logistics cost associated with a demand supply network include such costs as freight, warehousing, interest rate, duties, and taxes.

A typical problem that logistics professionals face in a global corporation is finding the cheapest and most reliable way of producing a product and delivering it to customers. Often, the product structures and supplier bases vary considerably during a product design phase. The logistics manager must decide the most economical component suppliers and the best-positioned assembly factories over the product's lifecycle. Typically there are hundreds or thousands of different demand supply network setup options for a given product. Therefore, manual analysis of demand supply networks is practically impossible.

Companies have considerable incentives to optimize their end-to-end demand supply chains. Firms approach this problem in two fronts: optimization of manufacturing functions on one hand and the demand supply chains on the other. As such, several methods for demand supply network analysis have been introduced in the literature. Most solutions use operations research paradigm—mixed integer programming—or discrete simulation to analyze demand supply networks (Bramel & Simchi-Levi, 1997; Simchi-Levi et al., 2003).

Recently, the industry has seen several examples of disasters brought up by broken demand supply networks (Norrmann & Jansson, 2004). A logistics manager must know all the demand supply network options available to reduce possible risks. This enumeration requires reachability analysis where each path (i.e., a possible demand supply network setup) is explored. Mathematical optimization may give the optimal setup quickly via analytic or heuristic methods. However, these techniques converge to the optimum, rather than enumerating the entire state space (including the costlier network possibilities). Discrete simulation, on the other hand, is excellent in dynamic analysis of a single demand supply network. Yet, it lacks the "helicopter view" of all demand supply network options which are possible to obtain using reachability analysis. Moreover, simulation and optimization software are costly in an environment with 200 potential users. It was realized that a reachability analysis-based solution, which solves small to medium size optimization problems in reasonable time, could be created in-house. The previous demand supply network analysis methods inside Nokia had relied on spreadsheets where each demand supply network setup was manually analyzed. In wake of increasing competition, the logistics team was looking for a powerful, yet cost efficient solution. Thus, I as a member of logistics team, started to consider the following research question:

How to apply reachability analysis in demand supply network analysis?

The result was a generic Petri Net model for describing arbitrary demand supply network options, and a reachability analysis algorithm that computes the network setups and costs from the Petri Net model. A Web-based analysis tool based on the methodology was constructed during 2004 and has been in production use since February, 2005.

The rest of the article is organized as follows: the remainder of the introduction reviews the current approaches to demand supply network analysis. The second section gives the generic Petri Net model for demand supply networks through example and formal definitions. The third section presents the reachability analysis algorithm for the model. The fourth section presents a concrete Nokia case for the tool use. The fifth section concludes with discussion and future work.

Literature Review

analyzing demand supply networks. Next, I describe operations research methods (Fandel & Stammen, 2004; Thomas & Griffin, 1996; Vidal & Goetschalckx, 2001; Zeng & Rossetti, 2003), analytic hierarchy processes (Dotoli et al., 2005;Wang, Huang,& Dismukes, 2004), control theoretical methods (Ortega & Lin, 2004), discrete simulation methods (Persson & Olhager, 2002), and workflow net related methods (vad der Aalst, 1998a; van der Aalst, 1998b; van der Aalst & ter Hofstede, 2005; Desel & Erwin, 2000). Each of these methods fits into one of four categories: deterministic analytical, stochastic analytical, economic, or simulation (Beamon, 1998). The five methods are briefly described along with their position in Beamon's categorization.

Operations research has been used to analyze demand supply network problems at least since the early 1970s (Thomas & Griffin, 1996; Zeng & Rossetti, 2003). The first mathematical programs had drawbacks, such as the possibility of analyzing only single transport modes, but the mixed integer programs have been developed to include multiple transport modes, transfer pricing (Vidal & Goetschalckx, 2001), development and recycling costs (Fandel & Stammen, 2004). Currently, mixed integer programs are the most powerful methods of finding the single best solution for very large problems. In finding the optimum, they converge to the result rather than enumerating the entire solution space. Operations research methods are deterministic analytical, however, so they must be augmented with simulation to understand the dynamic behaviour of solutions (Riddalls, Bennett, & Tipi, 2000).

Analytic hierarchy processes (Wang et al., 2004) can be employed in situations where each level in the product hierarchy has a large number of possible suppliers. Analytic hierarchy process uses balanced scorecard approach with set criteria to determine the best supplier choices (without regard to the complete product structure) for a single component. In the second stage of the analysis, the best supplier choices for each component are fed into preemptive goal programming for the entire product structure. This approach fits in situations where there are tens or hundreds of possible suppliers for each component, and a short list is needed first. However, it also requires expert knowledge to faithfully compare one supplier against another. Analytic hierarchy process is a deterministic analytical method.

Control theoretical methods for demand supply network analysis have recently surfaced as they provide an analytical method for estimating bullwhip effects in demand supply networks (Ortega & Lin, 2004). The demand supply networks are modeled in z-space, and z-transforms are used to arrive at Bode plots for dynamic behaviour. This method can analyze only one demand supply network setup at a time, but it has the benefit of estimating system dynamics without discrete simulation. However, the modeling of supply networks in Z-space requires expert knowledge, which may be a drawback in the business environment. Control theoretical methods of demand supply network analysis are stochastic analytical in nature.

Discrete simulation methods allows for dynamic analysis of a single demand supply network (Persson & Olhager, 2002). An arbitrary demand signal may be fed to the network, and simulation determines possible stockouts and order fulfillment lead time violations. The advantage of discrete simulation over control theoretical methods is the ease of specifying input signals, and the increasing processing power of computers keeps simulation runtimes reasonable. Discrete simulation is currently viewed as a de facto standard of analyzing dynamic behaviour of demand supply networks (Riddalls et al., 2000).

Workflow nets (Van der Aalst, 1998a; Van der Aalst 1998b; Van der Aalst & ter Hofstede, 2005) have been introduced in Petri Net community to analyze the dynamics of business processes. Workflow net is a stochastic analytical method for a single demand supply network. Each DSNnet setup (topic of the current article) may be refined to a workflow net for dynamic analysis. Process nets (Desel & Erwin, 2000) have also been used in Petri Net community to analyze business processes. In this technique, the user specifies demand supply network skeletons of interest, without any cost parameters. When the interesting skeletons are determined, actual cost parameters are inserted and analysis and simulation routines are run. This approach is useful when the number of possible demand supply network skeletons and suppliers is low. However, in situations where there are thousands of possibilities, the user involvement required may be too great. The DSNnet takes a different approach. The cost parameters are specified first for all possible suppliers of components, and the possible demand supply networks are determined via reachability analysis and are ordered by average cost.

Research Methodology

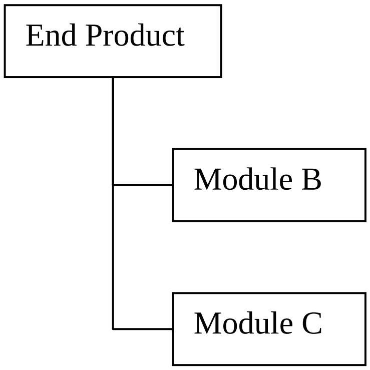
The current article uses constructive paradigm, where Petri Net theory is employed to solve a concrete business problem. The resulting solution was applied to solving demand supply network analysis problems more efficiently than earlier spreadsheet methodologies. The present work gives all the applicable decision algorithms and discusses validation issues. This research forms the foundation of an innovation diffusion study where the adoption of the presented method in Nokia is longitudinally followed. The research is done in the spirit of pragmatism (McDermott, 1976), where a theory's practical evidence is tested in real life: if it works, it is true.

DSN NET: NET FORMALISM FOR DEMAND SUPPLY NETWORKS

Introduction and Motivation

A demand supply network (DSNnet in the rest of this article) may be seen as a net whose topmost node is the combination of a product and its customer. All the nodes below contain the product's constituent modules (according to the product structure) and their alternative suppliers. Consider the simple product structure in Figure 1. The final product is called "end product," and it consists of two child modules, "Module B" and "Module C."

Figure 1. Simple product structure



An example of a scenario which a logistics professional may consider could be described as follows:

- End Product will have one customer
- End Product will have only one supplier, "End Product Manufacturer." In this case the end product is produced by the manufacturer itself, but the method also supports the analysis of contract manufacturers
- Module B can be sourced from two suppliers, and the sourcing options are:
    - Purchase all components from "Supplier 1 for Module B"
    - Buy 60 percent of the volume from "Supplier 1 for Module B" and 40 percent of the volume from "Supplier 2 for Module B"
- Module C has two suppliers and the sourcing options are:
    - Buy 100 percent of the volume from "Supplier 1 for Module C"
    - Buy 100 percent of the volume from "Supplier 2 for Module C"

Evidently the notion of choice and aggregation is vital in formalism for demand supply network options. Aggregation (AND logic) is needed for situations where a module has several parallel child modules. Choice (OR logic) is needed to describe alternative suppliers. Moreover, an OR may be immediately followed by an AND if two or more suppliers are simultaneously used to source a component in a given volume split.

The central idea of the DSNnet is to combine seamlessly the product structure and the associated demand supply network. The design of a product in parallel with its demand supply network renders a company's product design process more effective (Prasad, 1986). This mode of operation also requires specialized tool support. The logistics professional is looking for a tool where he can:

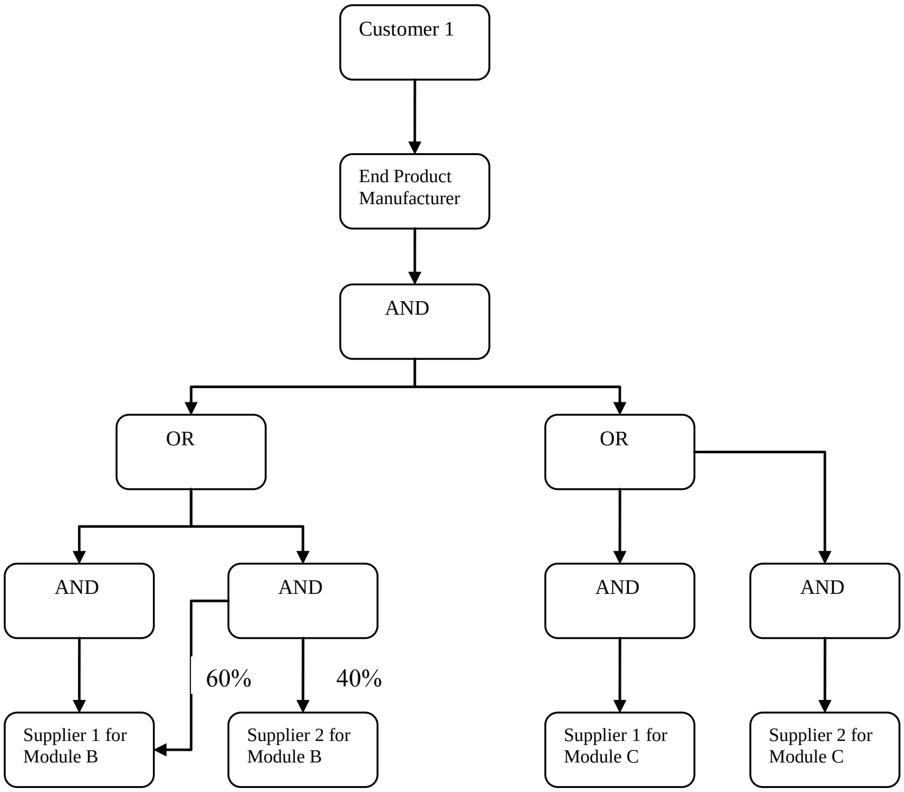
1. Choose the bill of materials for a product (key components)
2. Input the possible suppliers and associated costs for every component
3. Input the customers and their demand volumes

The logistics professional expects a computer to give all possible demand supply network combinations and associated costs for the input entered. The DSNnet instance in Figure 2 depicts the sourcing options for the product structure in Figure 1. Notice the inclusion of 'AND' nodes before single suppliers. Since volume splits between multiple suppliers are possible at every tier of the supply chain, the generic translation routine from product structure to DSNnet includes an AND-node after every OR-node. The AND node is really needed only in the 60/40 split of Suppliers 1 and 2 for Module B in Figure 2.

After the generation of DSNnet, a reachability analysis algorithm is executed to determine the demand supply network options and costs for each. For this example, there were no costs specified but the possible demand supply networks are:

1. End Product Manufacturer – 100% volume
   Supplier 1 for Module B – 100% volume
   Supplier 1 for Module C – 100% volume
2. End Product Manufacturer – 100% volume
   Supplier 1 for Module B – 100% volume
   Supplier 2 for Module C – 100% volume
3. End Product Manufacturer – 100% volume

Figure 2. DSNnet describing sourcing options for the product in Figure 1



Supplier 1 for Module B – 60% volume
Supplier 2 for Module B – 40% volume
Supplier 1 for Module C – 100% volume

4. End Product Manufacturer – 100% volume
   Supplier 1 for Module B – 60% volume
   Supplier 2 for Module B – 40% volume
   Supplier 2 for Module C – 100% volume

DSNnet does not resemble a Petri Net since the notion of transitions is missing as in Figure 2. However, between each pair of nodes a logistics network will incur , for example, freight and duty costs and these elements are included inside a transition. The transitions are not drawn in the figure for notational convenience, but Figure 3 shows an equivalent high level Petri net interpretation of a DSNnet instance. As indicated, the color of each place is the real number type and each arc contains a variable for a single real number token. Petri Net interpretations of AND and OR nodes are presented in Figures 4 and 5, respectively. AND-OR logic for Petri Nets was first introduced in (Agerwala & Flynn, 1973; Baer, 1973).

The formalism in Figure 5 satisfies the modeling requirements for network alternatives but the issue of data has not yet been addressed. The cost elements pertinent to logistics change from industry to industry, and some cost elements such as obsolescence rate per annum are very different for if one is selling bricks (low obsolescence rate) or mobile phones (high obsolescence rate). To address this requirement it is vital to have "metadata" on the types of cost elements as well as their values related to particular industry or firm. This metadata approach is adopted in the formal definitions described in the following pargraphs.

Formal Definitions

The definition of DSNnet is divided into three parts. First, I define DSNnet_skeleton (Definition 1), which gives the metadata for cost elements included in a particular company. Second, I define a particular DSNnet instance (Definition 2). Finally DSNnet system is defined in terms of high level Petri Net system with real number data types (Definition 3).

Definition 1

DSNnet_skeleton = { NodeTypes ∪{ AND_node, OR_node }, ArcTypes, ParameterPool, ParameterMap }, where

Figure 3. Showing equivalence between DSNnet and high level petri net

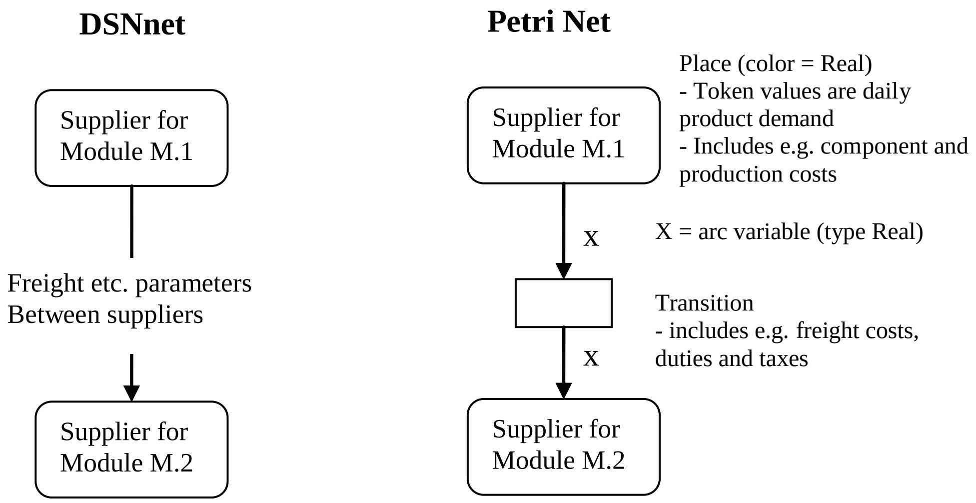


Figure 4. Semantics of DSNnet AND node

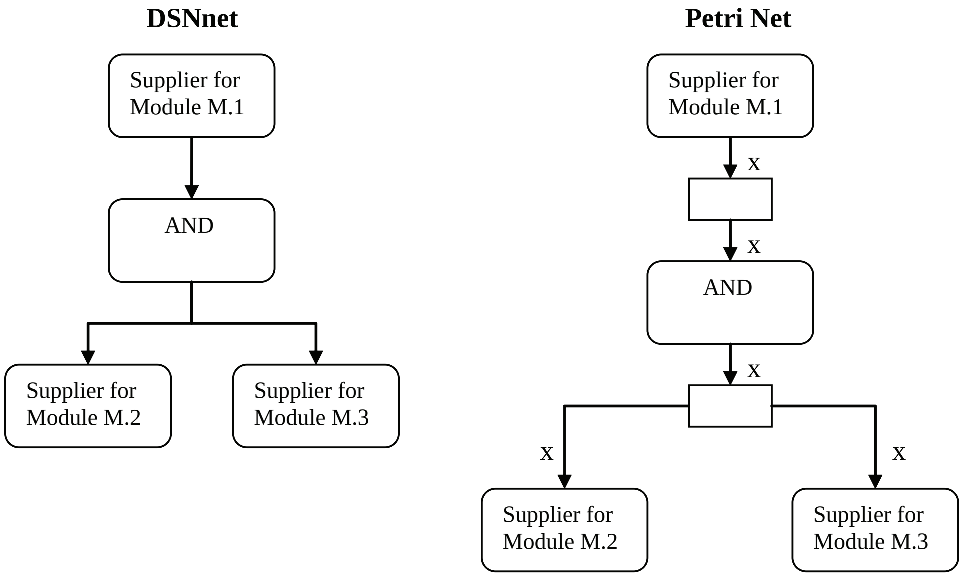
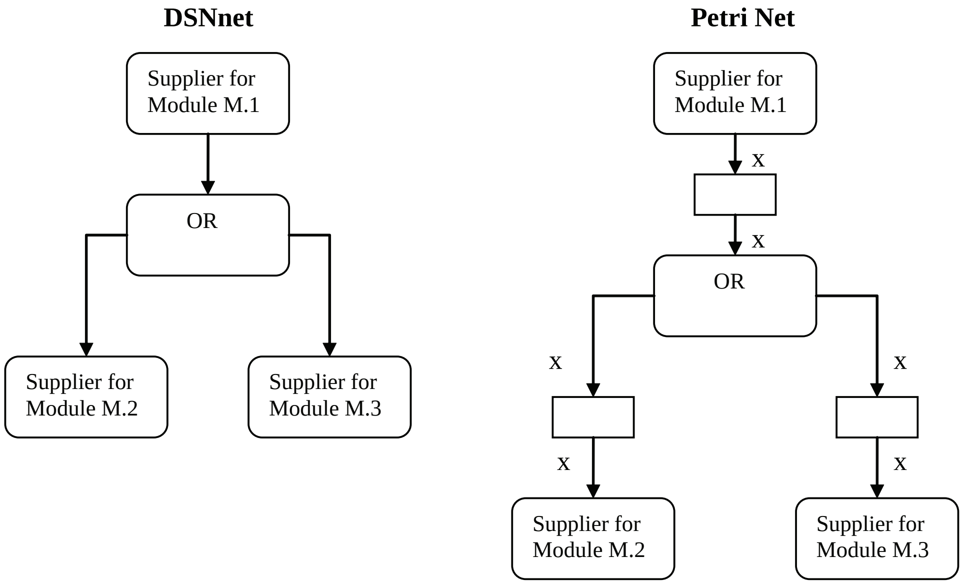


Figure 5. Semantics of DSNnet OR node



NodeTypes = types of nodes in analysis (e.g., customer, manufacturing, buffer)
ArcTypes = types of arcs in analysis (e.g., transportation arcs)
ParameterPool = collection of all cost parameters used in the analysis

$\mathit{ParameterMap} = \mathit{NodeTypes} \times 2^{\mathit{ParameterPool}} \cup \mathit{ArcTypes} \times 2^{\mathit{ParameterPool}}$

A company is responsible for defining its own DSNnet_skeleton. *NodeTypes* and *ArcTypes* are standard—customer node, manufacturing node, buffer node, and transport arc typically suffice. *ParameterPool* may differ greatly from company to company. For example, the percentage used to estimate stock obsolescence is different in ICT business as compared to construction business—value of bricks does not diminish as quickly in stock as that of unsold mobile phones or PCs. The companies in fast price erosion environments (e.g., Dell) have a stronger incentive to make their demand supply networks agile than construction material suppliers. ParameterPool may change during a company's lifetime. Finally, *ParameterMap* associates each NodeType and ArcType to the specific cost parameters associated with it. To illustrate, I show the DSNnet_skeleton in use inside Nokia Corporation.

Illustration 1 — *Nokia's DSNnet_skeleton*
{ NodeTypes = { Customer, Manufacturing, Buffer } ∪{ AND_node, OR_node},
ArcTypes = { DSNarc },
ParameterPool = { bill of materials cost, buffer inventory carrying cost, transport inventory carrying cost, freight cost, production cost, investment cost, duty cost, tax cost, manufacturing line verification cost, sales volume }, ParameterMap = { Customer node →{ sales volume }, Manufacturing node →{ bill of materials cost, production cost, investment cost, line verification cost },Buffer node →{ buffer inventory carrying cost }, DSNarc →{ transport inventory carrying cost, freight cost, duty cost, tax cost }}}

Definition 2 — *DSNnet*
DSNnet = { Nodes, Arcs, F, DSNnet_skeleton, Typing, Valuation}, where
Nodes = set of Nodes (Petri Net places, color = Real)
Arcs = set of Arcs (Petri Net transitions, transition guards are TRUE)
F = Nodes × Arcs ∪Arcs × Nodes, each arc's inscription is X, a Real number variable
DSNnet_skeleton = as defined above
Typing = Nodes × DSNnet_skeleton.NodeTypes ∪Arcs × DSNnet_skeleton.ArcTypes
Valuation = V(Nodes, Arcs, Typing) – a function that assigns relevant parameter values to each node and arc according to its type (joint responsibility of tool user and the user interface in real world)

Definition 3 — *DSNnet_system*
DSNnet_system = $\{ DSNnet, Nodes_0, M_0 : Nodes_0 \rightarrow Real \}$
A DSNnet_system has a valid DSNnet structure, a set of initial nodes (Customer nodes) $Nodes_0$*, and initial marking* M_0 *that maps a single token of type Real to each initial node (this value represents a customer's average daily demand for a certain product).*
The firing rule for DSNnet_system is that of High Level Petri Nets.

REACHABILITY ANALYSIS OF DSN NET

The traditional Petri Net reachability analysis algorithm computes all reachable system states. In DSNnet formalism, reachability analysis differs in two important points:

1. The algorithm computes all possible paths of a system (valid DSNnet structures are directed and acyclic, guaranteeing the absence of infinite paths)
2. The algorithm allows for several initial states, and aggregates the separate reachability graphs to a single result

The result of the reachability analysis is a list of complete paths in the DSNnet, each associated with a cost. The optimum path is the one with the lowest cost. In DSNnet context, a reachability graph is an array of arrays (matrix) where each component array (matrix column) is one demand supply network setup with its cost.

The pseudocode for the algorithm is presented next. RG is used as a shorthand for “reachability graph,” and arrays are indexed in C language style from 0 to array_size-1. The pseudocode uses four helper functions: *append_node*, *append_RG*, *aggregate_RG* and *add_per_item_costs*. *Append_node* appends a node (first argument) to all paths in the reachability graph (second argument). *Append_RG* joins two reachability graphs to form a single reachability graph—that is, the appending of RG1 with 5 paths and RG2 with 3 paths results in a single RG with eight paths. *Aggregate_RG* takes the Cartesian product of two reachability graphs, where each path in the resulting reachability graph has a cost equal to the sum of the two constituents. The Cartesian product of RG1 with 5 paths and RG2 with 3 paths has 15 paths. Finally, *add_per_item_costs* adds the costs of an arc or a node (the first argument) to each path in the reachability graph (the second argument). The preliminary version of the algorithm has been published in Tynjälä (2006).

Main DSNnet Analysis Routine

The main analysis routine is given in Figure 6. The investment costs are computed last because several customers can source their products from the same suppliers (manufacturing nodes). The total volumes for each supplier are known when the second for-loop has been executed. The second for loop—aggregation of individual customers’ reachability graphs—is also the source of the algorithm’s computational complexity. For, assume that we have C customers and P is the maximum of the number of DSN setup options for a customer. Then the size of the state space (and computation time) grows exponentially as $O(P^C)$. Parallelizing this part of the algorithm is included in the topics for future research.

Reachability Analysis Routine for a Single Customer Node

The algorithm that computes the reachability graph for one customer is presented in Figure 7. It follows the traditional reachability analysis algorithm with the addition of AND and OR nodes.

Computation of Investment Costs

This part of the algorithm computes investment costs that depend on production volume in a stepwise manner. For example, if a manufacturing line capacity for a particular phone is 7,500 phones per day, this algorithm computes the number of needed manufacturing lines based

Figure 6. Main analysis routine

```
RG_main(DSNnet_system — see Definition 3) returns all DSN setups with cost {
    RG[] = array of new Reachability Graphs;
    total_RG = new Reachability Graph;
    for each initial customer node do
        RG[i] = RG_1_customer(customer_node[i]);
    end
    for i = 0..number of customer nodes -1 do
        total_RG = aggregate_RG( total_RG, RG[i]);
    end
    for each path in total_RG do
        investment_cost = compute_investments(path);
        add investment_cost to the path’s cost;
    end
    return total_RG;
}
```

Figure 7. Reachability analysis routine for a single customer

```
RG_1_customer(Start Node with volume marking, Start RG) returns RG  {
    RG[] = array of empty Reachability Graphs;
    theChildNodes[] = Array for children of AND and OR nodes;
    theChildArcs[] = Array for arcs leading to theChildNodes;
    Add volume marking to Start Node's total volume;
    if Start Node has 0 children then
        append_node(Start RG, Start Node);
        Start RG = add_per_unit_costs(Start RG, Start Node, NULL);
        return Start RG;
    else if Start Node has 1 childNode then
        childArc = DSN Arc between Start Node and childNode;
        append_node(Start RG, Start Node);
        Add volume marking from Start Node to childNode and childArc;
        Start RG = RG_1_customer(childNode, Start RG);
        Start RG = add_per_unit_costs(Start RG, Start Node, childArc);
        return Start RG;
    else if Start Node is AND then
        total_RG = new Reachability Graph;
        append_node(Start RG, Start Node);
        Add the volume marking to theChildNodes[] and theChildArcs[];
        for each theChildNodes[i] do
            RG[i] = RG_1_customer(theChildNodes[i], RG[i]);
        end
        for i = 0..number of Child Nodes-1 do
            total_RG = aggregate_RG(total_RG, RG[i]);
        end
        total_RG = aggregate_RG(Start RG, total_RG);
        return total_RG;
    else if Start Node is OR then
        total_RG = new Reachability Graph;
        append_node(Start RG, Start Node);
        Add the volume marking to theChildNodes[] and theChildArcs[];
        for each theChildNodes[i] do
            RG[i] = RG_1_customer(theChildNodes[i], RG[i]);
        end
        for i = 0..number of Child Nodes-1 do
            total_RG = append_RG(total_RG, aggregate_RG(Start RG, RG[i]));
        end
       return total_RG;
}
```

on total volume throughput, and calculates the needed investments.

Algorithm Validation

The algorithm was validated in two steps. First, a series of tests with different product structures and customers was carried out to ensure that the paths were computed correctly. This step concentrated on the correct functioning of the AND and OR nodes which were our additions to the traditional reachability analysis algorithm. In the second phase, the cost figures obtained for a single setup were compared with those obtained from the previous spreadsheet-based tool. The second validation phase uncovered some errors in cost computation, which were corrected and revalidated.

Figure 8. Computation of investment costs

```
compute_investments(one DSN setup) returns InvestmentCost {
    for each manufacturing node in setup do
        determine total volume throughput;
        determine number of manufacturing lines;
        InvestmentCost = InvestmentCost + (no. of manuf. lines * investment per line);
     end
     return InvestmentCost;
      }
```

NOKIA IMPLEMENTATION AND CASE STUDY

Tool Implementation Method

The tool based on the previously mentioned formalism was developed in Java2 language, and embedded in the Oracle environment hosting demand supply planning data repository. The tool's Web user interface lets the logistics managers specify product structures, and costs for alternate suppliers. Common data such as transportation costs between cities, duty and tax rates are centrally updated by few key users. The Web UI has "analyze" button associated which invokes the Java algorithm. The Java algorithm first reads the database tables for product and supplier information, constructs the corresponding DSNnet instance, and runs the reachability analysis on it. Final results are stored in database tables and displayed in Web browser. Permissions to view data are granted in such a way that a normal user may see only his work when using the tool. Key users for each business group have view of all programs in that business unit. Finally, the global logistics directors see all programs in every business unit. The next subsection contains a real example of an analysis case for a product that started shipping in the summer of 2006.

Analysis of a New Handset

The product structure for the new handset that started to ship in the summer of 2006 is shown in Figure 9.

As indicated in the diagram modules A, B, and H had 2 supplier options, with the rest having a single decided supplier. For a single customer this product structure produces 8 (2*2*2) demand supply network setups. The analysis covered two customers, so the total number of demand supply networks came to 64 (8^2). Interestingly, the static costs for the alternative suppliers of modules A, B, and H (e.g., production costs, investment costs) were not radically different. However, their global position was such that the buffering and transportation costs associated with the total demand

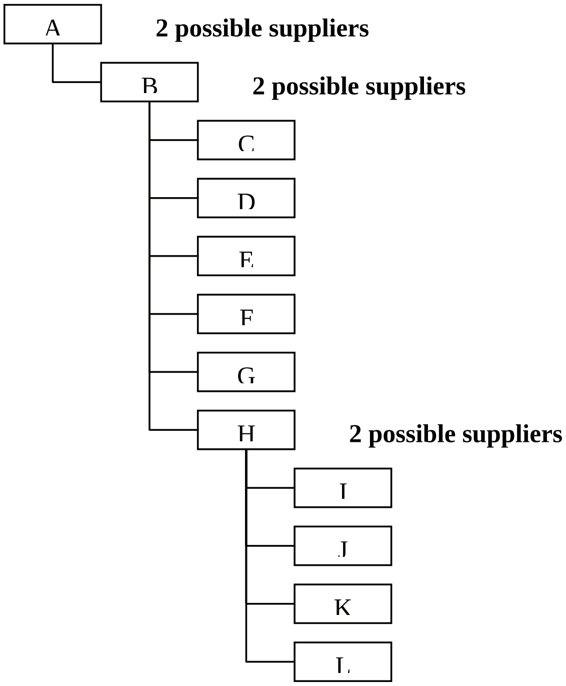


Figure 9. Product structure of a recently released Nokia handset

supply network were significantly different from one solution to another. For this product, whose expected lifetime is one year, the demonstrated cost differences from the cheapest to the most expensive demand supply network were ca. 15 Million Euros. The analysis tool was able to compute these 64 solutions in approximately 10 seconds, whereas the spreadsheet solution would have required several days (5 days with the optimistic target of 10 demand supply networks analyzed per day) to complete the job. The Nokia logistics team has established a target of one-week lead time for all demand supply network analyses (i.e., each week a new analysis report is generated based on the most current data). The spreadsheet method could not support this requirement because of time required for hand-generation of networks. With the new tool, this leadtime is feasible. The next subsection gives sample analysis times for problems of different complexity.

Usage and Performance Data in Nokia Environment

The tool has been actively used inside Nokia's business groups since February 10, 2005. The number of concrete product programs studied is over 200 at the end of July 2006. A product program represents a possible handset or network element under development that may or may not come to the market. The granularity of analyses is different in each business unit. The handset business units, where the volumes are large, consider few big customers, usually representing sales areas. The network business, where volumes are lower, relative logistics costs higher, and margins thinner, the granularity is more precise. The customers are modeled at least on a country level.

The typical performance of the tool is shown in Table 1. These measurements were single data points taken during a typical working day. The response times of the tool are practically the same globally, as the transport delays are small compared to the analysis time.

Table 1. Sample response times of Petri Net tool

Number of DSN Alternatives	Analysis time (sec)
4	0.5
16	2
64	7
256	40
1024	290

DISCUSSION AND FUTURE WORK

Applying Petri Nets and reachability analysis to demand supply network optimization has the benefit of exploring the complete state space of options. In wake of risks on the demand supply network, it is vital to explore also the expensive options for future contingencies.

I developed a high level Petri Net model expanding on the AND-AND, AND-XOR formalisms presented in (Baer, 1973; Agerwala, 1973), along with the associated reachability analysis algorithm. The Petri Net model is general and it may be employed in various types of businesses. In terms of expressive power, DSNnet stays within the normal Petri Net confines.

A tool based on the DSNnet methodology was developed during 2004 inside Nokia Corporation, and it has been in active use since February, 2005. The tool has been used in all business units and the results are very positive. The users have especially thanked the possibility of designing the product structure together with its demand supply network, which was not possible with the former spreadsheet methods.

The current reachability analysis algorithm is exponential, which may be a hindrance to some of the larger analyses, and finding the optimal supply network with mixed integer programming is much faster. However, a parallelized version of the reachability analysis algorithm could alleviate this problem and is part of the list of future research.

The work relating to DSNnet tool inside Nokia is ongoing, and the second release of the tool will become operational in October, 2006. This release enhances the tool with multimodal transport capabilities and improved duty and tax considerations. In the future, the tool is envisioned to become integrated to a data warehouse, which updates the cost and transport parameters automatically based on actual business transactions.

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Chapter 7.11

Empirical Assessment of Factors Influencing Success of Enterprise Resource Planning Implementations

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ABSTRACT

Enterprise resource planning (ERP) implementations in multinational manufacturing companies have experienced various degrees of success. This article investigates factors influencing the success of ERP implementations in multinational manufacturing companies in the Malaysian Free Trade Zone. The results indicate that enterprise-wide communication and a project management program are key factors influencing the success of ERP implementations, while other factors such as top management support as well as teamwork and composition are not as critical to the outcome. Organizational culture is a moderator of the relationships between enterprise-wide communication, a project management program, and the success of ERP implementations.

INTRODUCTION

Enterprise resource planning (ERP) refers to a seamlessly integrated family of software packages designed to integrate various financial, human resources, supply chain, and customer information functions. This system is a natural development and progression of Material Requirements Planning (MRP/MRP II) that was popular in the 1970's. Initially conceived to increase the efficiency of materials planning, the suite of software packages eventually evolved to cover a wide scope of organizational functions, including inventory control, finance, human resources, and manufacturing. Many companies experienced successes, but many more failed in their implementations. Some companies, such as FoxMeyer Corporation, experienced bankruptcy and resorted to suing the software company for failing to deliver the promises of the ERP system.

ERP implementation is a massive and costly affair (Davenport, 2000; Lee, Siau, & Hong, 2003; Siau, 2004). ERP implementations frequently consume a large portion of a company's time and resources (Siau & Messersmith, 2002, 2003). After more than twenty years of implementation and software development, much research has been gathered on the subject for developed nations (Bingi, Sharma, & Godla, 1999; Everdingen, Hilleegersberg, & Waarts, 2000; Kermers & van Dissel, 2000; Kumar, Maheshwari, & Kumar, 2003; Nadkarni & Nah, 2003; Scott & Vessey, 2002). However, the Southeast Asia region faced many challenges with ERP implementations (Davison, 2002; Soh, Sia, & Tay-Yap, 2000). The literature is scarce concerning ERP implementations and their success in this region (Tarafdar & Roy, 2003). The primary users of ERP systems are large multinational companies because local or regional small- to medium-sized companies have yet to fully embrace the benefits of ERP systems. In this research, we focus on investigating the factors contributing to the success of ERP implementations in multinational manufacturing companies in the Malaysian Free Trade Zone—a central zone in Southeast Asia.

LITERATURE REVIEW

ERP is a solution to fragmentation of information in large business organizations (Davenport, 1998). An ERP system typically comprises a central, state-of-the-art, comprehensive database that collects, stores, and disseminates data across all business functions and activities in an enterprise. By integrating all business functions, economies of scale are obtained and the business gains a significant operating cost reduction, in addition to improved capabilities and information transparency. The increased business trends of globalization, mergers, and acquisitions demand that companies must have the ability to control and coordinate increasingly remote operating units. An ERP system can help to achieve this by enabling the sharing of real-time information across departments, currencies, languages, and national borders.

The dream of creating an enterprise-wide system began in the 1970's, but was then unrealized due to the technological barriers at that time. Instead, most companies created what McKenney and McFarlan (1982) termed "islands of automation", which naturally evolved as new IT applications were introduced to fill the constantly-emerging business needs. This gave rise to a plethora of different systems that were loosely interfaced. As a result, information was scattered throughout an organization, and detailed analyses of an organization's performance across its business functions were not possible. Such information was impossible to obtain unless manual record-sifting or specialized programming requirements were carried out. In time, the organizational costs to maintain these "legacy" systems began to exceed the funds available for building new systems (Lientz & Swanson, 1980).

Enterprise systems provide a backbone of information, communication, and control for a company (Buckhout, Frey, & Nemec, 1999), and embody the current best business practices for organizational processes (Esteves & Pastor, 2000). Numerous benefits include improvements in:

- Cooperation between managers and employees;
- Consolidation of finance, marketing and sales, human resource, and manufacturing applications;

- Management information available—real-time information available anywhere, anytime;
- Informal systems for materials management/inventory/production control;
- Lead-times, manpower costs, overtime, safety stocks, work-in-progress; and
- Delivery times.

An ERP system is a set of customizable and highly-integrative real-time business application software modules sharing a common database and supporting core business, production, and administrative functions such as logistics, manufacturing, sales, distribution, finance, and accounting. Companies that are structurally complex, geographically dispersed, and culturally vibrant tend to present unique challenges to ERP implementation (Markus, Tanis & Fenma., 2000). Unique issues of change management are particularly important for multinational companies where their parent sites are geographically separate. This complexity involves several dimensions including business strategy, software configuration, technical platform, and management execution. Of these four, management execution contributes toward ERP implementation success to the greatest degree (Nah, Zuckweiler, & Lau, 2003). Different managerial reporting lines, languages, and national cultures also make managing a multi-site ERP implementation project challenging (Markus et al., 2000). Local management must therefore be prepared to deal with the issues of enterprise-wide implementation on a site level. In particular, companies in Asia confront issues substantially different from those faced by companies in the developed world (Tarafdar & Roy, 2003) due to the differences in sophistication of IT use and cultural influences.

THEORETICAL BACKGROUND ON FACTORS CONTRIBUTING TO ERP IMPLEMENTATION SUCCESS

To investigate specific metrics for ERP implementation success, we reviewed the literature and identified three sets of taxonomy or classification. They are: (i) the unified critical success factors model (see Table 1) proposed by Esteves and Pastor (2000), (ii) 22 critical success factors (see Table 2) identified by Somers and Nelson (2001, 2004), and (iii) seven broad categories of critical success factors (see Table 3) developed by Nah

Table 1. Unified critical success factors model

	Strategic	Tactical
Organizational	• Sustained management support • Effective organizational change management • Good project scope management • Adequate project team composition • Comprehensive business process reengineering • Adequate project champion role • User involvement and participation • Trust between partners	• Dedicated staff and consultants • Strong communication inwards and outwards • Formalized project plan/schedule • Adequate training program • Preventive troubleshooting • Appropriate usage of consultants • Empowered decision-makers
Technological	• Adequate ERP implementation strategy • Avoid customization • Adequate ERP version	• Adequate software configuration • Legacy systems knowledge

and Delgado (2006) which were derived from the 11 critical success factors (see Table 4) identified by Nah, Lau, and Kuang (2001).

Esteves and Pastor (2000) classify critical success factors into Organizational and Technological, and then further sub-divide them into strategic and tactical factors. By cross-referencing each of the factors with its citations in the literature, Esteves and Pastor (2000) derived the ERP implementation success matrix (also termed unified critical success factors model) presented in Table 1.

Somers and Nelson (2001) identified 22 critical success factors presented in Table 2 and evaluated them across stages of ERP implementation. The top six factors across the stages are: (i) top management support, (ii) project team competence, (iii) inter-departmental cooperation, (iv) clear goals and objectives, (v) project management, and (vi) inter-departmental communication.

Another comprehensive examination of the critical success factors of ERP implementation was carried out by Nah and her colleagues (Nah, et al., 2001; Nah, et al., 2003; Nah & Delgado, 2006). These factors fall into seven broad categories (see Table 3) and can be further broken down into 11 critical success factors (see Table 4).

Among the 11 critical success factors presented in Table 4, the top six critical success factors identified by Chief Information Officers of Fortune 1000 companies are: (i) top management support, (ii) project champion, (iii) ERP teamwork and composition, (iv) project management, (v) change management program and culture, and (vi) effective enterprise-wide communication (Nah et al., 2003).

Hence, top management support, project management, and enterprise-wide (or inter-departmental) communication are three common factors in Nah et al.'s (2003) and Somers and Nelson's (2001) "top factors" lists, whereas "ERP teamwork and composition" in Nah et al.'s (2003) list captures key aspects of project team competence and inter-departmental cooperation in Somers and Nelson's (2001) list. Therefore, we selected this set of four factors—top management support, project management, enterprise-wide communication, and ERP teamwork and composition—as independent variables for our study. These four factors are also ranked among the top five factors in Nah and Delgado's (2006) case study on ERP implementations in two organizations.

Figure 1 shows the research model, and the next section provides justifications for the hypotheses.

Hypotheses 1-4 specify the direct hypothesized effect of the independent variables—top management support, teamwork and composition, enterprise-wide communication, project management program—on the dependent variable—success of ERP implementation, whereas Hypotheses 5-8 state the moderating effect of organizational culture on these relationships.

Table 2. Twenty-two critical success factors model

Critical Success Factors
1. Top management support
2. Project team competence
3. Interdepartmental cooperation
4. Clear goals and objectives
5. Project management
6. Interdepartmental communication
7. Management of expectations
8. Project champion
9. Vendor support
10. Careful package selection
11. Data analysis and conversion
12. Dedicated resources
13. Use of steering committee
14. User training on software
15. Education on new business processes
16. Business process reengineering
17. Minimal customization
18. Architecture choices
19. Change management
20. Partnership with vendor
21. Use of vendors' tools
22. Use of consultants

Table 3. Seven broad categories of critical success factors

No.	Factor
1.	**Business plan and vision**
1.1	Business plan/vision
1.2	Project mission/goals
1.3	Justification for investment in ERP
2.	**Change management**
2.1	Recognizing the need for change
2.2	Enterprise-wide culture and structure management
2.3	Commitment to change—perseverance and determination
2.4	Business process reengineering
2.5	Analysis of user feedback
2.6	User education and training
2.7	User support organization and involvement
2.8	IT workforce re-skilling
3.	**Communication**
3.1	Targeted and effective communication
3.2	Communication among stakeholders
3.3	Expectations communicated at all levels
3.4	Project progress communication
4.	**ERP team composition, skills, and compensation**
4.1	Best people on team
4.2	Balanced or cross-functional team
4.3	Full-time team member
4.4	Partnerships, trust, risk-sharing, and incentives
4.5	Empowered decision-makers
4.6	Performance tied to compensation
4.7	Business and technical knowledge of team members and consultants
5.	**Project management**
5.1	Assign responsibility
5.2	Clearly establish project scope
5.3	Control project scope
5.4	Evaluate any proposed change
5.5	Control and assess scope expansion requests
5.6	Define project milestones
5.7	Set realistic milestones and end dates
5.8	Enforce project timeliness
5.9	Coordinate project activities across all affected parties
5.10	Track milestones and targets
6.	**Top management support and championship**
6.1	Approval and support from top management
6.2	Top management publicly and explicitly identifies project as top priority
6.3	Allocate resources
6.4	Existence of project champion
6.5	High-level executive sponsor as champion
6.6	Project sponsor commitment
7.	**Systems analysis, selection, and technical implementation**
7.1	Legacy system
7.2	Minimum customization
7.3	Configuration of overall ERP architecture
7.4	Vigorous and sophisticated testing
7.5	Integration
7.6	Use of vendor’s development tools and implementation methodologies
7.7	ERP package selection
7.8	Selection of ERP architecture
7.9	Selection of data to be converted
7.10	Data conversion
7.11	Appropriate modeling methods/techniques
7.12	Troubleshooting

Table 4. Eleven key critical success factors

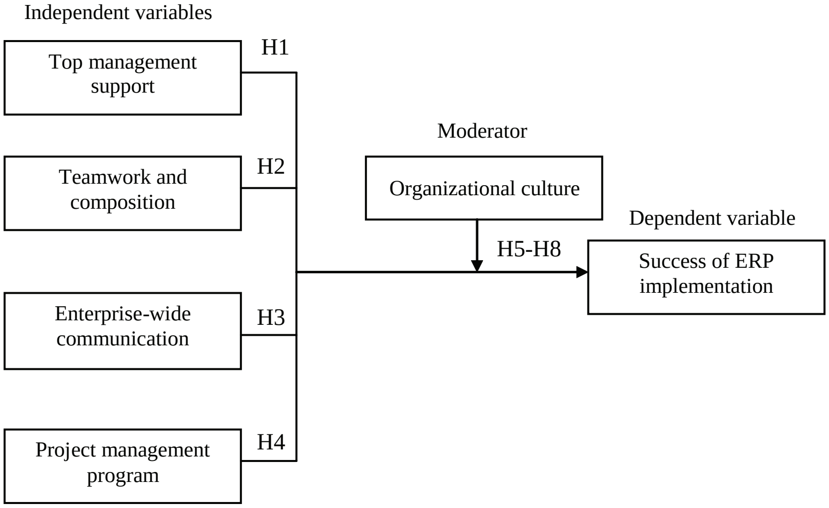
Critical Success Factors
1. ERP teamwork and composition
2. Change management program and culture
3. Top management support
4. Business plan and vision
5. Business process reengineering with minimum customization
6. Project management
7. Monitoring and evaluation of performance
8. Effective enterprise-wide communication
9. Software development, testing, and troubleshooting
10. Project champion
11. Appropriate business and IT legacy systems

ERP CRITICAL SUCCESS FACTORS

Rockart (1979) is one of the first researchers to study critical success factors of IT implementations. According to his account, these factors are the “areas in which results, if they are satisfactory, will ensure successful competitive performance for the organization” (p. 85).

Most of the literature in the MIS field list in excess of 20 critical success factors (Nielsen, 2002). Esteves and Pastor (2000) present a unified model of critical success factors, and further studied the effects of these factors in SAP’s ASAP

Figure 1. Research model



implementation methodology. To study key critical factors influencing ERP implementation success, we identified four "top" factors—top management support, ERP teamwork and composition, enterprise-wide communication, and project management program—that we examine in this research. Technological factors such as system configuration, customization, and legacy data migration are outside the scope of this research and are excluded from this study.

Top Management Support

Not only is the criticality of top management support widely cited throughout the ERP literature (e.g., Dong, 2001; Somers & Nelson, 2004), several studies (Akkermans & van Helden, 2002; Esteves & Pastor, 2000; Nah et al., 2003; Somers & Nelson, 2001) have also identified top management support as the top and most crucial factor in ERP implementation. Similarly, Sarker and Lee (2003) identified strong and committed leadership as a necessary condition for success in ERP implementation. Willocks and Sykes (2000) noted that senior-level sponsorship, championship, support, and participation is one of the critical enabling factors for success in an ERP project. Public, explicit, and sincere support for the project must be present to emphasize the priority of the project. Accordingly, commitment of valuable resources to the implementation effort (Holland, Light, & Gibson, 1999; Roberts & Barrar, 1992) provides the practical support that is needed to ensure success in an ERP project. Top management commitment is the most widely-studied factor in successful IS implementations (Dong, 2001) and is also the most severe source of difficulty in IS implementations. Top management support is even more important in the case of ERP because of the scale of the project and the amount of resources needed for the enterprise-wide project. Hence, we hypothesize that:

H1: *Top management support increases the level of success of ERP implementation.*

Teamwork and Composition

The ERP team should comprise the best people in the organization to maximize the chances of success of the project (Buckhout et al., 1999; Bingi et al, 1999; Rosario, 2000). The team should be cross-functional and possess the necessary technical and functional skills for design, implementation, and assimilation. The team will have to integrate business functions with the capabilities of the software as well as possess the necessary credentials to influence business process changes where necessary. The effective use of consultants also improves the likelihood of success of the project (Haines & Goodhue, 2003). Compensation, incentives, and the mandate for successfully implementing the system on time and within budget should be given to the team to foster teamwork in the project (Buckhout et al., 1999). It is also helpful to ensure that the ERP team is colocated to facilitate teamwork and coordination among the members. We, therefore, hypothesize that:

H2: *The use of cross-functional teams that comprise people with the best business and technical knowledge increases the level of success of ERP implementation.*

Enterprise-Wide Communication

Communication across the different levels and functions of an organization is necessary for success in ERP implementation (Akkermans & van Helden, 2002; Falkowski, Pedigo, Smith, & Swanson, 1998; Parr, Shanks, & Darke, 1999). Communication is a complex factor that includes, but is not limited to, specifications of individual roles and responsibilities, clear definitions of the project milestones, pre-implementation training, and unambiguous definition of the time horizon (Petroni, 2002). Monthly bulletins, newsletters, weekly meetings, and frequent e-mail updates are among the tools that can be employed. This communication needs to be two-way to avoid design gaps that can occur if the exact business requirements or comments and approval from the ground up are ignored. Esteves and Pastor (2000) also noted that both "outward" communication to the whole organization and "inward" communication to the project team are very important.

Rosario (2000) advocates an early "proof of concept" to minimize skepticism and sustain excitement. This kind of demonstration should be public and well endorsed by key project champions and top management. Keeping the morale high and convincing the users that the new ERP system is of benefit while convincing them to abandon the old, comfortable systems requires persuasiveness and acts of showmanship on the part of management and the implementation team. Users need to know that the feedback they provide will be considered and acted upon (Rosario, 2000). Among the stakeholders of companies studied by Holland et al. (1999), it was found that communication is a critical success factor of ERP implementation. For example, Shanks, Parr, Hu, Corbitt, Thanasankit, and Seddon (2000) found that the likelihood of ERP implementation failure increased when dates were not properly communicated well in advance to stakeholders.

Based on the above discussion, we hypothesize that:

H3: *Enterprise-wide communication during the implementation increases the level of success of ERP implementation.*

Project Management Program

The proper and effective management of an ERP project is essential for its success (Nah et al., 2003). An ERP project management program requires well-defined task assignments, accounting for resource allocations, project control-keeping, and avoiding "creep" (Bagranoff & Brewer, 2003; Rosario, 2000) which is the tendency of the project to acquire additional software requirements and customization and to uncover hidden issues as time goes by. Jiang, Klein, and Balloun (1996) found that a competent project manager is the second most important factor in an IS implementation. The scope of the project should be clearly established, managed, and controlled (Shanks et al., 2000). Ross (1999) indicated that establishing program scope is the key to successful ERP implementation. Proposed changes should be evaluated against business benefits, and scope expansion requests should be assessed in terms of the additional time and cost of proposed changes (Sumner, 1999). In addition, approved changes need to be coordinated across all affected parties (Falkowski et al., 1998). Schniederjans and Kim (2003) proposed that ERP systems implementations can be supplemented by Total Quality Management (TQM) and Business Process Re-engineering (BPR) programs to prepare an organization to be more receptive to the new ERP system. They suggested that the actual ERP implementation be preceded by BPR and followed up by a rigorous TQM program, to produce the effect of Lewin's (1951) recommended change criteria of unfreezing (BPR), change (ERP), and refreezing (TQM).

As discussed above, project management is essential to the success of ERP implementations. Thus, we hypothesize that:

H4: *A project management program increases the level of success of ERP implementation.*

ORGANIZATIONAL CULTURE

The organizational culture paradigm, as defined by Johnson and Scholes (2005), is a set of assumptions held relatively in common and taken for granted in an organization. It includes collective experience, values, beliefs, and behavioral norms. These assumptions exist at the organizational level, and they have worked well enough to be considered valid. An organizational culture that promotes learning and innovation can be especially influential to the success or failure of an organization's IT innovation or strategy (Johnson & Scholes, 2005; Sitkin, 1992). Scott and Vessey (2000) provide case study evidence to show that organizational culture can impact the success or failure of ERP implementation.

According to Sitkin (1992), the proximity of an organization towards a "learning" state would, in theory, greatly facilitate the process of change. An organizational culture that promotes learning encourages involvement/participation and adaptation. Edwards and Panagiotidis (2000) support the proposition that organizational culture is useful in understanding successful ERP implementations. They proposed a Business Systems Purpose Analysis (BSPA) methodology and recommended its integration into SAP's ASAP implementation methodology.

Skok and Legge (2002) highlight the importance of cultural as well as business process changes. According to them, ERP problems commonly lie in the employees feeling uncomfortable with the cultural changes, which follow from process changes in the ERP implementation. Thus, unless the organizational culture promotes openness in communication and facilitates learning, the employees may behave in a detrimental fashion towards the new ERP system, causing its failure.

Organizational Culture as a Moderator of ERP Implementation Success

A management team that readily accepts new concepts and is able to learn to accept and adapt to new tools as they become available is able to drive the implementation of a new enterprise-wide system more effectively, as opposed to a management team that prefers to maintain the "status quo" and is suspicious of progress (Dong, 2001). Since learning in an organization needs to be led from all levels of the organization, particularly from top-level management, a management team that is conducive to change (as in the case of an open and supportive organizational culture) is more likely to convince and persuade the rest of the organization to follow suit, which contributes toward the success of the ERP implementation.

H5: *Organizational culture moderates the relationship between top management support and the success of ERP implementation.*

ERP implementation teams are by necessity cross-functional, as the new system brings together and integrates the various functions within an organization. In order to derive the best benefits from the ERP system, the cross-functional teams working on the project should not only be able to work well together, but also understand and appreciate the different strengths and skills that each member brings to the teams. Closed or non-learning organizations are more prone to encounter difficulties in facilitating teamwork and coordination among members of cross-functional teams.

H6: *Organizational culture moderates the relationship between ERP teamwork-and-composition and the success of ERP implementation.*

An organizational culture that promotes openness in communication facilitates the process of organizational learning, which contributes toward ERP implementation success. An open and supportive organizational culture encourages increased interaction and improved communication, which help to facilitate communication of new and complex concepts of ERP systems to the end-users. Since the sheer scale and complexity of an ERP system will require almost all company personnel to learn new tools and new ways of working, organizational culture can facilitate the learning process involved in such implementations that are necessary for successful implementation.

H7: *Organizational culture moderates the relationship between enterprise-wide communication and the success of ERP implementation.*

Team leaders faced with the challenge of managing a project this massive typically face tight deadlines and a near-impossible means of disseminating all the required training to end-users. Furthermore, the leaders of the project team need to clearly specify responsibilities, establish and control project scope, evaluate any proposed change, assess scope expansion requests, define and set project milestones, enforce timeliness of the project, and coordinate project activities across all affected parties. Thus, a learning culture benefits these processes and increases the success of the implementation.

H8: *Organizational culture moderates the relationship between a project management program and the success of ERP implementation.*

SUCCESS OF ERP IMPLEMENTATION

The dependent variable in this study is success of EPR implementation. "Success" can be defined in several ways. For project leaders, a successful implementation means that the project is completed on time and within budget and where there is minimal disruption to product shipment and customer service during the cutover period. However, from a strategic point of view, success does not only refer to meeting the "Go Live" date, but also to the increased value of the business from usage of the new ERP system.

Markus and Tanis (2000) also pointed out that success means different things depending on the perspectives that one is taking and the person defining it. For example, project managers often define success in terms of completing the project on time and within budget. The business, however, takes the view of a smooth transition to stable operations with the new system, achieving intended business improvements like inventory reductions, and gaining improved decision-support capabilities (Markus & Tanis, 2000). Markus and Tanis define optimal success as the "best outcomes the organization could achieve with enterprise systems, given its business situation, measured against a portfolio of project, early operational, and longer-term business results metrics" (p. 186). Similarly, in this study, we will adopt the business value and performance perspective of success in ERP implementation. This perspective is also adopted by other researchers studying IS/IT success (Langdon, 2006; Mukhopadhyay, Kekre, & Kalathur, 1995; Tallon & Kraemer, 2006).

Petroni (2002) pointed out that simply asking users to rate their level of satisfaction would not be accurate or sufficient to assess success of an implementation. Neither would it be practical to ask a manager to define an implementation as anything less than successful, since no one is typically willing to shoulder the responsibility of failure. Petroni therefore suggests a set of criteria for judging the success of implementation (see Table 5) to help minimize respondent bias. We adapt Petroni's criteria, which include assessment of both performance and user satisfaction, to quantify optimal success from the business and strategic perspective. These criteria are also in line with Gable, Sedera, and Chan's (2003) measurement model for enterprise system success which covers organizational and individual impact as well as user satisfaction.

RESEARCH METHODOLOGY

The primary source of data collection was a survey, which was administered to both managerial and non-managerial staff from multinational companies in the Free Trade Zone of Malaysia. These companies had implemented ERP systems and were involved in distribution and manufacturing activities. The survey questionnaire was adapted from Nah et al. (2003) and Petroni (2002), and is presented in the Appendix. Pilot studies were conducted to validate these measures prior to finalizing the questionnaire. The primary means of distributing the survey questionnaire was via e-mail. The questionnaire was distributed after pre-contacting the recipients and informing them about the pending survey. Two hundred copies of the questionnaire were distributed, and the responses were collected electronically over a three-month period. A total of 110 questionnaires were returned. Hence, the response rate is 55%.

RESULTS

Respondents were asked to provide demographic information. Analysis of the demographic data indicates that 63% of the respondents were male and 37% were female. In terms of education, 66%

Table 5. Optimal success criteria

Improved ability	Ability to meet volume/product changes Capacity planning Cost estimation Inventory control Delivery dates Production scheduling
Improved efficiency and user satisfaction	Cooperation between managers and employees Coordination between finance, marketing, and sales
Reductions	Delivery or lead-times Informal systems for materials management Informal systems for inventory control Informal systems for production control Expediting of shipments Expediting of incoming materials Work in progress (WIP)

Table 6. Summary of reliability analysis

Variables	Number of items	Cronbach Alpha
Top Management Support	5	.82
Teamwork and Composition	5	.72
Effective Communication	5	.89
Project Management Program	5	.75
Organizational Culture	6	.83
Success of ERP Implementation	5	.83

reported holding a Master's degree and 14% have a Ph.D. Thirty-seven percent of the respondents reported holding managerial positions, while 54% were in non-managerial positions. A majority of the respondents (63%) have been with their companies for less than five years, and 18% of the respondents have been with their companies for 6 to 10 years. Eighty percent of the respondents were from companies that exceeded $4 million USD in annual revenue, and 64% have more than 3,000 employees in their organizations.

Table 6 shows the reliability assessments for both the independent and dependent variables. To assess the internal consistency and stability of data, Cronbach Alpha was used to establish the inter-item consistency. Since the Cronbach Alpha coefficients are all above 0.7 (Nunnally, 1978), it can be concluded that the measures are reliable.

Regression analysis was first carried out to assess H1-H4. Hierarchal regression was then used to test H5-H8, the moderating effect of organizational culture on the relationships between the independent variables and success of ERP implementation. We used a significance level of 0.05, or 5%, as the basis for accepting or rejecting the hypotheses.

As shown in the regression table in Table 7, the coefficient of R^2 is 0.389, indicating that the four independent variables explain 38.9% of the variance. Durbin Watson of 1.71 indicates that there is no auto-correlation problem. Tolerance and VIF values are also within the acceptable range indicating that there is no multi-collinearity problem.

The results presented in Table 7 prompted rejection of Hypotheses 1 and 2, and acceptance of Hypotheses 3 and 4. The results suggest that top management support (p=0.42) and teamwork and composition (p=0.42) did not influence success of ERP implementation. On the other hand, enterprise-wide communication (p<0.05) and project management (p<0.05) have significant impact on success of ERP implementation.

The results of hierarchical regression analysis for the moderating variable, organizational culture, are shown in Table 8. Recall that the R-square value is 0.389 when no moderating variable is taken into account. This value increases to 0.495 when culture is considered in the model and to 0.543 when culture is considered to moderate the interaction terms. The increased R-square suggests that organizational culture is a moderator in the proposed model.

Table 7. Summary of regression model output

R^2 = 0.389			Sig. = 0.00	
F-value = 15.80			Durbin Watson = 1.71	
Variables	**Beta**	**Sig. (p)**	**Tolerance**	**VIF**
MSUP	0.089	0.42	0.52	1.94
TEAM	0.099	0.42	0.41	2.45
COMM	0.334	**0.01***	0.35	2.83
PROJECT	0.294	**0.04***	0.32	3.11

** **p**<0.05*

Table 8. Summary of hierarchical regression models

Model	R^2	Change in R^2	Change in F	Change in Sig.	Durbin Watson
1 (OC ignored)	.389	.389	15.58	.00	
2 (OC as IV)	.495	.107	20.50	.00	
3 (OC as moderator)	.543	.048	2.42	.05	1.70

Variables	Beta	Sig. (*p*)
MSUP	0.089	0.42
TEAM	0.099	0.42
COMM	0.334	0.01*
PROJECT	0.294	0.04*
CULTURE	0.381	**0.00***
MSUP*CULTURE	0.209	0.82
TEAM*CULTURE	-0.409	0.68
COMM*CULTURE	2.501	**0.01***
PROJECT*CULTURE	2.850	**0.04***

* $p<0.05$

The model with organizational culture as a moderator explains 54.3% of the variance of success of ERP implementation. Durbin-Watson of 1.70 falls within the accepted range (1.5—2.5), indicating no auto-correlation problem. Condition index, VIF, and tolerance are all within the acceptable range (Condition Index < 40, Tolerance > 0.1 and VIF < 10), which means there is no multi-collinearity problem. Histograms for the regression model were plotted to validate that normality distribution is achieved and there is no heteroscedasticity problem.

The moderated relationship between enterprise-wide communication and success of ERP implementation is significant ($p<0.05$), which implies that organizational culture moderates the relationship between enterprise-wide communication and success of ERP implementation. We also tested the moderating effect of organizational culture on the relationship between project management and success of ERP implementation, and the result is significant ($p<0.05$), implying that organizational culture moderates the relationship between project management and success of ERP implementation. The results, however, indicate that organizational culture is not a moderator of the relationships between each of top management support (p=0.82) and teamwork-and-composition (p=0.68), and success of ERP implementation.

DISCUSSION OF RESULTS

The degree of enterprise-wide communication on the EPR implementation impacts positively on the success of the ERP implementation. This finding is also supported by the work of other researchers (e.g., Esteves & Pastor, 2000; Falkowski et al., 1998; Petroni, 2002; Rosario, 2000). Our research provides support for the importance of enterprise-wide communication and its purported benefits on ERP implementation in the context of multinational companies operating in Malaysia.

A project management program is also found to be important for ERP implementation success, which is consistent with the findings by Rosario

(2000) and Bagranoff and Brewer (2003). A project management program is essential for success, as it establishes project scope and ensures that scope expansion requests are carefully assessed before they are approved. An effective project management program defines and sets realistic milestones and enforces them. The success of ERP implementation also depends on coordination of project activities across the different parties involved, which is another important component of a project management program.

A surprising finding of this study is that top management support does not impact the success of ERP implementation. This contradicts findings of previous research (Dong, 2001; Esteves & Pastor, 2000; Nah et. al., 2003; Sarker & Lee, 2003) where top management support was cited as the top or a key factor influencing ERP implementation success. However, not all the previous studies run contradictory to this finding, as many studies have focused on different aspects of management involvement. For example, the unified critical success factors model by Esteves and Pastor (2000) examined *sustained* management support at all levels and phases of the implementation, which is conceptually different from top management support. Others, like Petroni (2002), found that top management support was a far more critical factor for small- and medium-sized firms than for large multinationals. Another possible explanation for this observed phenomenon lies in the nature of management style in multinational corporations operating in South-East Asia. Tarafdar and Roy (2003) indicated that management staff in developing nations confronted issues differently from management staff in developed countries. Hence, top management support may be more critical for ERP implementation in developed than developing countries. Power distance between top management and the employees could also account for the difference. In other words, with high power distance in Malaysia, the mandate for ERP implementation is strong across the different levels of an organization regardless of whether top management support is perceived to be present. Since the majority of the ERP literature has mainly focused on top management support in primarily developed nations, this new finding suggests that top management support may act more like an "enabling" rather than a "necessary" factor for the success of ERP implementation in developing nations. Another possible explanation is that top management support, when measured against optimal success from the business and strategic perspective, may not influence success. In other words, top management support may be necessary for the completion of an ERP project but may not directly affect the effectiveness of the system.

Another result of this study suggests that teamwork and composition of ERP implementation teams does not relate to ERP implementation success. This further contradicts previous findings (Bingi et al, 1999; Buckhout et al., 1999; Rosario, 2000). In the context of a multinational environment, it is likely that the selected teams might be too far removed from the actual implementation details and were focusing more on the system architecture rather than the change process, a phenomenon that is cautioned against by Davenport and Stoddard (1994). This is even more likely to happen if the company believes that the IS architecture is the most important aspect or if customization to suit existing business processes is given precedence (Brehm, Heinzl, & Markus, 2001) without due consideration of the pros and cons of customizing the software versus making changes to business processes to suit the new ERP system. It was established earlier that ERP systems are more about adaptation of business processes to the demands of the ERP system (Davenport, 2000) rather than the design of the ERP system to fit the demands of the business. It is also possible that the optimal teamwork and composition for ERP implementation is harder to achieve in developing nations due to limitations in human and technological resources.

The relationship between enterprise-wide communication and success of ERP implementation is positively moderated by the presence of a learning culture. A culture that is open to continuous learning and challenge, as evidenced in a “learning organization” (Senge, 1994), can help to facilitate effective communication across the enterprise, which is a key to success in ERP implementation. Similarly, an open and learning organizational culture also facilitates the execution of a project management program, which increases the chances of success in ERP implementation. These findings validate research by proponents of the learning culture theory (Edwards & Panagiotidis, 2000; Senge, 1994; Skok & Legge, 2002). In fact, the moderating influence of organizational culture was found to be so strong that it warrants cultural change programs as proposed by Schniederjans and Kim (2003) as the means to adjust the culture of an organization to one that is more receptive to changes.

CONCLUSION

From a comprehensive review of the literature on critical success factors of ERP implementation, Finney and Corbett (2007) identified a major gap in the literature, which is the lack of research to examine ERP critical success factors from the perspectives of key stakeholders. Our study is one of the few that examine success of ERP implementation from the perspectives of key stakeholders by assessing business value derived from ERP implementation. In addition, this is one of the few studies that examine ERP implementation in developing nations. Despite these strengths, our study also has limitations.

One of the limitations of this study is its generalizability. The findings of this study may be limited to multinational corporations operating in Malaysia. Follow-up work is needed to assess if the results are applicable to corporations in other developing nations. Another limitation is that a wider range of CSFs was not included due to practical constraints such as time and cost. The survey questionnaire spans several pages, and we were concerned that adding more factors would increase its length to the point where reliability of the responses would be affected (due to respondents’ fatigue) or participation would be discouraged/avoided. Some key CSFs that were deemed important but were not included in this study are:

- Comprehensive business process re-engineering (BPR),
- Project championship,
- ERP customization, and
- Adequate training program.

ERP implementation is a challenging task due to its complexity and cost. This research provides further insights into the critical success factors of ERP implementation, and presents some guidelines for organizations to focus their attention and resources in carrying out such implementations. This study has highlighted the significance of enterprise-wide communication and project management programs on ERP implementation success. It also reveals the importance and crucial role of organizational culture for ERP implementation success.

The findings of this study also suggest that the traditional views of change management are insufficient to influence success of ERP implementation. Businesses have to realize that their top managers, while functioning as leaders of the organization, are insufficient on their own to guarantee success. While continuous management support is required, more effort and focus on communication across the different functions and levels of the organization, management of the project, and the capability of the organization to learn are key considerations. In addition, due to the critical role of project management, it is recommended that businesses form a separate and formal project management team that works closely with the rest of the organization to manage both the implementation and the changes associated with the implementation.

Several studies have examined critical success factors across stages of ERP implementation (Holland & Light, 2001; Nah & Delgado, 2006; Somers & Nelson, 2001; Somers & Nelson, 2004). This is an important research direction, as it provides more specific guidelines on the key factors across the different stages of the implementation. However, since ERP implementation in most multinational companies is moving into the various stages of maintenance, it is also important to study and understand the various factors, issues, and activities in ERP maintenance to better utilize existing ERP resources and to further improve efficiency and effectiveness in organizations (Kang, 2007; Nah, Faja, & Cata, 2001). For example, data warehousing interoperability for extended enterprises (Triantafillakis, Kanellis, & Martakos, 2004) and challenges in upgrading ERP systems (Nah & Delgado, 2006) are also issues that warrant further research.

This study provides a unique view of multinationals operating in Malaysia's Free Trade Zone. It cautions us against assuming that best practices and success factors in developed nations will necessarily apply for developing nations. This is especially important for multinational companies intending to implement major changes to their operations in Malaysia or developing nations in the Southeast Asia. Accordingly, adapting to the ERP system environment can help to establish a win-win scenario for multinational companies, but management of the implementation is critical to achieve this goal.

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APPENDIX

Questionnaire: Success of ERP Implementation

A. Top Management Support

Please indicate the extent to which you agree with the following statements by marking an "X" against the appropriate scale shown.	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Sufficient incentive for ERP implementation was provided by top management.	☐	☐	☐	☐	☐
The ERP implementation is/was viewed as a strategic decision by (local) top management.	☐	☐	☐	☐	☐
There is/was sufficient top management commitment to this ERP implementation.	☐	☐	☐	☐	☐
The CEO, CIO, or COO is/was actively supporting this ERP implementation.	☐	☐	☐	☐	☐
The ERP implementation received explicit identification from (local) top management as a critical priority.	☐	☐	☐	☐	☐

B. Teamwork and Composition

Please indicate the extent to which you agree with the following statements by marking an "X" against the appropriate scale shown.	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
The people selected for ERP implementation teams had the best business and technical knowledge.	☐	☐	☐	☐	☐
A variety of cross-functional people were selected for the ERP implementation.	☐	☐	☐	☐	☐
Those selected for the ERP implementation were working on the project full-time as their only priority.	☐	☐	☐	☐	☐
Sufficient incentives or compensation were given to those selected for the ERP project.	☐	☐	☐	☐	☐
Those selected for the ERP project were relocated together.	☐	☐	☐	☐	☐

C. Enterprise-Wide Communication

Please indicate the extent to which you agree with the following statements by marking an "X" against the appropriate scale shown.	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
The project team or core design team was well-prepared to communicate effectively with the users.	☐	☐	☐	☐	☐
Persons involved in the ERP project clearly understood the goals/ objectives/purposes of the implementation.	☐	☐	☐	☐	☐
There were enough communication channels to inform the users of the stage of the ERP project and help users resolve problems.	☐	☐	☐	☐	☐
Enough reviews were conducted to ensure continued ERP end-user satisfaction.	☐	☐	☐	☐	☐
There were enough evaluations to assess the workings of the ERP system.	☐	☐	☐	☐	☐

D. Project Management Program

Please indicate the extent to which you agree with the following statements by marking an "X" against the appropriate scale shown.	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
During the ERP implementation, milestones were set with measurable results.	☐	☐	☐	☐	☐
There was commitment to promote and manage the ERP implementation project.	☐	☐	☐	☐	☐
Regular communication of expectation and challenges, education, training, and support were provided during the ERP implementation.	☐	☐	☐	☐	☐
Task assignments were well-defined during the ERP implementation.	☐	☐	☐	☐	☐
Customization of the ERP system was well-managed by the business team.	☐	☐	☐	☐	☐

E. Organizational Culture

Please indicate the extent to which you agree with the following statements by marking an "X" against the appropriate scale shown.	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
In my organization . . .					
Employees are supportive and helpful.	☐	☐	☐	☐	☐
Adequate organizational resources are available to the employees.	☐	☐	☐	☐	☐
There is willingness to collaborate across organizational units.	☐	☐	☐	☐	☐
Employees are encouraged or rewarded by their superiors to express and exchange their opinions and ideas regarding work.	☐	☐	☐	☐	☐
Opportunities are provided for individual development, other than formal training (e.g., work assignments and job rotation).	☐	☐	☐	☐	☐
Employees are encouraged to analyze mistakes that have been made and learn from them.	☐	☐	☐	☐	☐

F. ERP Implementation Success

Please compare the following statements to the situation before ERP/MRPII/MRP implementation and indicate the extent to which you agree with the statements by marking an "X" against the appropriate scale shown.	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
There is a reduction in informal systems for either materials management, inventory, or production control.	☐	☐	☐	☐	☐
Capacity planning, cost estimation, and inventory control has improved.	☐	☐	☐	☐	☐
Cooperation between finance, marketing, production, engineering, and sales have improved.	☐	☐	☐	☐	☐
Employee job satisfaction and morale has improved.	☐	☐	☐	☐	☐
There is a reduced need for "expediting" business requirements such as customer orders.	☐	☐	☐	☐	☐

G. Demographics

Your job position in your company:	Managerial	☐
	Non-managerial	☐
	Other. Please specify	☐
How long have you been in your company:	< 1 year	☐
	1-5 years	☐
	6-10 years	☐
	> 10 years	☐
Your education level:	PhD	☐
	Masters	☐
	Bachelors	☐
	Diploma	☐
	Others. Please specify	☐
Organizational annual revenue:	< USD 1.0m	☐
	USD 1.0-4.0m	☐
	> USD 4.0m	☐
Number of employees at your site:	<100	☐
	101-1000	☐
	1001-3000	☐
	3001-5000	☐
	>5000	☐
Gender:	Male	☐
	Female	☐
Thank you very much for spending your time to participate in this questionnaire. Your inputs are of tremendous importance to my research. Any constructive feedback would be very much appreciated.	☐	

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Chapter 7.12

Federated Enterprise Resource Planning Systems

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ABSTRACT

Enterprise resource planning (ERP) systems consist of many software components, which provide specific functionality. As ERP systems become more complex, the financial expenditures that are associated with the application of such systems dramatically increase. Furthermore, ERP system development of nowadays is product-oriented and coordinated by only one instance at any one time. Consequently, each product has a separate data model, which is the basis for the integration of various types of business applications. Based on this fact, the selection of the covered functional enterprise sectors as well as the implemented functions is controlled by the respective vendor, too. Thus, enhancements and modifications of the standard software product are incumbent upon the software vendors. A cross-vendor standardization of data models for ERP systems and the establishment of unified architectural model, however, would change this situation. The new idea is to develop a novel ERP system architecture, which facilitates an overall reusability of individual business components (BC) through a shared and non-monolithic architecture based on Web services. The presented approach uses Web services to wrap up ERP components that are provided within a distributed system, which appears as an ERP community and serves as a vendor-independent platform.

INTRODUCTION

Since the advent of Web services during the last years, software components can be easily distributed and remotely accessed. These components become small services, which provide clients with specific functions. These can be invoked using standardized protocols like simple object access protocol (SOAP) (Gudgin, Hadley, Mendelsohn, Moreau, & Nielsen, 2003). The goal is to create an infrastructure allowing business applications to seamlessly discover and use Web services. This will hopefully make the integration of different applications and the development of distributed applications easier. This kind of architecture, called service oriented architecture (SOA), provides a transparent environment in which applications can be composed out of services.

Some hopes and visions are associated with SOA, for example, enterprise application integration (EAI) strives to seamlessly connect different systems in an enterprise mainly by utilizing Web service standards. While EAI has become an objective for larger enterprises due to the huge number of deployed systems, small- and medium-sized enterprises (SME) still struggle to support business processes using integrated IT systems. SMEs compete against larger corporations utilizing their flexibility and their ability to innovate. In order to compete better, these SMEs need to deploy ERP systems to support their business processes. But to stay as flexible and competitive as today, SMEs have to customize their ERP system each time the business processes change. However, ERP systems are complex and their customization as well as maintenance is costly. Therefore, investments into large and powerful ERP systems often do not pay off financially for SMEs who do not have the necessary financial resources to deploy and maintain such systems at all.

Two approaches try to fill this gap: Cheaper ERP systems with less functionality have been offered and the concept of application service providing (ASP) has emerged. However, both solutions have their drawbacks. ERP systems offering less functionality do not realize all possible opportunities and do not address maintenance costs. Even worse, ASP (i.e., the operation of systems by a third party in an external data-center) has been rejected by the market because enterprises are not willing to store their valuable data externally and the distribution of responsibilities creates management problems (Walsh, 2003). Our aim is therefore a solution, which combines local data management with reduced costs and flexible support for changing and optimizing business processes.

The result is an ERP system whose logic is completely composed of Web services called federated ERP (FERP). The Web services are dynamically arranged to support the company's business processes (Krüger, Marx Gómez, Rautenstrauch, & Lübke, 2004). Such an ERP system has the advantage of storing all relevant data in-house as well as being extensible by integrating as many Web services as required for realizing the desired functionality. For implementing these ideas, some challenges have to be overcome. In course of this chapter, we will focus on the following problems:

- Management of user interfaces in highly dynamic, model-driven environments.
- Server-side data-management.
- Organization and standardization of Web services for the envisioned FERP system.
- Security considerations.

This chapter is structured as follows: Within the next section, we present background information and definitions of the most important terms. In the third section, we discuss the four main points as previously presented. The open research questions and future problems are presented in the fourth section. Finally, a conclusion is given.

BACKGROUND

An ERP system is a highly integrated software system representing different types of business application systems. In the majority of cases, there is a smooth transition between these system parts whereby it is almost impossible to locate isolated components. In fact, ERP vendors provide packages of business functions, which can be associated to different enterprise sectors. These functions are interwoven, which means that a function can invoke another function without a central control instance. This characteristic causes the problem that it is difficult to isolate a group of functions as a discrete component. With the intention of a sustainable reusability of discrete software components, ERP vendors started redesigning their products step by step. The main objective is to achieve a component-oriented software design. One example for this phenomenon is the company SAP®AG with their ERP system SAP®/R3™. Earlier versions of this product appeared as a monolithic solution. With the BAPI technology (business application programming interface) (see SAP Library, 2005), it is now possible to encapsulate single business functions in business objects. Furthermore, there is the possibility to remotely access these business objects or to recombine them within business workflows.

This chapter introduces the conceptual foundation of FERP systems and shows how a component-oriented ERP solution is transferred to a Web service-based FERP system. The visionary development process of such a system is supposed to be pushed by a community of ERP software vendors whereby the degree of implementation varies according to the different entrepreneurial motives of different developers.

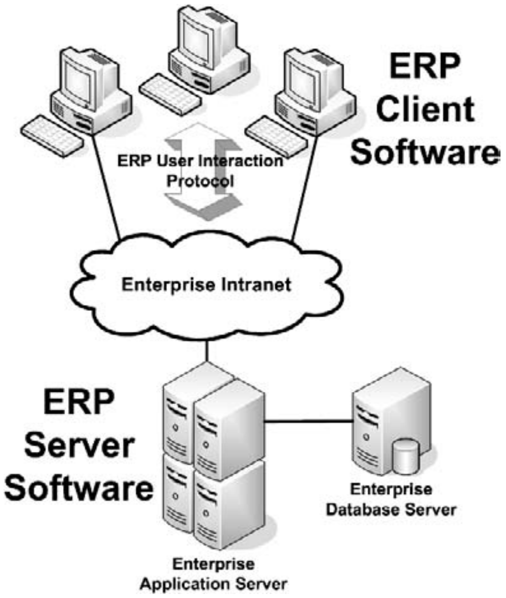
Definition 1

An *ERP system* is a standard software system, which provides functionality to integrate and automate the business practices associated with the operations or production aspects of a company. The integration is based on a common data model for all system components and extents to more than one enterprise sectors (see Rautenstrauch & Schulze, 2003; Robey, Ross, & Boudreau, 2002).

Conventional ERP architectures are based on n-tier models including presentation tier, potentially different application tiers, and a database tier. The functional software components of ERP systems are administered on a central application server, which is responsible for the coordination of interactions with end users, for the execution of business logic, and for the communication with the enterprise database server. The communication between the application server and GUI clients can be either based on standard protocols like HTTP or proprietary protocols like the DIAG protocol, which was developed by SAP® in order to exchange requests and responses between SAP®GUI and SAP®R3 servers or in later versions SAP® enterprise central component servers, which act as applications servers in this context. In cases where different application servers have to be interconnected (e.g., in order to invoke remote functions calls), protocols like RFC or also HTTP are used. Figure 1 shows the architecture of today's ERP systems.

ERP system development of nowadays is product-oriented and coordinated by only one instance at any one time. Consequently, each product has a separate data model, which is the basis for the integration of various types of business applications. Based on this fact, the selection of the covered functional enterprise sectors as well as the implemented functions is controlled by the respective vendor, too. Thus, enhancements and modifications of the standard software product are incumbent upon the software vendors. Various managerial motives (e.g., actual situation of the company, missing know-how, strategic objectives, or inadequate empathy for cooperation) are the deciding factors for the mostly compromise-driven orchestration of ERP system components.

Figure 1. Conventional ERP system architecture



A cross-vendor standardization of a data model for ERP systems and the establishment of unified architectural model, however, would change this situation. Thus in theory a cross-vendor composition of ERP functions becomes possible whereas the coordination of this process is individual and vendor-independent.

Definition 2
A *federated ERP system* (FERP system) is an ERP system that consists of system components that are distributed within a computer network. The overall functionality is provided by an ensemble of allied network nodes that all together appear as a single ERP system to the user. Different ERP system components can be developed by different vendors.

Definition 3
An *ERP system component* in this case is a reusable, closed, and marketable software module, which provides services over a well-defined interface. These components can be combined with other components in a not foreseeable manner (see Turowski, 2003, p. 19).

Figure 2 shows the two approaches in comparison to each other. The left hand side represents the architecture of a conventional ERP system where a closed amount of ERP components (C1, C2, …, C6) are installed on the same application server and were developed by the same software vendor. The right hand side shows an open ERP network where each node is assigned to one ERP component, which is provided as service (S1, S2, …, Sn). This network consists of allied network nodes that all together represent a federated ERP system. New components are added as new network nodes that provide corresponding services.

The main disadvantages of conventional ERP systems are that in most cases, not all of the installed components are needed, high-end computer hardware is required, and that the customizing of such systems is very expensive because product specific know-how of experts is necessary. Due to the expensive proceedings of installation and maintenance, only large enterprises can afford complex ERP systems, which provide business logic of all sectors of the functional enterprise organisation. Contrary to these aspects, FERP systems allow the separation of local and remote functions whereby no local resources are wasted for unnecessary components. Furthermore, single components are executable on small computers and due to decreasing complexity of the local system also installation and maintenance costs subside. Figure 3 shows how the ERP system is supplied by a network of FERP business logic components, which provide all potentially needed business functions.

ARCHITECTURE OF FEDERATED ERP SYSTEMS

Overview

The federated ERP-system as presented in the second section is a distributed system composed of

Figure 2. Conventional ERP system with ERP components (C1-C6) vs. a federated ERP system that provides its ERP components as services (S1-Sn)

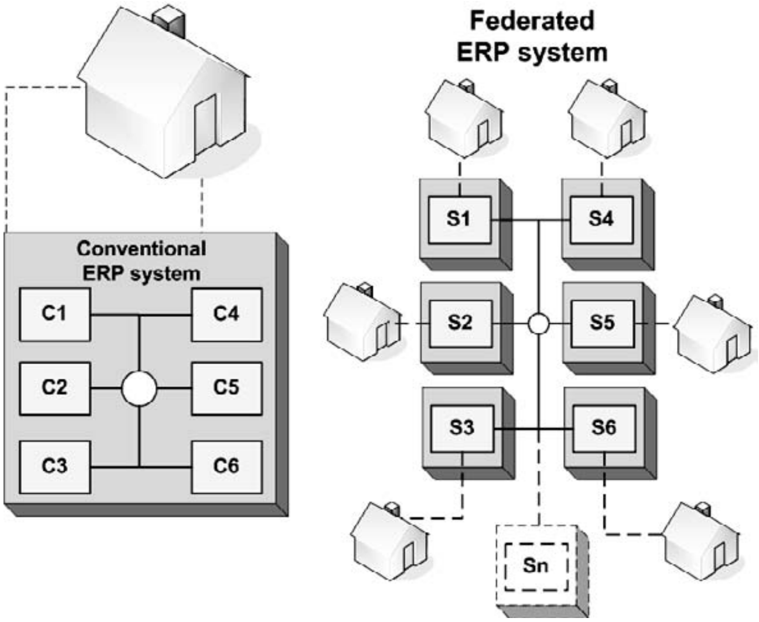
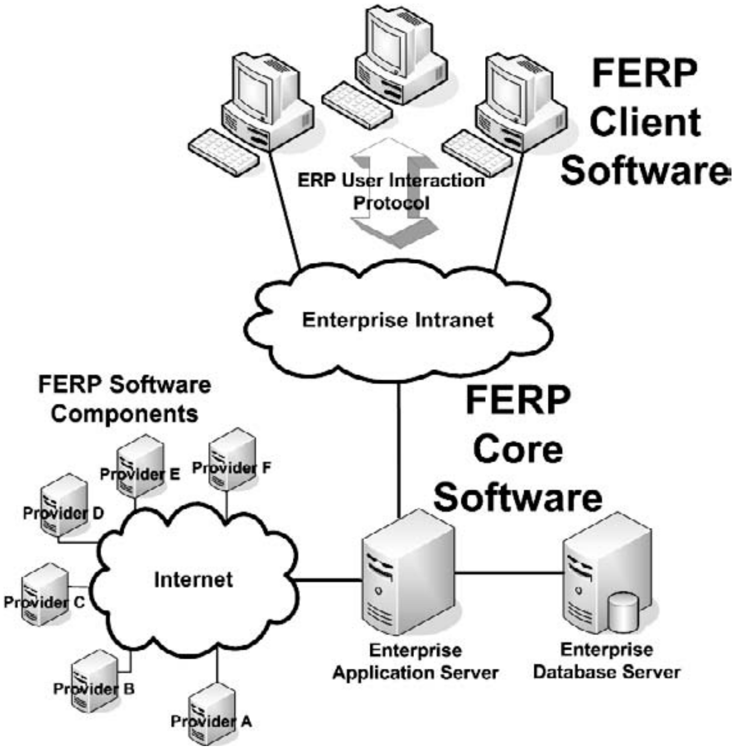


Figure 3. Vision of a federated ERP system landscape where ERP software components can be developed and provided by different software vendors



Web services. Therefore, the underlying architecture needs to fulfill the following requirements:

- Integrate the Web services to provide the needed functionality.
- Execute and control the workflow.
- Manage data access and storage.
- Authenticate and authorize users.
- Provide usable interfaces to the users.

For minimizing customization effort and reduction costs for changing business processes, the following non-functional requirements hold:

- Changes in business processes should be easy to introduce into the system.
- Changes in the federated ERP-system should be easy to incorporate.
- Changes in the federated ERP-system should require minimal software distribution effort for changes.

Requirements were grouped and assigned to layers resulting in a three-tier system design (see Figure 4):

1. Web services are the standard logic components of the system and the set of all Web services forms the first layer.
2. The Web service orchestration and business process layer is in charge of managing the data and control flow of the application through the business processes.
3. The presentation layer generates user interface descriptions for interactive steps in the business processes.

We decided to use an application server infrastructure in order to be able to centralize many tasks. Thus, many updates need only be done on the application server and do not affect clients. For our prototype implementation, we used the J2EE platform represented by a Tomcat Web container and the AXIS Web services framework. The clients were implemented in Java Swing.

For better explanation of the concepts, we will use the same example process throughout the next sections (the process is taken from Lübke, Lüecke, Schneider, & Marx Gómez, 2006). The example is a simple process of an order acceptance. The profit margin of an incoming order is checked. If the profit margin has been breached, a manager must decide if the order is accepted or not. For example, some orders of important clients can be seen as advertising and therefore, need to make not as much profit as orders normally would do. If the order is accepted, it is forwarded to production. The whole process is illustrated as an event-driven process chain (EPC) in Figure 5. EPCs consist of so-called events symbolizing the state of an organization and functions representing actions taken within the process. A function is triggered by a certain state and results in a new state. A whole process is triggered by events as well and results in a changed overall system. Therefore, an EPC is roughly an alternating event-function sequence starting and finishing with an event. To control the execution of process connectors can be added for splitting and joining the control flow as illustrated in the example process. EPCs are used for modeling all business processes in the Federated-ERP project and are stored at the application server in EPML (Mendling & Nüttgens, 2005).

User Interface Generation

Every ERP system needs to be operated by users. In the end, they need to make decisions, retrieve data, or enter new records. While classical ERP

Figure 4. Layers of a federated-ERP system

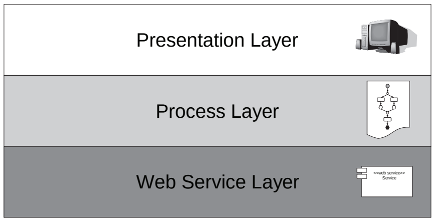
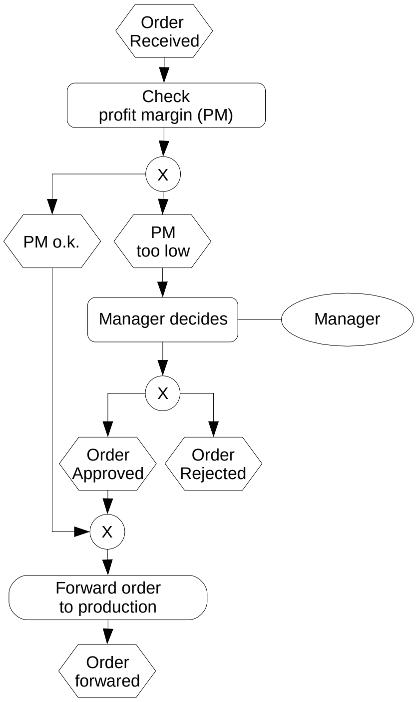


Figure 5. Example order process



systems offer clients for personal computers only, now mobile devices, like handhelds and mobile phones, are emerging. Because of this situation, the federated ERP system will face many types of clients. Furthermore, these clients need to be easily updatable. For a simple process change, it is not feasible to update hundreds of possibly mobile or distributed computers. Thus, the user interface must be managed on the server-side and must be platform-neutral.

Our approach for minimizing the effort needed to develop and customize the user interface is to automatically generate the interfaces from the business process descriptions. Much research has been done in the field of model-based user interface (MB-UI), which aims to model user interfaces in the way program logic is modeled in UML. Research in these fields has been going on for more than a decade. For example, Paterno (1999) gives an overview over of the field of MB-UI. Numerous design environments have been proposed as result of MB-UI. Each differs in the number and type of models used (for a thorough overview the reader is referred to da Silva (2002). However, most approaches share a common element: the task model. Fortunately, this task model is easily related to our approach. The business process model is in fact a task model on a very high abstraction level (see Trætteberg, 1999). Furthermore, the field of MB-UI has matured; especially insight into reasons for failure of some approaches has been beneficial for our research. Common mistakes and problems concerning practical adoption of MB-UI techniques are listed by Trætteberg, Molina, & Nunes, 2004): The biggest problem has been the complexity of the introduced models. While complex and detailed models give the designer the best level of control, such models are difficult to learn, time-consuming to design, and hard to maintain. Therefore, our approach particularly strives to reduce the inherent complexity. This is especially important for being useful for the targeted, non-expert audience.

Because we assume the business process to be already modeled, the user interface is expressed by stereotyping business functions. Four stereotypes have been introduced:

- **Selection:** The user shall select data from a collection of possible choices. For example, select product from a catalogue.
- **Edit:** The user shall edit some information object from the data model. For example, edit order.
- **Control:** The user wants to explicitly invoke some action. This is used to model navigational decisions. For example, “Accept order.”
- **User:** The user has to do something by himself (e.g., planning, comparing, etc.).

These four actions can be attached to a business function and are visualized by small icons on the left-hand side of the function. The annotated business processes are downloaded by the client software, which generates user interfaces from these models and sends the data and user decisions back to the server. This way, the user interface can simply be edited by installing new business process models on the server. For generating the user interfaces, the data types are used to create matching editors: Because Web services are based on XML, the data types are represented by XML Schema definitions. XML schema recursively defines data types: Primitive types can be grouped to complex types. Complex and primitive types can be grouped to new complex types and so on. Editors are created by traversing this tree-structure and look for matching editors registered in the system. At least for each primitive type, like integers and strings, an editor is provided by the system. Therefore, a (possibly primitive) editor can be generated for each XML Schema. Figure 6 shows a simple generated editor for a customer record.

Figure 7 shows the hierarchical refinement of the example process with user interface stereotypes and the resulting user interface using a custom editor. The client application shows the processes needing further action by the user and the processes, which are currently executed by someone else. This information is given on the right hand side.

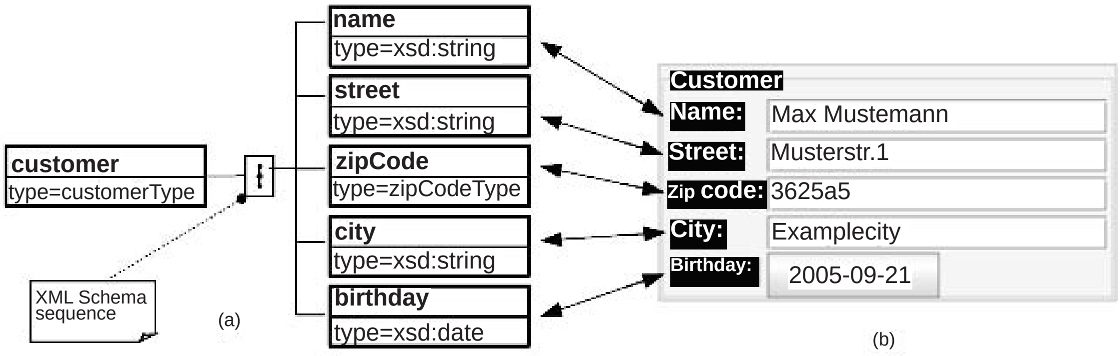
Since the user interface generation is based on the business process description, context information can be given to the user. For example, descriptions of the currently active business function can be displayed. In our prototype, these are realized by giving tool-tip information. At this point, it is even possible to integrate experience bases to facilitate the communication between developers, process designers, and end users.

Since this approach is based on the process description only, it is possible to generate user interfaces for different target platforms. For example, a connector for XForms—an XML standard for describing input forms—is under development and generation of HTML pages is possible as well for integration into intranet and portal applications. For further discussion on the topic of generation of user interfaces from EPC models see Lüecke (2005) and Lübke et al. (2006).

Server-Side Data Management

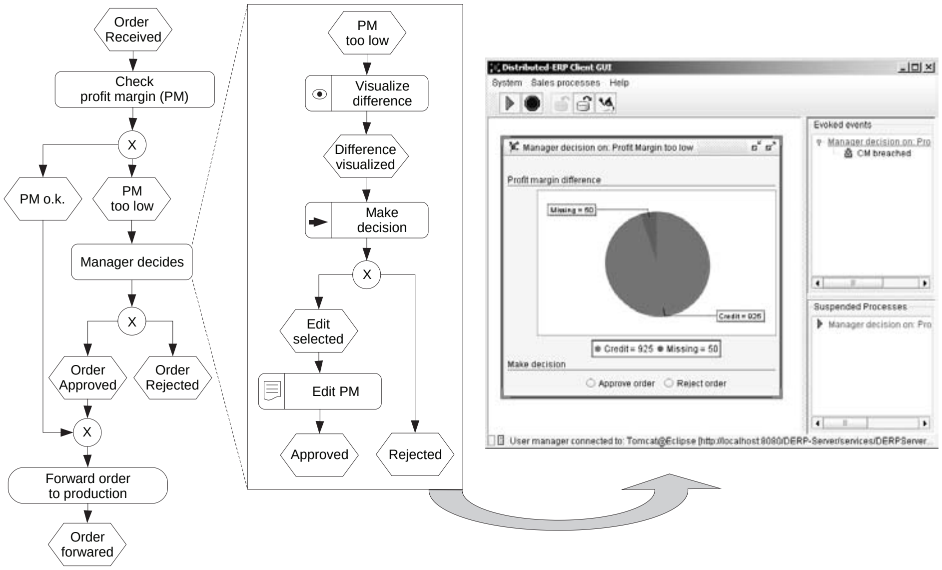
When executing a process model, which can not only include user interfaces but also Web service calls, corresponding data in terms of business objects needs to be managed. If a process shall be started, the application server creates a new process instance. The instance represents a running process including its whole state. The state is comprised of the data objects currently in use and the statistics which business functions have already been executed in order to evaluate the joins in the control flow. The data management currently follows the blackboard approach as presented by Alonso, Casati, Kuno, and Machi-

Figure 6. Generation of a simple user interface for a customer record



Name: Max Mustemann
Street: Musterstr.1
Zip code: 3625a5
City: Examplecity
Birthday: 2005-09-21

Figure 7. Refinement of the business process and user interface generation



User manager connected to: Tomcat@Eclipse [http://localhost:8080/DERP-Server/services/DERPServer...

raju (2004). All process instance data is stored as XML at the process' instance. The advantages of the deep usage of XML are:

- Consistent use of XML between the whole platform.
- Efficiency during development because powerful XML technologies like XPath and XSLT are available.
- Easy user interface generation through XML schema.

Using XML throughout the application has the advantage that Web services' parameters can be simply extracted from the blackboard by use of XSLT. The Web services' output can be stored after XSLT transformations to the native XML Schema, too. The application server needs to offer local services for data management. The business processes need to be able to store and retrieve persistent data. The corresponding functionality is offered by the means of services. Data objects referenced by XPath expressions can be used from the business processes. The application server must retrieve the matching business objects from the database and save any changes made.

However, some disadvantages are also connected to this approach:

- XML processing is not efficient. Using plain objects would increase performance.
- If non-XML technologies are to be used like relational database systems or CORBA services instead of Web services, the XML data need to be transformed, which is an expensive operation.
- The XML data format is very space-consuming hindering replication within cluster environments.

These weaknesses can be addressed by building scalable applications, which can be distributed to many servers in order to improve performance. To overcome the third disadvantage, "sticky sessions" can be used in which a process instance is always run on the same server. Thus, replication is minimized.

Organization and Standardization of Web Services

Starting from the syntactical standardization approach of FERP systems as proposed in Brehm & Marx Gómez, 2005), it is possible to define dependencies between the different operations of FERP Web services. This structure is based on the preliminary idea that FERP Web services are classified according to the enterprise sector which their offered operations belong to. The basis of the FERP Web service specification model is the summarization of all functions (Web service operations) that belong to the same sector of the functional business organization. Functions of the same sector are assigned to the same FERP Web service. In this first proposal, we classify the following Web service types in the context of FERP systems whereas we have to mention that this classification is incomplete and only serves as an example:

- Production planning and controlling.
- Accounting.
- Logistics.
- Sales and distribution.
- Materials management.
- Quality management.
- Project management.
- Human resource management.

According to a literature review in the area of component standardization models as Turowski (2003) described, the standardization of FERP Web services must include the following levels:

- Syntactic level
- Behavioral level
- Synchronization level
- Quality-of-service level

Figure 8 shows an uncompleted example syntactic specification of a production planning and controlling (PP) Web service as presented in Brehm et al. (2005). Based on the specification of data types (e.g., BOM, work plan, operation, etc.), message types are specified. These message types are used to describe the functions of the PP Web service. Out of this functionality specification, different Web services can be derived, which implement the overall component functionality in a different completeness. The Web service descriptions are expressed in the Web service description language (WSDL).

Semantic Web services are Web services whose properties, capabilities, interfaces, and effects are encoded in an unambiguous, machine-understandable form (see McIlraith, Son, & Zeng, 2001). Research works that deal with semantic Web services aim at the provision of a comprehensive Web service description, discovery, and mediation framework. Because UDDI, WSDL, and SOAP are not sufficient, other specification languages like Web ontology language (OWL) (see W3C, 2004) and the resource description framework (RDF) (see W3C, 2004a) are used. This approach is more abstract then the presented proposal because the efforts within the scope of semantic Web services do not concentrate on a specific type of Web service. The shown proposal is based on XML schema to define a fixed language for ERP systems as basis for the communication between software components of a distributed application.

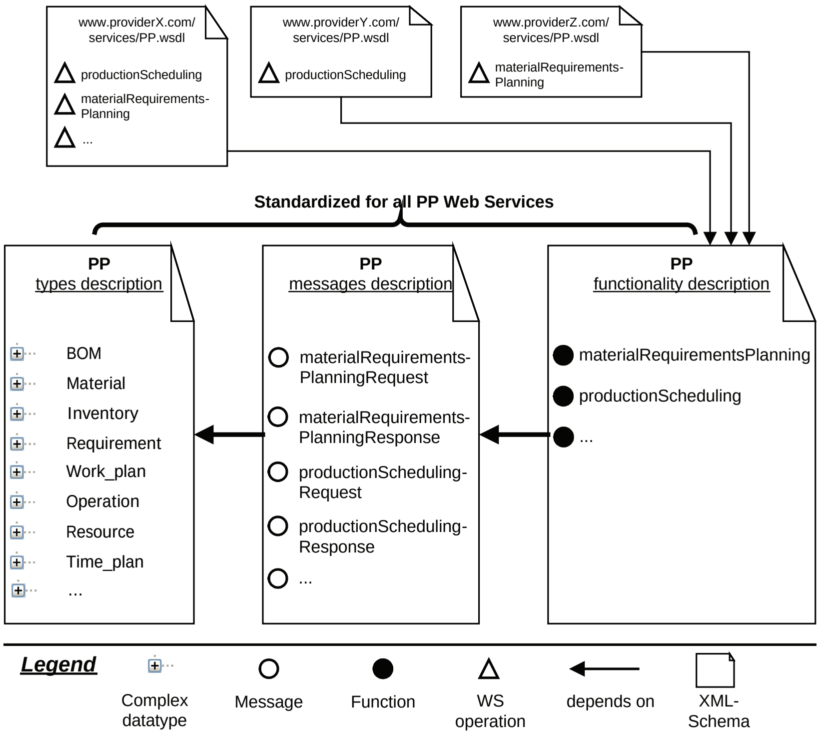
Security Considerations

Security Model and Requirements

In connection with the common use of distributed applications, several *security problems* exist. The most important security objectives in the case of distributed ERP systems are:

- *Confidentiality* of transmitted data.
- *Integrity* of transmitted data.
- *Authenticity* of communication partners.
- *Availability* of data and functionality.

Figure 8. Uncompleted example FERP Web service specification and three possible Web service descriptions (see Brehm et al., 2005)



- *Anonymity* of communication partners against unauthorized parties.
- *Non-repudiation* of transactions.
- *Reliability* (trustability) of communication partners.

Constructing a security layer and involving it into the already existing architecture, attention should be paid to the different specifications of individual security requirements of different companies. Within the shown context of a shared ERP system, those requirements commonly correspond to message integrity, authenticity, and data confidentiality of all interface calls and responses and thus, of the whole network traffic. As these strategic security objectives differ from each utilizing enterprise to another, it is essential that the security model is open for virtually all security mechanisms and standards, which allows the processing of generic definitions of security policies. Referring to the existing security mechanisms, security policies describe the concrete security requirements of the appropriate network node including the respective configuration parameters. Based on this approach, a suitable policy processor is able to audit all incoming messages for security conformance on the enterprises security policy and to extend all outgoing messages according to the security policy of the remote network node, which is commonly the service provider as proposed by Brehm, Marx Gómez, and Rautenstrauch, 2005b). Attributes of such security policies can partly be modeled directly in the EPCs. Functions in EPCs can be assigned to security mechanisms like encryption or decryption algorithms or user roles (e.g., the manager role in Figure 5).

Local and Remote Security

Within the context of FERP systems, local and remote security considerations have to be differentiated. Concerning this matter, the primary tasks of the FERP system core component, which is installed on the application server of an enterprise, can be split into responsibilities regarding access control and the assurance of confidentiality. Local access control mechanisms use role-based authentication and authorization models (e.g., passwords or public key infrastructure (PKI) elements like certificates) as to authenticate local users and to permit or deny their requests accordingly. Therefore, the system is equipped with a user management module, which maps possible activities to user permissions. A typical requirement in this case is that only users in the corresponding role can invoke a function or may access the corresponding user interface. However, in some situations the roles must be fine-grained. For example, it may be necessary to have a special manager who has to approve the order. In our example, it may be necessary that the manager of the customer's consultant must approve the order. For realizing this functionality, conditions can be appended to the roles: These conditions can access the process' instance data. In this case, the order is assigned to a customer who is assigned to his consultant. Therefore, the manager role can have the restriction of being accessible only to the consultant's manager. This security information can be used during run-time to control the access to ERP functionality.

Contrary to conventional ERP systems, FERP systems have to access functions of potentially not well-known component providers whereas the authentication of these providers and the establishment of a secure communication channel are not sufficient. Following the vision of a flexible and open FERP network where FERP component vendors can provide their functionality to all participating network nodes as straight forward as possible, it is not practicable to establish trust relationships, which are exclusively based on directly applied human intelligence (e.g., by persons who are talking to each other). This aspect is still unsolved and shows a frequently discussed research question. A number of trust models as for instance centralized rating systems as applied in *Ebay* and *Amazon* auctions or social network analysis techniques (e.g., Friend of a Friend (FOAF) networks) have been developed in e-commerce, e-business, security, and multi-agent systems, which have to be investigated according to their practicability in future research work.

FUTURE TRENDS AND RESEARCH

Many options concerning process modeling and service composition have to be researched. While SOA promises to better integrate software with its underlying processes, the models are still not integrated well nor even are unified. Our approach so far has been to simply use and extend EPCs, which are a business process modeling language. However, they are not as powerful as some workflow languages. If in practice, these additional abilities of workflow languages like Petri nets are needed, much research has to be done how to synchronize between different models. Business models are an important part of the software requirements and therefore often need to be traced forward and backward during the development. If EPCs cannot be used everywhere, a mapping between EPCs and the workflow language used needs to be established. However, tracing problems still arise if only using EPCs; Software requirements are more than business processes. For example, use cases are a very beneficial way of documenting software requirements. These need to be linked to the processes. The same holds true for test cases, which are based on requirements and the executable processes.

On the technical side, the internal modeling and mapping between business objects and their external representation in XML can be improved.

While the deep use of XML and the blackboard approach is sufficient for use within our prototype, this approach is not well suited for productive use. XML processing is very slow in contrast to the use of native objects like Java Beans. Furthermore, other types of services like those offered by Enterprise Java Beans via RMI and CORBA cannot be called with XML data. However, the migration to an object-oriented approach for data management results in the need for converting huge amounts of data from and to XML. Furthermore, the use of practical techniques like XPath has to be emulated. The system's user interface part can be extended with modules for generating interfaces for mobile devices and Web applications. The necessary infrastructure is already existent making these tasks easy to solve.

Chances, Problems, and Risks

The difficulties of the application of conventional ERP systems are based on the complexity of the currently available products. The ERP market offers small, medium, and large ERP systems, which can be classified by the amount of covered enterprise sectors and the amount of included functions. Starting from the general statement that small- and medium-sized enterprises (SME) have almost the same functional ERP system requirements like large enterprises have, a dilemma opens up. Because SME cannot afford large ERP systems such as SAP®R3, Oracle®E-Business Suite, or SSA®Baan ERP 5, choices are based on compromise-driven decisions. Contrary to conventional ERP systems, FERP systems feature the following advantages, which aim at the solution of these problems:

- Due to the provision of isolated components, it is possible to charge the utilizing enterprises according to their needs and by this to decrease the overall ERP system application costs.
- Enterprises do not have to run high-end hardware in order to meet the requirements related to the application of complex ERP systems. Hardware can be made available by service providers.
- ERP service providers only have to make a part of the total system available, which reduces their time to market and their financial investment.
- A distributed system architecture is more scalable then a monolithic system.
- Distributed systems may be more reliable then monolithic systems. If one service goes down, then other services might continue to work. Moreover, it might be possible to replace the service with another one.

Beside this advantages various disadvantages, problems, and risks exist:

- Security considerations play an important role when a public network is used as communication basis. Particularly confidentiality of enterprise data is a critical aspect, which has to be considered in this context. Furthermore, a distributed access control model has to be developed in order to ensure the protection of local and remote resources, which means that only authorized users are permitted to access these resources. A federated identity management provides a solution of this problem (see Siddharth et al., 2003).
- The relationships between the different participating parties are based on different trust levels. Trust not only refers to misuse aspects but also the professional correctness of the provided functionality has to be secured. This was already discussed in Brehm and Marx Gómez (2005a), but trust measurement techniques deserve closer attention in this case.

- Performance problems will arise because the volume of data to be submitted is going to be immense in many cases (e.g., a large number of input and output data has to be exchanged between accounting-service consumer and service provider in order to calculate an actual target report).

Data models, interfaces, and architectural components have to be standardized in order to make FERP services interoperable. A solution for this problem was already previously shown and proposed in Brehm et al. (2005).

CONCLUSION

Comparing distributed ERP systems and ERP systems running on only one computer, distributed systems offer a lot of advantages. However, the design and development of such architectures are subject to a number of problems. The chapter presents a basis for the introduction of FERP Web services and discusses the pros and cons of an ERP solution as part of a service landscape where different vendors are appealed for the implementation and provision of ERP Web services in a federated manner. The proposed approach tunes in to the vision of a development process, which abstracts from concrete implementations. Nevertheless, there are a lot of open questions left which hinder machines to interact as providers of ERP software based on a process model even if ERP Web services act on standardized requirements. Because ERP systems process confidential enterprise data, security considerations play an important role when an open network like the internet is used. The future work must pick up these problems to realize the vision of a loosely coupled ERP system, which allows the combination of software components of different providers.

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Chapter 7.13

Integrated Product Life Cycle Management for Software:

CMMI[1], SPICE, and ISO/IEC 20000

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ABSTRACT

This chapter describes how models for software development and service delivery can be integrated into a common approach to reach an integrated product life cycle for software. The models covered by this chapter are the capability maturity model integration (CMMI), SPICE (software process improvement and capability determination, ISO 15504) and ISO 20000 (service management). Whilst the CMMI constellation approach delivers an integration perspective defined in three models (development, acquisition and services), SPICE and ISO 20000 need additional alignment to be usable in an integrated approach.

INTRODUCTION

The focus of the market for IT solutions has changed. Whilst many companies and organizations followed the latest "hype" several years ago, they now trust in reliable and sustainable solutions.

To ensure this, standardization of quality evaluation becomes more and more important. For supplier selection, make-or-buy decisions and outsourcing strategies, a powerful set of procedures, that can help to assess the capability of internal and external software processes, is required. These procedures have to be based on best practices and must be widely accepted.

On this basis, standards offer the best possibilities: they are usually defined by a wide group of experts, which all contribute their experiences and best practices. Standards are either sponsored by an industry or by national bodies—therefore making these standards de facto mandatory for an industry, nation, or combination of both enforces the acceptance. If a significant group uses a standard, market dynamics have an additional impact. Official certificates, levels, and so forth can be and are used for marketing activities.

In the field of software related standards, lots of different standards have been defined for special topics, but one standard is still missing: a standard that covers a software product from the very beginning—the first idea—up to the very end—the retirement of the software.

On the one hand powerful standards, for example the capability maturity model integration (CMMI) or SPICE (ISO 15504), have been defined for software development. On the other hand, standards for service delivery, for example ITIL or ISO 20000, have been well established; but there is still a wall between the worlds of software development and service delivery. Even though some standards – like SPICE – take a look over the wall, an integrated approach has not been delivered yet.

The need for this integration is obvious. A customer is not interested in having some quality for development and some other quality for service delivery—the customer needs one quality approach that covers the full life cycle of a software product.

BACKGROUND

The Wall Between Software Development and Service Delivery

When IT systems are planned, the focus of the planning is mostly restricted to software development. Topics like operation environment or data management are discussed, but the strategy usually ends with the delivery of the software product.

On the other hand, service-delivering organizations mostly just provide "services" and are not really interested in the software development process.

This behavior leads to multiple difficulties and inefficiencies:

- Software developers and service people do not understand each other. They work in different worlds and have their own "language" and processes.
- The efficiency and effectiveness of service delivery highly depends on the architecture of and assumptions for the software, therefore the service organization has to be integrated early into the software development.
- Service level agreements can be optimized, when both sides reach a common understanding. The development of service level agreements is often based on the "what we need" position of both sides and not on the "what will be best for the customer" position.
- Problem Management is not transparent to the customer. The customer is not interested whether he has a service problem or a software problem—the customer wants a quick and reliable solution. If the software side does not understand the service side, problems often become ping-pong balls.
- Software usually lives longer than the original developer intends. Systems often have to be enhanced just to fulfil the requirements of a new service platform. If this is not taken into account when the software is developed, the effort for updating software may become enormous. Sometimes software has to be retired, just because it is not executable on the new platform!
- New approaches like service oriented architectures (SOA) demand the high integration of software and service elements. Future trends will rather lead to small combined software/service environments than to big software solutions operated by massive computer environments.

Just to ensure that I am not misunderstood: software developing and service delivering organizations will still deliver and operate solutions with high quality—but the will not do it in the most efficient and effective way. Organizations and companies aiming for the delivery of sustainable and reliable solutions have to ensure, that the solutions are not only developed in the best way but will meet the requirements of the future efficiently, effectively and still with high quality.

Standards for Software Development and Service Delivery

Regarding software development, two standard are widely accepted all over the world: the Capability Maturity Model Integration, published by the Software Engineering Institute (SEI) at the Carnegie Mellon University, and SPICE (Software Process Improvement and Capability Determination), which is published as ISO standard 15504. Both standards define a process framework based on best practices and provide an assessment model to evaluate process capability.

A process reference model (PRM) and a process assessment model (PAM) usually characterize a process framework. The PRM defines processes that have shown evidence to support high quality for the defined domain – in our case software development. The PAM builds the basis for collecting evidence that the PRM is adhered to and to evaluate the capability of the processes defined in the PRM.

In the world of service delivery, ITIL (IT Infrastructure Library) is the most acknowledged standard. To make ITIL assessable, the ISO 20000 standard was developed.

But as it was said before, none of these standards cover the complete software life cycle. This gap is seen by the SEI and discussed by relevant contributors to the ISO standards. In this article two approaches for this integration are discussed—one based on the CMMI and the other based on the connection of SPICE and ISO 20000.

CMMI INTEGRATION PERSPECTIVE

CMMI is one of the best-established process frameworks for software development. Starting with the publication of Watts Humphreys book “Managing the Software Process” in 1989, the CMM and its successor—the CMMI—nearly became a synonym for process improvement in the software world.

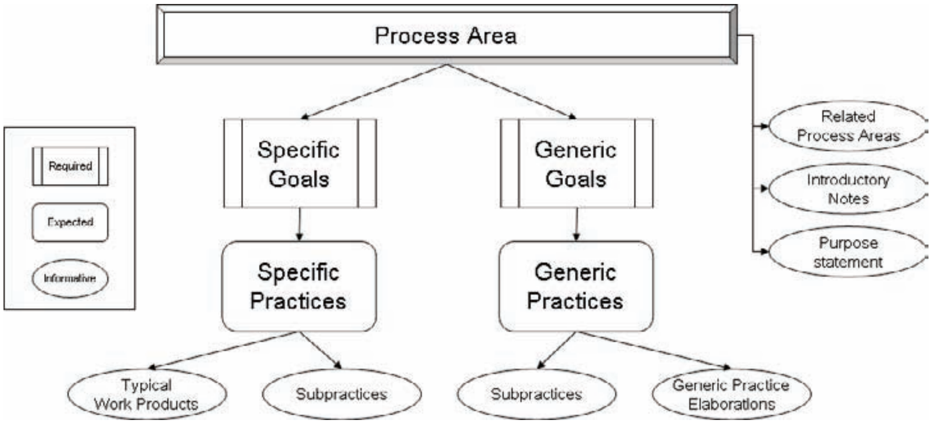
Nevertheless, until 2006, the CMMI was restricted on software and systems development. Since then a new initiative has been started to further develop the CMMI in the direction of acquisition and service processes. If one is talking about “CMMI” mostly the CMMI-DEV (for Development) is meant. This is the classical CMMI stream that covers service development. Other ideas concerning the usage and benefits of the CMMI for organizations that only acquire software, lead to the CMMI-ACQ (for Acquisition), which was published in November 2007. In 2006 and 2007 a CMMI for Services (CMM-SVC) has been developed to close the gap between software development and service delivery. The CMMI-SVC awaits publication in 2008.

CMMI Basics

Independent from the different CMMIs each of these models follows the same structure as shown in Figure 1.

In each CMMI a set of process areas is defined. For each process area the purpose is described, some introductory notes are given and other process areas which have a relation to this process area are listed. To satisfy the process area, goals must be fulfilled. Each process area has specific goals which are unique for this process area. Additional generic goals are defined, which are common for all process areas. For each goal a set of practices is defined, which are considered important for reaching the goal. For each practice subpractices, typical work products and elaborations are defined.

Figure 1. CMMI structure



From an evaluation perspective, only the goals are required. To reach a so-called "level" an organization has to fulfil the goals of the processes for this level. Nevertheless it is expected, that the defined practices are also fulfilled.

Process Capability vs. Organization Maturity

Talking about the CMMI always means talking about "level". But before the different levels can be explored, the different representations have to be discussed. CMMI knows two different representations, staged and continuous. In the staged representation each process area is assigned to a specified maturity level. To reach a maturity level, all specific goals of the assigned processes and a subset of generic goals have to be fulfilled.

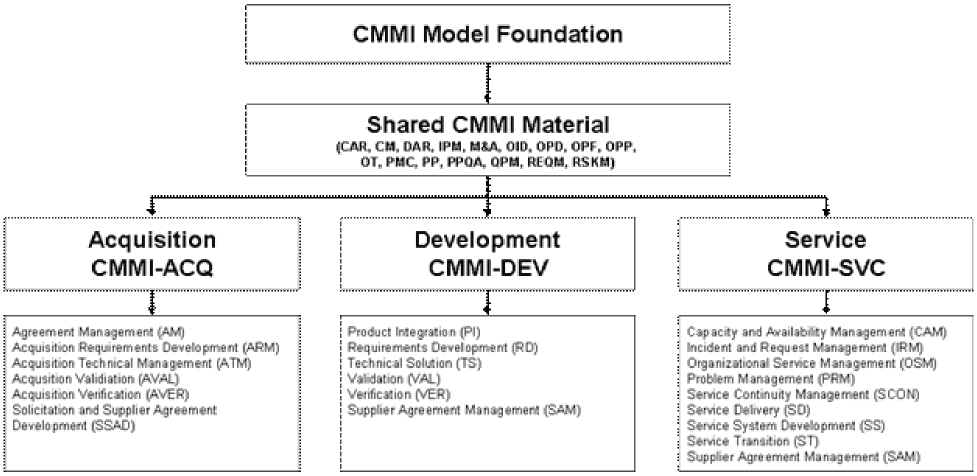
In the continuous representation, each process area is evaluated separately by fulfilling generic goals for this process area. Based on the set of generic goals that are fulfilled, the capability of the process area is measured.

In both representations, the generic goals have high importance. In total 5 generic goals are defined:

- **GG1:** The process supports and enables achievement of the specific goals of the process area by transforming identifiable input work products to produce identifiable output work products[2].
- **GG2:** The process is institutionalized as a managed process.
- **GG3:** The process is institutionalized as a defined process.
- **GG4:** The process is institutionalized as a quantitatively managed process.
- **GG5:** The process is institutionalized as an optimizing process.

In the staged representation 5 levels are defined. The lowest level is level 1, which means that the processes of the organization are still overwhelmingly chaotic. Goals for process maturity start with the definition of maturity level 2. For this level the specific goals of the assigned process areas and generic goal 2 have to be satisfied. For maturity level 3 the specific goals of the process areas assigned to level 2, the specific goals of the process areas assigned to level 3 and the generic goals 2 and 3 have to be satisfied. For level 4 and 5 specific goals of other process areas are added, but even for these higher levels, only generic goal 2 and 3 have to be satisfied.

Figure 2. CMMI constellation approach



In the continuous representation, 6 levels are defined, starting with level 0 and ending with level 5. Remembering, that a capability level is evaluated for each process area, the level is given by the fulfilment of the generic goals. On level 0 no generic goal is satisfied. On level 1, GG1 has to be satisfied, on level 2 GG1 and GG2 have to be satisfied and so on.

As this article is focused on the integration of activities and not mainly on evaluation issues, we will restrict the following chapters to the parts specific to certain process areas. For more information on the generic parts and evaluation procedures the CMMI itself should be used (Software Engineering Institute, 2006a).

The Constellation Approach

As said before, there is not the "one" CMMI. The idea of the current CMMI version is to have different constellations which share some process areas that are common for all constellations and have additional process areas that are unique for the constellation.

Currently, three constellations are published or planned to be published in 2007:

- **CMMI-DEV:** For development (June 2006) (Software Engineering Institute, 2006-1)
- **CMMI-ACQ:** For acquisition (November 2007) (Software Engineering Institute, 2007)
- **CMMI-SCV:** For services (2008, initial draft September 2006) (Software Engineering Institute, 2006b)

These constellations only differ in the number and content of process areas. All other contents of the CMMI, for example generic elements, level definitions, typographical conventions, build the model's foundation and are identical for all constellations.

In a first overview the constellation approach can be structured as shown in Figure 2.

The purposes of all process areas are explained in the next chapter.

Shared Process Areas

Causal Analysis and Resolution

The purpose of causal analysis and resolution (CAR) is to identify causes of defects and other problems and take action to prevent them from occurring in the future.

Configuration Management

The purpose of configuration management (CM) is to establish and maintain the integrity of work products using configuration identification, configuration control, configuration status accounting, and configuration audits.

Decision Analysis and Resolution

The purpose of decision analysis and resolution (DAR) is to analyze possible decisions using a formal evaluation process that evaluates identified alternatives against established criteria.

The IPPD Addition (Integrated Product and Process Development)

Before describing the next process area, a new term has to be defined: the "IPPD addition". In CMMI, "additions" are used to include material that may be of interest to particular users. The IPPD group of additions covers an IPPD approach that includes practices that help organizations achieve the timely collaboration of relevant stakeholders throughout the life of the product to satisfy customers' needs, expectations, and requirements (Department of Defense, 1996). If you apply the CMMI, you are free to add the IPPD addition or not.

Integrated Project Management + IPPD

The purpose of integrated project management (IPM) is to establish and manage the project and the involvement of the relevant stakeholders according to an integrated and defined process that is tailored from the organization's set of standard processes.

IPPD Addition: For IPPD, integrated project management +IPPD also cover the establishment of a shared vision for the project and the establishment of integrated teams that will carry out objectives of the project.

Measurement and Analysis

The purpose of measurement and analysis (MA) is to develop and sustain a measurement capability that is used to support management information needs.

Organizational Innovation and Deployment

The purpose of organizational innovation and deployment (OID) is to select and deploy incremental and innovative improvements that measurably improve the organization's processes and technologies. The improvements support the organization's quality and process-performance objectives as derived from the organization's business objectives.

Organizational Process Definition + IPPD

The purpose of organizational process definition (OPD) is to establish and maintain a usable set of organizational process assets and work environment standards.

IPPD Addition: For IPPD, organizational process definition +IPPD also cover the establishment of organizational rules and guidelines that enable conducting work using integrated teams.

Organizational Process Focus

The purpose of organizational process focus (OPF) is to plan, implement, and deploy organizational process improvements based on a thorough understanding of the current strengths and weaknesses of the organization's processes and process assets.

Organizational Process Performance

The purpose of organizational process performance (OPP) is to establish and maintain a quantitative understanding of the performance of the organization's set of standard processes in support of quality and process-performance objectives, and to provide the process-performance data, baselines, and models to quantitatively manage the organization's projects.

Organizational Training

The purpose of organizational training (OT) is to develop the skills and knowledge of people so they can perform their roles effectively and efficiently.

Project Monitoring and Control

The purpose of project monitoring and control (PMC) is to provide an understanding of the project's progress so that appropriate corrective actions can be taken when the project's performance deviates significantly from the plan.

Project Planning

The purpose of project planning (PP) is to establish and maintain plans that define project activities.

Process and Product Quality Assurance

The purpose of process and product quality assurance (PPQA) is to provide staff and management with objective insight into processes and associated work products.

Quantitative Project Management

The purpose of quantitative project management (QPM) is to quantitatively manage the project's defined process to achieve the project's established quality and process-performance objectives.

Requirements Management

The purpose of requirements management (REQM) is to manage the requirements of the project's products and product components and to identify inconsistencies between those requirements and the project's plans and work products.

Risk Management

The purpose of risk management (RSKM) is to identify potential problems before they occur so that risk-handling activities can be planned and invoked as needed across the life of the product or project to mitigate adverse impacts on achieving objectives.

Acquisition Process Areas

Solicitation and Supplier Agreement Development

The purpose of solicitation and supplier agreement development (SSAM) is to prepare a solicitation package and to select one or more suppliers for delivering the product or service and establish and maintain the supplier agreement.

Acquisitions Management

The purpose of agreement management (AM) is to ensure that the supplier and the acquirer perform according to the terms of the supplier agreement

Acquisition Requirements Development

The purpose of the acquisition requirements development (ARD) is to produce and analyze customer and contractual requirements.

Acquisition Technical Management

The purpose of the acquisition technical management (ATM) is to evaluate the supplier's technical solution and to manage selected interfaces of that solution.

Acquisition Validation

The purpose of the acquisition validation (AVAL) is to demonstrate that an acquired product or service fulfils its intended use when placed in its intended environment.

Acquisition Verification

The purpose of acquisition verification (AVER) is to ensure that selected work products meet their specified requirements.

Development Process Areas

Product Integration

The purpose of product integration (PI) is to assemble the product from the product components, ensure that the product, as integrated, functions properly, and deliver the product.

Requirements Development

The purpose of requirements development (RD) is to produce and analyze customer, product, and product component requirements.

Supplier Agreement Management

The purpose of supplier agreement management (SAM) is to manage the acquisition of products from suppliers.

Technical Solution

The purpose of technical solution (TS) is to design, develop, and implement solutions to requirements. Solutions, designs, and implementations encompass products, product components, and product-related lifecycle processes either singly or in combination as appropriate.

Validation

The purpose of validation (VAL) is to demonstrate that a product or product component fulfils its intended use when placed in its intended environment.

Verification

The purpose of verification (VER) is to ensure that selected work products meet their specified requirements.

Service Process Areas

As mentioned before, the CMMI-SVC has not been published yet. Nevertheless, it is available as initial draft (Software Engineering Institute, 2006b) and was already widely discussed on several conferences (Hollenbach & Buteau, 2006).

Capacity and Availability Management

The purpose of capacity and availability management (CAM) is to plan and monitor the effective provision of resources to support service requirements.

Incident and Request Management

The purpose of the incident and request management (IRM) process area is to ensure the timely resolution of requests for service and incidents that occur during service delivery.

Organizational Service Management*

The purpose of the organizational service management (OSM) process area is to establish and maintain standard services that ensure the satisfaction of the organization's customer base.

Problem Management

The purpose of the problem management (PRM) process area is to prevent incidents from recurring by identifying and addressing underlying causes of incidents.

Service Continuity*

The purpose of the service continuity (SCON) is to establish and maintain contingency plans for continuity of agreed services during and following any significant disruption of normal operations.

Service Delivery

The purpose of the service delivery (SD) process area is to deliver services in accordance with service agreements.

Service System Development*

The purpose of the service system development (SSD) process area is to analyze, design, develop, integrate, and test service systems to satisfy existing or anticipated service agreements.

Service Transition

The purpose of the service transition (ST) process area is to deploy new or significantly changed service systems while managing their effect on ongoing service delivery.

Supplier Agreement Management

The purpose of supplier agreement management (SAM) is to manage the acquisition of products from suppliers.

The process areas marked with an asterisk (*) are additions (like IPPD in the CMMI for Development) and therefore optional.

CMMI Process Categories

In order to develop a better understanding for the dependencies between the process areas, the CMMI-DEV defines 4 categories which are applied to the other constellations below, and collect process areas with a similar focus. Therefore, 3 categories are identical for all constellations. These are

- Process management
- Project management
- Support

The fourth category is focussed on the field of application of the constellation and is labelled

- Acquisition (in CMMI-ACQ)
- Engineering (in CMMI-DEV)
- Service Establishment and Delivery (in CMMI-SVC)

Based on this categorization the complete set of CMMI process areas can be categorized as follows.

For shared process areas see Table 1; for CMMI-ACQ see Table 2; for CMMI-DEV see Table 3; for CMMI-SVC see Table 4.

Constellation Based Maturity Levels

As described before, each process area is assigned to a defined maturity level. Whilst on level 4 and

5 only shared process areas are assigned, the assignment on level 2 and 3 is dependent on the constellation (see Table 5).

The shared processes assigned to level 4 are

- Organizational process performance
- Quantitative project management

The shared processes assigned to level 5 are

- Causal Analysis and Resolution
- Organizational Innovation and Deployment

Table 1. Shared process areas

	Process Management	**Project Management**	**Support**	**Acquisition / Engineering / Service Establishment and Delivery**
Shared process areas	Organizational Innovation and Deployment, Organizational Process Definition +IPPD, Organizational Process Focus, Organizational Process Performance, Organizational Training	Project Monitoring and Control, Project Planning, Quantitative Project Management, Risk Management	Causal Analysis and Resolution, Configuration Management, Decision Analysis and Resolution, Measurement and Analysis, Process and Product Quality Assurance	Requirements Management

Table 2. CMMI-ACQ process areas

	Process Management	**Project Management**	**Support**	**Acquisition / Engineering / Service Establishment and Delivery**
CMMI-ACQ				Solicitation and Supplier Agreement Development, Agreement Management, Acquisition Requirements Development, Acquisition Technical Management, Acquisition Validation, Acquisition Verification

Table 3. CMMI-DEV process areas

	Process Management	**Project Management**	**Support**	**Acquisition / Engineering / Service Establishment and Delivery**
CMMI-DEV		Supplier Agreement Management		Product Integration, Requirements Development, Technical Solution, Validation, Verification

Table 4. CMMI-SVC process areas

	Process Management	**Project Management**	**Support**	**Acquisition / Engineering / Service Establishment and Delivery**
CMMI-SVC	Organizational Service Management	Supplier Agreement Management, Capacity and Availability Management	Problem Management	Incident and Request Management, Service Continuity, Service Delivery, Service System Development, Service Transition

A CMMI Based, Integrated Product Life Cycle

Even though the CMMI provides 3 different constellations, these constellations can be used to define 2 different integrated product life cycles:

- Organizations which provide service delivery for acquired software products should use the process areas of the CMMI-ACQ in combination with the process areas of the CMMI-SVC.
- Organizations which develop software and provide service delivery should use the process areas of the CMMI-DEV in combination with the process areas of the CMMI-SVC.

Even the combination of all three constellations is thinkable, when a service delivering organization partially acquires and partially develops the software.

SPICE / ISO 20000 INTEGRATION PERSPECTIVE

Besides the CMMI world, another possibility for an integrated product life cycle is the combina-

Table 5. Maturity level 2 and 3 for CMMI constellations

	Maturity Level 2	Maturity Level 3
Shared process areas	Requirements Management, Project Planning, Project Monitoring and Control, Measurement and Analysis, Process and Product Quality Assurance, Configuration Management	Decision Analysis and Resolution, Integrated Project Management +IPPD, Organizational Process Definition +IPPD, Organizational Process Focus, Organizational Training, Project Management
CMMI-ACQ	Solicitation and Supplier Agreement Development, Agreement Management, Acquisition Requirements Development	Acquisition Technical Management Acquisition Validation, Acquisition Verification
CMMI-DEV	Supplier Agreement Management	Product Integration, Requirements Development, Technical Solution, Validation, Verification
CMMI-SVC	Supplier Agreement Management, Incident and Request Management	Capacity and Availability Management, Service Continuity Service Delivery, Service System Development, Service Transition, Organizational Service Management, Problem Management

tion of two ISO standards: the ISO 15504—better known as SPICE—and the ISO 20000.

SPICE Basics

The ISO 15504 (SPICE) is structured in 5 parts. Part 1 defines the basic concept and the vocabulary. In part 2 rules for performing an assessment are defined, and in part 3 guidance for the assessment is given. Part 4 gives additional guidance on the use for process improvement and capability determination.

The interesting part under the integration perspective is part 5. This part defines an exemplar process assessment model.

Whilst the capability determination is widely similar to the approach of the CMMI continuous representation, the process model is different from the CMMI.

SPICE defines 3 categories. These categories are structured in groups and each group has several processes (ISO/IEC, 2006). The categories with their groups are:

- Primary life cycle processes
  - Acquisition process group (ACQ)
  - Supply process group (SPL)
  - Engineering process group (ENG)
  - Operation process group (OPE)
- Organizational life cycle processes
  - Management process group (MAN)
  - Process improvement process group (PIM)
  - Resource and infrastructure process group (RIN)
  - Reuse process group (REU)
- Supporting life cycle processes
  - Supporting process group (SUP)

Comparing the SPICE categories with the CMMI constellations, strong connections can be identified between the process groups of the primary life cycle processes and the CMMI constellations. The acquisition process group and supply process group have the same focus as the CMMI-ACQ as well as the engineering process group and the CMMI-DEV. Only the CMMI-SVC does not have a counterpart in SPICE. The operation processes group and some processes of the supporting process group address service related topics, but a common approach is not delivered.

To better understand the content of the SPICE process groups each group with its processes should be further described—as defined in SPICE (ISO/IEC, 2006):

Primary Life Cycle Processes

The primary life cycle processes consist of processes that serve primary parties during the life cycle of software. A primary party is one that initiates or performs the development, operation, or maintenance of software products. These primary parties are the acquirer, the supplier, the developer, the operator, and the maintainer of software products.

- The acquisition process group (ACQ) consists of processes performed by the customer, in order to acquire a product and/or a service. The processes of this group are:
  - ACQ.1: Acquisition preparation
  - ACQ.2: Supplier selection
  - ACQ.3: Contract agreement
  - ACQ.4: Supplier monitoring
  - ACQ.5: Customer acceptance
- The supply process group (SPL) consists of processes performed by the supplier in order to propose and deliver a product and/or a service. The processes of this group are:
  - SPL.1: Supplier tendering
  - SPL.2: Product release
  - SPL.3: Product acceptance support
- The engineering process group (ENG) consists of processes that directly elicit and manage the customer's requirements, specify, implement, and/or maintain the software product and it's relation to the system. The processes of this group are:
  - ENG.1: Requirements elicitation
  - ENG.2: System requirements analysis
  - ENG.3: System architectural design
  - ENG.4: Software requirements analysis
  - ENG.5: Software design
  - ENG.6: Software construction
  - ENG.7: Software integration
  - ENG.8: Software testing
  - ENG.9: System integration
  - ENG.10: System testing
  - ENG.11: Software installation
  - ENG.12: Software and system maintenance
- The operation process group (OPE) consists of processes performed in order to provide for the correct operation and use of the soft-

ware product and/or service. The processes of this group are:

- OPE.1: Operational use
- OPE.2: Customer support

Organizational Life Cycle Processes

The organizational life cycle processes consist of processes employed by an organization to establish and implement an underlying structure made up of associated life cycle processes and personnel and continuously improve the structure and processes. They are typically employed outside the realm of specific projects and contracts; however, lessons from such projects and contracts contribute to the improvement of the organization.

- The management process group (MAN) consists of processes that contain practices that may be used by anyone who manages any type of project or process within a software life cycle. The processes of this group are:
    - MAN.1: Organizational alignment
    - MAN.2: Organizational management
    - MAN.3: Project management
    - MAN.4: Quality management
    - MAN.5: Risk management
    - MAN.6: Measurement
- The process improvement process group (PIM) consists of processes performed in order to define, deploy, assess and improve the processes performed in the organizational unit. The processes of this group are:
    - PIM.1: Process establishment
    - PIM.2: Process assessment
    - PIM.3: Process improvement
- The resource and infrastructure process group (RIN) consists of processes performed in order to provide adequate human resources and necessary infrastructure as required by any other process performed by the organizational unit. The processes of this group are:
    - RIN.1: Human resource management
    - RIN.2: Training
    - RIN.3: Knowledge management
    - RIN.4: Infrastructure
- The reuse process group (REU) consists of processes performed in order to systematically exploit reuse opportunities in the organization's reuse programmes. The processes of this group are:
- REU.1: Asset management
- REU.2: Reuse program management
- REU.3: Domain engineering

Supporting Life Cycle Processes

The supporting life cycle processes consist of processes that support another process as an integral part with a distinct purpose and contribute to the success and quality of the software project. A supporting process is employed and executed, as needed, by another process. The processes of this group are:

- SUP.1: Quality assurance
- SUP.2: Verification
- SUP.3: Validation
- SUP.4: Joint review
- SUP.5: Audit
- SUP.6: Product evaluation
- SUP.7: Documentation
- SUP.8: Configuration management
- SUP.9: Problem resolution management
- SUP.10: Change request management

Each SPICE process has a well-defined structure. After the process ID (e.g., SUP.10) and the process name (e.g., change request management), the purpose of the process is described. Then the process outcomes are defined. These process outcomes—plus process attributes—have to be achieved to reach a capability level in SPICE. Afterwards base practices for each process are defined and work products of the process are listed.

Table 6. CMMI and SPICE process structure

CMMI	SPICE
Acronym	Process ID
Process Name	Process Name
Purpose Statement	Process Purpose
Specific Goals	Process Outcomes
Specific Practices	Base Practices
Generic Goals	Process Attributes
Typical Work Products	Work Products

Comparing the structure of a CMMI process area and a SPICE process, there are lots of similarities (see Table 6).

All in all, SPICE has 48 processes that mainly cover software development and have only small focus on service delivery. For this part, the ISO 20000 seems more applicable.

ISO 20000 Basics

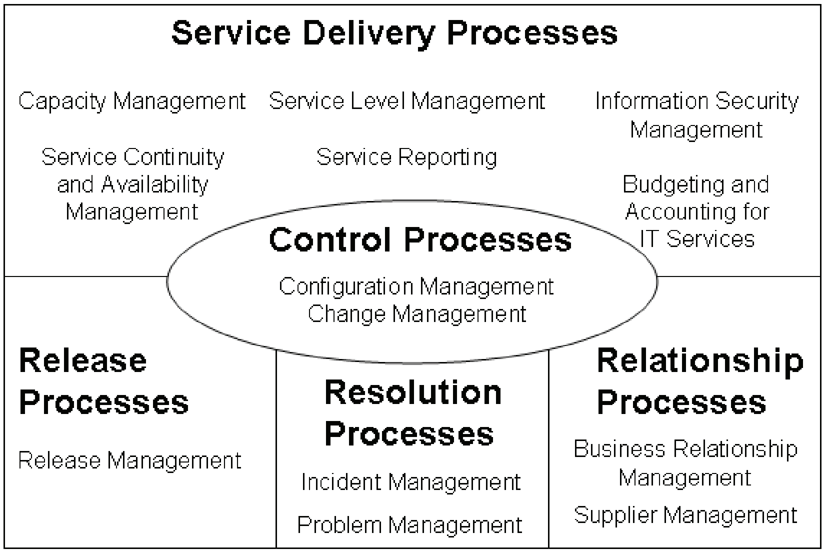
ISO 20000—Service Management covers the classical service delivery processes. Regarding the scope of ISO 20000, this standard represents "an industry consensus on quality standards for IT service management processes. These service management processes deliver the best possible service to meet a customer's business needs within agreed resource levels" (ISO/IEC, 2005b).

ISO 20000 defines 13 processes in 5 process groups.

Regarding each process group,

- The objective of the service delivery process group is to define, agree, record and manage levels of service, and consists of the processes
    - ◦ Capacity management
    - ◦ Service continuity and availability management
    - ◦ Service level management
    - ◦ Service reporting
    - ◦ Information security management
    - ◦ Budgeting and accounting for IT services
- The objective of the relationship process group is to describe the related aspects of supplier management and business relationship management, and consists of the processes
    - ◦ Business relationship management
    - ◦ Supplier management
- The objectives of the resolution process group are to restore agreed service and minimize disruption to the business, and consists of the processes
    - ◦ Incident management
    - ◦ Problem management
- The objective of the control process group is to define and control the components of service and infrastructure, and consists of the processes
    - ◦ Configuration management
    - ◦ Change management
- The objective of the release process group is to deliver, distribute and track changes, and consists of the process
    - ◦ Release management

Figure 3. ISO 20000 processes



Those who know ITIL may have found lots of similarities in the process names and structure of ISO 20000. The ISO 20000 is well aligned with ITIL. Whilst ITIL is a collection of best practices, ISO 20000 defines specifications to support a service provider in delivering high quality services. The other way round, ITIL best practices help to achieve the quality of service management as defined by ISO 20000. It has to be recognized that ISO 20000 and ITIL are developed in strong connection, often impacted by the same persons.

Interfaces Between SPICE and ISO 20000

Trying to integrate SPICE and ISO 20000 it has to be taken into account, that both standards cover similar or identical elements in some processes. If an integrated product life cycle should be defined, these interfaces have to be harmonized.

First of all, the operational process group of SPICE has to be analyzed. This process group consists of two processes, operational use (OPE.1) and customer support (OPE.2).

The operational use process has the purpose to ensure the correct and efficient operation of the product for the duration of its intended usage and in its installed environment. Topics like operational risks, operational testing, criteria for operational use and the monitoring of the operational use are covered by this process.

The customer support process has the purpose of establishing and maintaining an acceptable level of service. Topics of this process are establishing of product support, performance monitoring and customer satisfaction.

Even though these processes address service aspects, they only deliver a high level overview. Nevertheless these topics address similar elements as the ISO 20000 processes service level management and business relationship management.

Other service delivery related processes can be found in the group of the supporting life cycle processes. The processes in focus are:

- SUP.8: Configuration management
- SUP.9: Problem resolution management
- SUP.10: Change request management

With configuration management the integrity of work products is established and maintained and these work products are made available to parties concerned. The problem resolution management process focuses on identification, analysis, management and controlling of discovered problems, while change request management ensures that change requests are managed, tracked and controlled.

Some other useful information for service delivery can be found in the process related to supplier management (acquisition / supply process groups).

Integration of SPICE and ISO 20000

To reach a fully integrated product life cycle, two requirements have to be satisfied:

- A set of processes has to be defined, which covers all stages of the life cycle—a so called process reference model (PRM)
- A model to evaluate the process capability has to be defined and must be applicable to all processes—a so called process assessment model (PAM)

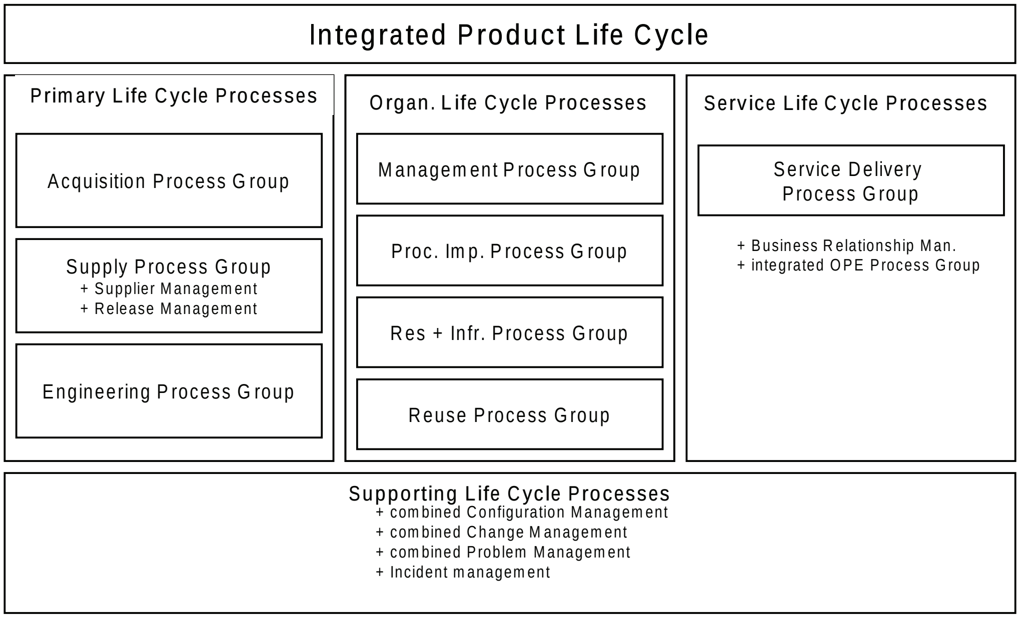
Both requirements are satisfied by the CMMI constellations: the PAM is defined in the model foundation which is mandatory for all constellations and the PRM is given by the defined process areas.

For the SPICE and ISO 20000 integration, this is not that easy. On the one hand SPICE and ISO 20000 address identical topics in different processes, on the other hand, only SPICE has an assessment model. A way to solve this problem was defined in early 2007 (Malzahn, 2007) and should be described in the following chapters.

A Combined PRM for SPICE and ISO 20000

As described before, double definitions in SPICE and ISO 20000 have to be eliminated and all processes need to have an identical structure. Therefore in a first step, the ISO 20000 processes have to be restructured into the SPICE process

Figure 4. Integrated Product Life Cycle based on SPICE and ISO 20000



structure. In a second step, processes with a similar focus must be aligned.

For the first step, the ISO 20000 process groups and processes become process groups and processes of the combined model. For each ISO 20000 process the defined objective becomes the process purpose. For the rest of the text it has to be decided, which text passage becomes an outcome, a base practice, or a work product.

In the second step, all processes with a similar focus have to be aligned. Concerning SPICE and ISO 20000 it is proposed to

- Integrate the SPICE OPE process group into the service level management, service reporting and business relationship management processes of ISO 20000,
- Combine configuration management
- Combine problem resolution management and problem management,
- Combine change request management and change management.

Other possibilities for further alignment are e.g., given by the combination of the ISO 20000 release management process and the SPICE product release process, and by integrating the relationship processes into the acquisition / supply process group.

After this integration and combination, the process groups may be restructured as follows:

- The ISO 20000 control processes become part of the support process group,
- The ISO 20000 release management process becomes part of the Supply process group,
- ISO 20000 problem management and incident management become part of the support process group,
- Business relationship management may become part of the service delivery process group.

In the very end, a combined PRM for SPICE and ISO 20000 may consist of the SPICE process categories and a new service life cycle category with the following amendments:

A Combined PAM for ISO 20000 and SPICE

The definition of a process assessment model for the integration of SPICE and ISO 20000 is easy to define—it is the approach defined for SPICE. Regarding ISO 20000, no measurement framework is defined. The requirements concerning measurement are given in part one of the ISO 20000 as follows:

"The service provider shall apply suitable methods for monitoring and, where applicable, measurement of the service management processes" (ISO/IEC, 2005a). Therefore no inconsistencies in the measurement and rating can occur. The SPICE definitions are applicable because each ISO 20000 process was restructured in the PRM and therefore all contextual and structural requirements are satisfied.

COMPARISON OF BOTH APPROACHES

Regarding both approaches—the CMMI constellations and the integration of SPICE and ISO 20000—there are pros and cons for each approach:

- The CMMI constellations are highly integrated by using the same model foundation, but CMMI-SVC will not see the light of day before 2008
- SPICE and ISO 20000 require additional effort to be integrated, but both are ISO standards and therefore widely accepted—especially if legal matters have to be taken into account.

Other impacts may be the region or industry of the organization. The CMMI is very strong in the United States; SPICE is heavily used in Europe. Most defence industry companies are interested in CMMI, whilst major parts of the automotive industry prefer SPICE.

FUTURE TRENDS

This article covers two possible integration approaches. Nowadays more and more approaches see the light of day. Especially the integration of ITIL and CMMI or SPICE is widely discussed (Barafort, Di Renzo, Lejeune, Prime & Simon, 2005; Foegen & Graumann, 2007). Nevertheless ITIL is a best practice collection and not a measurement framework and therefore we still see some problems in the ITIL integration.

Hopefully the CMMI-SVC proves that it is a powerful tool for this intended integration and maybe at some point in time the ISO will find a way to publish an assessment model that covers the complete product life cycle for software.

Another promising approach will be the Enterprise SPICE initiative. The goal of this initiative is to “integrate and harmonize existing standards […] to provide a single process reference model and process assessment model that addresses broad enterprise processes. Enterprise SPICE will provide an efficient and effective mechanism for assessing and improving processes deployed across an enterprise” (SPICE User Group, 2007).

Using Integrated Models

Defining an integration approach is only a short part on the way to software development and service delivery integration. Even though it builds the indispensable basis, integration only works, if it is accepted by organizations, teams, and people. To reach this, some simple rules of the thumb should be followed:

- Integrate the working level of development and service delivery at least in the review of an integrated model – preferably in the development. If the working level understands the need for integration and is part of the integration process, the integrated model is better accepted.
- Provide translation between the development, service delivery and integration approach. Only if software development and service delivery people reach a common understanding, an integrated approach can be established.
- Provide training on the approach. Training must not be focused on “we combine standard A with standard B” but on “we define an approach for the complete life cycle”. There is no longer “their work” and “our work” but a common responsibility from first idea to retirement.

If and only if the need for integration is understood and accepted by people on working level, integration can be established – otherwise there will still be two worlds with all their differences and borders.

CONCLUSION

The decision, which approach may deliver the best benefit, must be taken by the organization itself. But one thing is inevitable: if the capability of the processes of an organization is not evaluated against accepted standards and for the complete life cycle, the organization keeps the back door open for chaotic elements in their process suite and therefore has an open door for abusing strategies, processes, and procedures.

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ENDNOTES

[1] CMMI is a registered trademark of the Software Engineering Institute, Carnegie Melon University.

[2] This explains why the continuous representation only requires to satisfy generic goals. GG1 specifies, that the specific goals have to be achieved.

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Chapter 7.14
Customer Relationship Management (CRM) Metrics:
What's the Holdup?

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ABSTRACT

Adopting a focus on CRM has been an industry standard for nearly two decades. While evidence suggests that a majority of the attempts to implement CRM systems fail, no single reason for the failures has been identified. Assuming that CRM implementation is an extension of a customer-oriented business strategy and assuming successful integration with Enterprise Information Systems such as Enterprise Resource Planning (ERP) systems, the authors contend that the lack of valid and reliable CRM metrics leads to the perception of failed CRM implementation. Only through the development, application, and use of CRM metrics can organizations hope to achieve their CRM goals.

INTRODUCTION

For nearly two decades, businesses worldwide have sought a means to connect meaningfully with their customers. For many, the integration of information technology and marketing has provided a platform on which to build this connection. Thus, Customer Relationship Management (CRM) has emerged as the strategic bridge between information technology and marketing strategy (Wehmeyer, 2005). CRM is a customer-centric business strategy in which an organization seeks to increase customer satisfaction and loyalty by offering customer-specific services (Kristoffersen & Singh, 2004). CRM allows companies to collect and analyze data on customer patterns, interpret customer behavior, develop predictive models, respond with timely and effective customized communications, and deliver product and service value to individual customers (Chen & Popovich, 2003). Acquiring a better understanding of existing customers allows companies to interact, respond, and communicate more effectively with them in order to improve retention rates, among other things. The goal is to return to the feeling of yesteryear, when small business owners and customers knew each other intimately and shared a sense of community (Chen & Popovich, 2003).

Since CRM requires an integration of information technology and marketing, cross-functional cooperation becomes mandatory for success (Nairn, 2002). But this cooperation isn't the only prerequisite for success. Two other critical success factors have been identified: (1) a customer-centric business model (Chen & Popovich, 2003) and (2) appropriate business processes and integrated systems (Bull, 2003). In addition, resource constraints impact CRM implementation. It is estimated that the average investment in CRM applications per company is U.S.$2.2 million (Chen & Popovich, 2003). Estimates of 2004 global corporate expenditures on CRM range from U.S.$23.5 billion (Bull, 2003) to U.S. $125 billion (Adebanjo, 2003; Winer, 2001).

OVERLAP BETWEEN ENTERPRISE RESOURCE PLANNING (ERP) AND CUSTOMER RELATIONSHIP MANAGEMENT (CRM)

Many CRM packages were developed by legacy systems vendors (ERP) to be seamless additions or modules (Adebanjo, 2003). ERP systems are thought of as back-office systems, whereas CRM systems are thought of as front-office systems (Corner & Hinton, 2002). ERP systems address fragmented information systems, while CRM systems address fragmented customer data. The two systems work together interactively in order to produce data on which managers are able to increase competitiveness by reducing costs and increasing sales. The goal of CRM technology is to link front-office (i.e., sales, marketing, and customer service) and back-office (i.e., financial, operations, logistics, and human resource) functions with the company's customers (Chen & Popovich, 2003).

The importance of integrated corporate applications such as ERP and CRM is increasing despite reports of negative experiences and failed implementations (Huang, Yen, Chou & Xu, 2003). But prior to focusing on the pitfalls of CRM implementation, the following sections offer the potential benefits sought by businesses that pursue CRM as an active business strategy.

POTENTIAL BENEFITS OF CRM

There are many potential benefits of integrating ERP and CRM systems (Huang et al., 2003). Some of the possible outcomes of successful CRM implementation include increased competitiveness through higher revenues and lower operating costs; increased customer satisfaction and retention rates; increased customer value; potential to assess customer loyalty, profitability, and ability to measure repeat purchase; dollars spent;and customer longevity (Chen & Popovich, 2003; Ling & Yen, 2001).

Companywide, CRM systems provide each employee with a tool to manage contacts, activities, documents, and the information necessary for personalizing or customizing marketing efforts in order to meet individual consumer needs (Bygstad, 2003). The most frequently cited critical success factors for implementation include defining a CRM strategy that is consistent with corporate strategy and determining the scope and scale of the cross-departmental infrastructure changes needed (Kotorov, 2003). Finally, all businesses seeking to develop and implement a CRM system would be wise to realize that the goal of developing a perfect CRM system is unattainable (Corner & Rogers, 2005).

THE DARK SIDE OF CRM

CRM implementation is hard work (Bygstad, 2003). By some estimates, 75% to 85% of the CRM systems implementations either are outright failures (Bygstad, 2003; Earley, 2002; Tafti, 2002) or disappoint to the level that CRM frequently has come to mean "Can't Recover Money." In a recent study of Australian businesses that adopted CRM systems, 60% were less than satisfied with the results achieved to date (Ang & Buttle, 2005).

Therefore, it is safe to say that many of the companies who have implemented CRM systems have failed to realize the potential benefits sought (Kristoffersen & Singh, 2004). The question is why? Many companies underestimate the complexities of CRM, lack clear business objectives, and tend to invest inadequately in implementation (Bull, 2003). Others fail because they assume that the same methodologies used for implementing ERP systems are suitable for implementing CRM systems (Corner & Rogers, 2005). Still others fail because they do not successfully integrate with ERP systems (Chan, 2005). To be fair, the failure rate is consistent with the implementation success rate of other Enterprise Information Systems such as ERP systems. How can we improve the situation? One interesting area to investigate is the use, or lack of use, of CRM metrics. Chan (2005) contends that the inability to align the correct metrics across business activities is a critical reason for CRM failure.

THE CURRENT STATUS OF CRM METRICS

In a sample drawn from Fortune 1000 companies, 39% had no CRM metrics, 48% had internal metrics, and only 12% had external goals and metrics (Rogers, 2003). The need for valid and reliable metrics is clear. In order to optimize CRM performance, metrics need to be enterprise-wide, customer-centric (Chan, 2005), and relevant (Rogers, 2003). Metrics from sales, marketing, customer service, and operations should be unified in order to drive measures of customer profitability, customer satisfaction, and market share (Chan, 2005). The disconnect between CRM and CRM metrics negatively impacts marketing effectiveness, customer retention, and loyalty (Chan, 2005). The problem with CRM metrics today is that they mostly are focused internally, measuring items such as increase in sales revenue, improved sales productivity, reduction in marketing waste, reduction in costs in call centers, reduction in sales cycle time, increase in campaign response, and decrease in cost of response. In order to be useful, metrics are needed that focus on the customer's experience, measuring items such as improvement in first contact resolution or improved speed of order fulfillment (Rogers, 2003).

BUILDING THE CASE FOR THE DEVELOPMENT OF CRM METRICS

The emergence of the quality movement in the 1980s in the United States, spurred on by Edward

Demming's mantra "You can't manage what you can't measure," helped energize the push for performance management, benchmarking, metrics, and the like. While initially focused on financial and non-financial measures for manufacturing, performance measures have evolved to include the full range of activities within a company, including service activities and even strategic activities. The Metrus Group (2002) is one of many to document the effectiveness of performance management.

At the same time, as already addressed, there is also considerable evidence that CRM implementations today are not very good at measuring their impact or the benefit to the company, and the company often lacks an established approach to metrics or analytics. Granted, like other new technology waves, the CRM wave began with too many vendors promoting flash over substance. However, now that we are about 10 years into the wave and have the benefit of thousands of ERP and CRM implementations, what's the holdup? Why are we still fumbling with metrics?

It is true that metrics simply cannot be slapped on to the front bumper and be expected to provide value. A company needs to know what it is trying to accomplish with its CRM before developing metrics. That is, a company first needs to have an overall strategic plan as well as an enterprise-wide CRM strategy that integrates information needs, technology needs, and alignment with company processes and goals. The CRM should have organizational goals, technology goals, and goals for customer offerings (Sawhney, 2001). A company with many legacy systems that make it difficult to integrate across various information silos will have a slow start.

Others have suggested that people, culture, and processes also are factors that can inhibit a company from adding value across its customer value chain from the integrated information that a CRM can provide. Put a slightly different way, we suggest it is not the technology anymore, be it data communications issues or application maturity; it is people, culture, and change. A simple example is a new CRM system that identifies problem areas. Who wants to be the messenger to deliver the bad news in a corporate culture that does not support such activities?

Distance learning technology was at a similar point about five years ago. For a number of years, people had plenty of legitimate complaints about distance learning technology: it doesn't work, the server is down too often, the connection is too slow, the software is too frustrating and doesn't do what I need it to do, it takes too much time, and so forth. Over a few short years, connection speeds even to the home became fast and reli-

Table 1. Benefits of strategic performance management (© Metrus Group, 2002)

Measure of Success	Measurement-Managed Organizations	Non-Measurement-Managed Organizations
Industry leader over the past three years	74%	44%
Three-year return on investment (ROI)	80%	45%
Success in last major change effort	97%	55%
Clear agreement on strategy among senior management	93%	37%
Effective communication of strategy to organization	60%	8%

able, the learning management software matured, and adequate infrastructure such as servers was in place. Seemingly in a flash, the discussions moved from technology to pedagogy and assessment. Likewise, we believe the maturity of CRM applications available today and the experience of companies using CRM applications are now permitting companies to move from a technology focus to an application focus as well as the evaluation of CRM's performance and benefits.

We believe it is time to revisit and reinvigorate efforts to develop, implement, and research CRM metrics. Some CRM metrics, such as developing useful measures to support return on investment (ROI) or using the balanced scorecard technique, can take time to learn and implement. One such metric proposed is the Customer Value Scorecard (CVS). The CVS is a customer performance metric that looks at transition rates from stages and segments that affect the value of the customer base (Hansotia, 2002). However, many current CRM metrics exist today that can be applied quite readily to help demonstrate value and profitability. Metrics such as Relative Customer Satisfaction, Customer Retention, and Customer Lifetime Value provide valuable benchmarks for managers (Rogers, 2003). The following suggested metrics assume a full CRM implementation, integration with ERP reporting, and data mining capabilities. CRM metrics include the following:

- **Changes in Conversion or Sales Rate.** An increase in the number of opportunities vs. the number of wins can show growth. Data-mining techniques can show conversion results in specific markets or within a range of customers.
- **Changes in Cross-Selling Rate for Existing Customers.** Silos often are built in organizations between diverse product offerings. The ability to show an increase in cross selling to existing customers provides many intrinsic returns in an organization's ability to maximize its share of customer wallets.
- **Evaluating Marketing Campaigns.** The ability to measure the productivity of a campaign with hard numbers and trend data is especially important to organizations in which larger individual investments in marketing are needed to produce a win.
- **Predicting Future Sales.** Over time, an integrated CRM system can provide more information about future sales and more accurate probabilities about potential wins.
- **Evaluating the CRM System.** The data documenting the effectiveness of the customer life cycle for customers, including order and supply process improvements, customer support, sales, sales and marketing expenses, and customer satisfaction, can document the value of the CRM system.
- **Bringing New Marketing and Sales Personnel up to Speed.** Staff transition is a fact of doing business, especially in today's dynamic environment. CRM systems metrics as well as the valuable history of past and present interactions with customers can significantly speed up a new employee's productivity learning curve.

The following do not require an integrated, full CRM implementation. They just some time and, for most of them, an Excel spreadsheet:

- **Cost Per Acquisition.** Customer acquisition costs are the costs associated with convincing a consumer to buy a product or service, including marketing, research, advertising costs, and Web content. It is calculated by dividing the costs by the number of acquisitions. Customer acquisition cost should be considered along with other data, especially the value of the customer to the company and the resulting return on investment (ROI) of acquisition.
- **Customer Lifetime Value.** Loyal customers mean future revenues. Customer Lifetime Value (CLV) is the present value of the future

revenue generated from a customer for as long as you retain that customer. If CLV is an indication of the value of a relationship, companies must find ways to maximize CLV by utilizing strategies that maximize incremental sales and by launching effective customer loyalty programs. The formula for CLV is Customer Lifetime Value = Revenue from initial purchase + Present Value of Future Revenues over the Projected Lifetime—the Acquisition Cost of the Customer

- **Changes in Customer Satisfaction.** While satisfaction measures may not provide verifiable results as quickly as other metrics, they provide important overall, long-term trends as well as valuable feedback on the organization's most important customers.
- **E-mail Effectiveness.** E-mail effectiveness can be measured a number of ways. The Return on Investment (ROI) of a particular e-mail campaign can be calculated by dividing the total cost of the mailing into the net income produced. A monthly e-mail churn rate (number of undeliverable e-mail names plus the names deleted from the list during the month divided by the total number of e-mail names on your list at the end of the month) measures how much your customer base rolls over every month.
- **Web Traffic Analysis.** There are a number of Web traffic analysis packages available, many of which are very affordable (e.g., ClickTracks, Hitslink, FastCounter Pro). They can support Web marketing through ROI analysis, detailed visitor analysis, content performance, and ad tracking.

SUMMARY

For some, the development and use of CRM metrics is a case of too little too late and can only confirm that the organization is already in trouble (Rogers, 2003). But this should not dissuade organizations from the pursuit of the development of well-defined CRM metrics. Metrics provide actionable data, either positive or negative, and have the ability to help to demonstrate the value and profit attributable to a CRM implementation. Our hope is to illustrate that an opportunity exists for developing customer-focused CRM metrics and that starting down the road of CRM metric development does not require either a Ph.D. in statistics or even a full CRM implementation.

It is clear that just as the implementation of a CRM system is a cross-functional endeavor, so is the development of the metrics needed to manage these systems. We are attempting to walk the walk: one author is a management information systems professor, two are marketing professors, one is an accounting and finance professor, and the final one is from the CRM industry. Our goal is to promote and reinvigorate the CRM metrics conversation. We issue a challenge to our colleagues in the academy to join us in our pursuit of the development of valid and reliable CRM metrics that have broad applications. Do you measure up?

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Chapter 7.15

Security Policies and Procedures

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ABSTRACT

The number and severity of attacks on computer and information systems in the last two decades has steadily risen and mandates the use of security policies by organizations to protect digital as well as physical assets. Although the adoption and implementation of such policies still falls far short, progress is being made. Issues of management commitment, flexibility, structural informality, training, and compliance are among the obstacles that currently hinder greater and more comprehensive coverage for businesses. As security awareness and security-conscious cultures continue to grow, it is likely that research into better methodologies will increase with concomitant efficiency of security policy creation and implementation. However, attacks are becoming increasingly more sophisticated. While the human element is often the weakest link in security, much can be done to mitigate this problem provided security policies are kept focused and properly disseminated, and training and enforcement are applied.

INTRODUCTION

In the days of mainframes, users were given a username and password, and perhaps an electronic badge to admit them to a computer facility. Those days have long evaporated. With the advent of private broadcast networks, intranets, portable media devices, laptops, and the commercial development of the Internet, security for any kind of business has become a lot more complicated. Moreover, it is costing more. The average loss from unauthorized access to data increased by 488 percent from $51,545 in 2004 to $303,234 in 2005, according to the most recent Computer Security Institute/FBI Computer Crime and Security Survey (McFadden, 2006). For larger companies, recent security breaches were estimated by Ernst and Young to range from $17 to

$28 million per incident (Garg, Curtis, & Halper, 2003), and Austin & Darby (2003) reported that the cost of security breaches to businesses in the USA was $17 billion. Further, correcting the long-term damage, which includes loss of customer confidence, damage to the company's image, and financial consequences, such as stock devaluation for public companies, can be extremely costly, although difficult to estimate. Therefore, developing an effective security policy, implementing it, and ensuring that it is understood and practiced by all employees is essential.

The Approach to Security Policies and Procedures

Companywide policies should be initiated and enforced from the top, and that includes IT security policies. That does not mean to say that technical policies, such as those developed by IT departments, cannot have a specific focus, but the level of technical complexity itself should not be regarded as a barrier that top management can ignore. Tuesday (2002) cites a case study in which an old approved policy was updated at a lower level but ignored by a CEO's assistant, who was essentially acting as the gatekeeper. The eventual result was that the CEO applied for an exception dispensation; however, the antics of the assistant probably caused sufficient disruption that enforcing the updated policy was difficult.

Policies must focus on the most important aspects of security rather than comprise a long list of laundry items in a 200-page manual. For example, one of the most productive ways to review security from scratch is for each business unit to determine what devices and associated data (digital assets) are the most important (Austin & Darby, 2003). From this data, common policies can be formulated, with the establishment of exception procedures for those groups that are not impacted, or who require a different solution.

The creation of simple, nonspecific technology-dependent policies allows for the possibility of change, and flexible approaches. Tomorrow's security problems are not necessarily going to be solved by today's solutions. Both threats and technology change, and policies should be broad enough to accommodate these facts.

Enforcement of policies is also important. Policies can be written and implemented, but if breaches occur, they must be addressed. Not reacting to breaches in policy causes employees to think that a policy can be safely ignored, and increases the risk that real damage will be done the next time an incident occurs.

Last, the roles of individuals in shaping, implementing, and enforcing security policies must be delineated. If responsibilities are not created, there is a tendency for some individuals to assume roles and proceed unilaterally, and others to ignore situations that must be addressed.

This chapter comprises six main sections: (a) methods to determine the constitution of security policies (frameworks, scope, and creation), (b) adoption and implementation of policies into specific procedures, (c) exception procedures, (d) training in security policies, (e) enforcement of security policies, and (f) leadership roles in security policies. Rather than focusing on specific technologies, the intent of the chapter is to create a framework from which security policies and procedures can be derived for any type of business entity. These elements, with emphasis on the constitution of security policies, are discussed in terms of (a) the research that has been conducted, and (b) practical advice that can be utilized.

BACKGROUND

Constitution of Security Policies

Developing Frameworks

Many IS (information security) researchers express skepticism about the use and effectiveness of security policies (Höne & Eloff, 2002), citing perception of security controls as barriers to efficiency and progress, which leads to circumvention (Wood, 2000). To be effective, IS security policies depend must on the specific organization and its environment (Karyda, Kiountouzis, & Kokolakis, 2005). These twin issues must always be borne in mind when creating security policies.

Several approaches have been taken regarding frameworks for security policies. Baskerville (1993) notes that the development of information security systems (ISS) in general has proceeded by generation, starting with the first generation, which relied upon checklists or security management standards; the second, which were mechanistic in nature, focusing on functional, technical, and natural science factors in ISS design, and neglecting the social nature of organizations; and the third, comprising logical modeling methods that abstract ISS problems. Siponen (2005) advances these concepts, describing five paradigms in modern ISS approaches, which include the viable and survivable, security-modified, responsibility modeling, business process, and information modeling. The reader might ask what relation this fundamental research has to do with security policies, and the answer is that the future fifth generation, which Siponen (2005) advocates, incorporates the use of social techniques, such as user participation to ensure the social acceptance of security techniques and procedures. In addition, although the use of sanctions and deterrents needs justification, such practices should be accepted by all the employees of an organization. In other words, future ISS designs will be synonymous with security acceptability. Details of these ISS approaches can be found in the papers by Baskerville and Siponen (2002), and Siponen (2005).

Karyda et al. (2005) base the framework of their approach to security policies on the theory of contextualism (Pettigrew, 1987). In essence, contextualism seeks to analyze the relationship and interaction between the content of strategic change, the context of that change, and the process involved in managing that change (Pettigrew & Whipp, 1993). The interrelationships transform dynamically over time, as a result of both outer contexts, such as the economic, social, competitive factors found in an organization's external environment, and inner contexts, such as the structural, political, and cultural factors present within an organization. By investigating security policy content, formulation processes, implementation, and adoption in this manner at three levels—organization, work system, and information technology—Karyda, et al. (2005) made four crucial findings in two case studies. First, employees with increased responsibilities and varied activities have higher security awareness. The corollary to this is that organizations with rigid, hierarchical structures will likely develop problems in the application of security policies. Second, organizations with coherent cultures, especially codes of ethics, have an easier time of adopting and implementing IS security policies. Third, the more management participates and visibly supports security policies, the better the outcome. Finally, security awareness and security policy evaluation programs assist in promoting successful adoption and implementation.

Alignment is another concept that has implications for the development of security policies. In her case study of eight companies Chan (2002) discovered that aligning IS and business strategies improved IS performance, but another key finding was that informal organization mattered more than formal structure. These results bear on another alignment, that between information security policy (ISP) and the strategic information systems plan (SISP), of which the latter is aligned with corporate strategy (Doherty & Fulford, 2006; Doherty, Marples, & Suhami, 1999). According to Doherty and Fulford (2006), the traditional method of SISP is to assemble a team, conduct a situation analysis, formulate, and then implement a strategy, and modify it as necessary after review. These researchers suggest that during the formulation phase, the SISP should be created or modified, and when the review is phase is conducted, the ISP should then be reviewed and modified in parallel. This linkage ought to provide several benefits: (a) imbue the ISP with a stronger business orientation; (b) provide advance warning of security risks or the need for new controls when new SISP directives are initiated; (c) move the security culture from one of reactive to proactive; (d) incorporate security management issues into user manuals, training, and procedures prior to the introduction of new systems; and (e) raise awareness of security breaches in management. The findings of Chan (2002) suggest that this process is best carried out using maximum flexibility and informal structure, rather than a rigid, completely defined structural organization.

Maynard and Ruighaver (2001) adapted software quality factors to create a framework for the quality of information security policies, utilizing measures of functionality, reliability, usability, efficiency, maintainability, and compliance. Functionality focuses on the appropriateness of security policies, whether the policies operate as intended in "real life," avoidance of contradiction (corollary harmony), and a careful balance between unintended disclosure of sensitive information versus the need by employees to comprehend all policies. Reliability highlights the developing maturity of security policies as they are reviewed and modified, and the ability of the policies to tolerate faults and not "fail hard." Usability is the ability to easily comprehend the policies, obtain them in a variety of formats, and execute them without going against psychological norms. Being able to easily update and implement policies without inordinate consumption of time or resources constitutes efficiency. Measures of maintainability focus on the ease with which deficiencies can be analyzed, rectified or changed, while compliance tests the ability of the policies to adhere to the standards of the organization, as well as legislative or regulatory requirements.

Scope of Security Policies

Baskerville and Siponen (2002) have proposed three levels of security policies: high-level reference, lower-level reference, and meta-policies. High-level reference security policies emanate from and are written by top management. Lower-level reference policy documents address specific departments, areas, or processes and are more concrete in nature, describing specific procedures to control authorization, protect assets, or minimize vulnerabilities. Security meta-policies are concerned with policy-making—for example, which entities or individuals are responsible for making policies, or when activities should trigger policy-making.

In practice, the scope of security policies is linked to the perceived strategic importance of information and security management practice. Some research shows that this is influenced by the risk perceptions of senior management and board of a company, and by internal or external events that are deemed significant by a company's decision-makers (Ezingeard, Bowen-Schire, & Birchall, 2004). In support of their findings, Ezingeard et al. (2004) also cite the novel security issue, which reduces to difficulty in judging the impact of a security problem if it has never been experienced (Frank, Shamir, & Briggs, 1991). There is also the sequential attention to goals issue, which manifests itself in change as a result of a major incident, and reversion to old practice for other reasons some time later (Cyert & March, 1992). This occurrence has been used to explain paradoxical decision in IS strategy (Hirscheim & Sabherwal, 2001). In addition, Doherty and Fulford (2005), who surveyed IT managers of large UK organizations, found no statistical association between the adoption of information security policies and the incidence or severity of security breaches. Distilled, this research intimates that both the scope and development of security policy content as currently practiced have a long way to go to reach maturity.

Security policy content has often developed from the BS 7799 standard that became the ISO 17799 standard in 2000. Doherty and Fulford (2006) have elaborated individual components of this standard as follows: personal usage of information systems (rights and responsibilities), disclosure of information (restrictions), physical security of infrastructure and information resources, violations and breaches of security, prevention of viruses and worms, user access management (who has access to what), mobile computing (security controls), Internet access, software development and maintenance, encryption (when and how), and contingency and continuity planning. Based on a validated survey of large UK companies, Fulford and Doherty (2003) determined that ≥ 89 percent of these components were covered in security policies, with the exception of software development, encryption, and contingency planning, with figures of 27 percent, 55 percent, and 18 percent, respectively. The factors affecting the success of information security policies identified as most important by respondents, which are listed in ISO 17799, were visible commitment from management, a good understanding of security risks, distribution of guidance on IT security policy to all employees, and a good understanding of security requirements. However, adoption of these success factors appears to be substantially lacking and worrisome (Fulford & Doherty, 2003).

Dhillon and Torkzadeh (2006) proposed a value-focused assessment of information system security as the baseline for developing an instrument for measuring IS security concerns. According to Keeney (1992; 1999), by identifying values, individuals can decide what they want and how to obtain it. The methodology involves three steps: (a) interviews with appropriate individuals to elicit values in the decision context, which typically produces long lists of wishes; (b) conversion to a common format (object and preference); and (c) classification of objectives into fundamental with respect to context, or a means to support/inform fundamental objectives (means objectives) (Dhillon & Torkzadeh, 2006). Based upon this approach, these authors interviewed 103 user managers from a broad range of industries and obtained 86 objectives, which were grouped into 25 clusters. Fundamental objectives included maximize awareness, maximize data integrity, maximize organizational integrity, whereas means objectives included improve authority structures, understand work situation, maximize access control, and maximize fulfillment of personal needs. What is most interesting is that this approach could be used to define the scope of security policies that moves beyond the ISO standards.

Security Policy Creation

Baskerville and Siponen (2002) advocate three imperatives for the creation of security meta-policies: flexibility (responsiveness), political simplicity, and criterion-orientation. Political simplicity in this context refers to due consideration of compliance by policy makers so that exceptions to policies can be explicit and reasoned, and criterion-orientation to the focus on the organization's priorities without exact specification on how the criteria should be met. In addition, the objective of such policies is to identify and classify security subjects and objects, which are the employees, business partners, and third parties associated with the organization, and the organization's assets, respectively (Baskerville & Siponen, 2002). Further, meta-policies are concerned with what type of access security subjects have to security objects.

In general, formulation of a security policy according to Karyda et al. (2005) is accomplished at three levels: organizational level, works system level, and the information technology level. The organizational level embodies structure, management style, norms and culture, defines the role and support of management, and describes both internal and external relationships. The work system level encompasses IS users, business processes, customers or users, and the technology and information utilized. Finally, the information technology level elaborates the specifications and configurations of technical components, as well as the software and hardware for implementation. The process of security policy creation follows the input → activities → output schema, in which input is typified by risk evaluation assessment, legal requirements, structural and cultural characteristics of the organization, existing security practices, knowledge of IT technology and security controls, and management standards and best practices. Activities constitute the identification of security requirements and controls, compilation of the policy document, the writing of individual procedures, and assemblage of the specifications for technical security controls. Finally, the output is in the form of a security policy for information systems and specifications for countermeasures. Separating IT security policies that are focused toward IT employees from those targeting all employees (Vijayan, 2006) can be easily accomplished using this methodology.

Adoption and Implementation of Security Policies

While creation of a security policy is the first step, is must be adopted and implemented or it is useless. Recent research in the UK shows that 60 percent of all companies surveyed have still not implemented a security policy (DTI, 2006), and even among larger companies, adoption is still an issue (DTI, 2006; Fulford & Doherty, 2003). May (2003) suggests that this is a result of security policies not being placed high enough on the agenda of company boards.

Karyda et al. (2005) suggest that the activities involved in adoption of a security policy include establishing norms that support security management, promoting the issue of security to IT users, and resolving conflicts and difficulties found in the application of security controls. They also suggest keeping users and management informed regarding IS security agenda. Through their contextual analysis, these investigators also studied two organizations, following security policy creation, adoption, and implementation. In one of these case studies, the Social Security Institute in the UK, management supported the creation of the security policy but failed to provide a linkage between security and the overall strategy of the organization. After creation of the policies, adoption and implementation stalled. Lack of flexibility in organizational structure and employing qualified personnel, competitive relationships, unbalanced workload in the IT department, and lack of understanding by users on security issues, as well as the security policy were among the reasons cited for the lengthy delays.

Behavioral research can provide insight into adoption and implementation. For example, by creating responsibility and accountability in structures, management can ensure that employees have a sense of ownership regarding security measures (Mishra & Dhillon, 2006). However, if these “top-down” directives are absent or half-hearted, one can see why members of an organization might not take security policies seriously. Other behavioral facets impinging on security concerns include alignment (if the goals of individuals are not aligned with those of the organization, security threats from the “inside” are likely) (Loch & Conger, 1996; Stanton, Stam, Mastrangelo, & Jolton 2005); ownership (employees should be treated as owners of information assets) (Adams & Sasse, 1999); and environment (a proactive environment promoting the importance of security behavior is important) (Dhillon & Torkzadeh, 2006; Vroom & Solms, 2004). All these factors are likely to enhance the goal of adopting and implementing a security policy once it has been formulated.

Physical implementation of IT security policies occurs at the works system or information technology levels. Although a technical discussion is beyond the scope of this chapter, the modeling approach exemplified by the work of Nagaratnam, Nadalin, Hondo, McIntosh, and Austel (2005) will be used as an illustration. Initially, a security policy officer and business analyst translate the security policy and using a business model, analyze and design the security requirements for the application, with the assistance of security and application architects. Implementation begins by writing the application policy, followed by building and testing the secure application. Deployment of the policy follows under the auspices of the application or security administrator by configuring the infrastructure for the application security, customizing the policies, and developing a list of subscribers who will utilize the policy. Finally the specific policy is managed and monitored under IT administration, with changes as necessary. Ultimately, many IT security policies depend on the utilization of service-oriented architecture templates for process mapping, efficiency, and elimination of redundancy in conjunction with mark-up using the appropriate machine language, for example, BPEL (Business Process Execution language). Once a specific policy is in place, it should be periodically audited. Bishop and Peisert (2006) caution that because of the complexity of modern systems, it is not always apparent that the low-level policy actually reflects the high-level policy. This could be the result of a "lost-in-translation" problem because "not only must a higher-level policy language be transformable into an implementation of a policy (or set of policies) on systems, but also deriveable from the existing configuration of systems. This means that mechanisms to handle contradictions must be defined, as must syntax and semantics to handle procedures external to the computer" (Bishop & Peisert, 2006, p. 1).

Exception Procedures, Training, Enforcement, and Leadership Roles

Exception Procedures

A good security meta-policy attempts to maximize compliance without outlawing noncompliance (Baskerville & Siponen, 2002). Following this, while adherence to security policies is important, cultural, legislative, and technological factors might make full compliance difficult to achieve (Maynard & Ruighaver, 2006). These are instances in which exceptions or deviations from policy can be created. In each case, a formal request for exemption should be made with documented reasons. An example of this would be the adoption of handheld BlackBerry 7200s by Unilever for their top executives, in which an exception from the policy of using the BlackBerries for both voice and data was granted in the form of permitting executives to use cell phones or smart phones for telephone conversations (McFadden, 2006).

Another historical example of the development of exceptions was reported by Couger (1986), which was a case study that involved approaches to configuration control of desktop computers. Three approaches were categorized: laissez faire (basically a free hand), hard controls (no exception to standardized configuration, under penalties), and soft controls (encouragement of desktop technology acquisition through a centralized agency by the addition of supplementary budgets). The first two approaches resulted in incompatible desktop technology, but the third did not, because of incentives and market-driven standards, and the fact that internal economics forced exceptions to be well justified (Baskerville & Siponen, 2002). However, if the number of exceptions reached critical mass, the central standard was changed.

Training

McCarthy (2006) reported that in a survey conducted by the Computing Technology Association in 2006, just 29 percent of respondents indicated that information security training was required at their companies. Yet of those 29 percent, 84 percent indicated that such training had reduced the number of major security breaches since implementation. Further, those respondents that did not mandate security training said that it was not a departmental or business priority or top management support for it was lacking.

Training has been referred to as a key ingredient to ensuring that a security policy is successful by a number of researchers. Maynard and Ruighaver (2006) link training to the learnability element. Besides the learning of the security policy itself, the complexity or simplicity of the policy will dictate the amount of training required. Overly complex policies can fail because users do not understand them no matter how much training they receive. Training is also one of the five emergent themes found in behavioral analysis of information systems security governance research and helps the implementation and communication of policies, as well as raising awareness of security issues, and improving efficiency (Mishra & Dhillon, 2006). Additionally, it results in improved internal control management. In their case study of the Social Security Institute, lack of training was also cited by Karyda et al. (2005) as a prime cause for failure to implement a security policy.

Enforcement

The foundation for any kind of enforcement policy as it pertains to security policies, whether it contains deterrent action, sanctions, or punishment are the various behavioral theories borrowed from psychology and the social sciences (Mishra & Dhillon, 2006). Foremost are the deterrence theories (Straub & Welke, 1998; Theoharidou & Kokolakis, 2005) that discuss individual and group behavior, and relate to the intention to commit crime. In our context, this would be breaking the rules embedded in the security policy. Theories of reasoned action (Loch & Conger, 1996; Park, 2000) and planned behavior try to understand how individuals react to security issues in a behavioral context and how superimposed control is perceived. Research from social bond theory (Lee, Lee, & Yoo, 2004; Theoharidou & Kokolakis, 2005) suggests that strong normative pressure forces individuals to behave correctly, while results from social learning theory (Hollinger, 1993; Theoharidou & Kokolakis, 2005) provide insight into why peer pressure can force individuals to do certain things that they would not otherwise do. In connection with this concept, the research conducted by Milgram (1963), suggests that certain actions can be brought about when the agent for instruction is perceived as an authoritative figure. Mathias (2004) describes such a real-life incident involving the installation of unauthorized application processors that occurred due to lack of policy awareness and because a supervisor told an employee “it was okay to do it.” Finally, social engineering, based on a knowledge of the beliefs, values, and attitudes of individuals seeks to impose a set of values or beliefs to given situations and is commonly used in the security industry (Loch & Conger, 1996).

In an ideal world, security policy enforcement would not be necessary. However, enforcement is necessary in order to reinforce a normative culture that “security policies matter.” What form enforcement takes is a matter for discussion within an organization, and should be predicated on an assumption that (a) security policies are widely available via a number of media types within an organization; (b) that all employees have received training in security policies (initial and recurrent as necessary); so that (c) there is not only an awareness, but a comprehension of such policies as they apply to individuals within organizations. Enforcement can take forms of reminders or reprimands for “first offenses,” or mandatory retraining or dismissal for severe breaches of security policy and repeated offenses.

Leadership Roles

Throughout this section, the recurrent theme of leadership has been emphasized with regard to the formulation and implementation of security policies. Many case studies have amply demonstrated that if senior management and the board of a company are not actively involved in security policies, the result will either be no security policy or one that takes an inordinate amount of time and resources to become operational. However, leadership roles do not cease with senior management. Lower and middle management must also be on board. This helps develop a security-conscious culture and prevents conflicts from emerging or behavior that runs contra to the security policy.

PRACTICAL GUIDANCE FOR SECURITY POLICIES

Creation, Adoption, and Implementation

Earlier it was indicated that IT-related policies should be separated from non-IT-related security policies targeting all employees. However, that should not imply that there would be two entirely separate "teams" dealing with such policies. Top management, and/or the board of an organization should kick off the security policy initiative in a variety of ways via companywide memos, meetings with employees, and use any available intranet. The point is to instill into the organization a firm top-down commitment to the project, begin the process of building a security-conscious culture, and delineate the general procedures by which the security policies will be created, adopted, and implemented. This should not be a one-time event for top management, especially for those companies that are not heavily invested in IT operations. Indeed, the involvement of senior management in all phases of the project is encouraged.

How should the security policy teams be constituted? This will depend on the size of the organization, its complexity, as well as its level of IT operations. One answer is to create the position of a security officer (if such a position does not already exist), a tsar-like figure who will guide the whole process and be answerable to the board or top management (Karyda et al., 2005). Another solution might be to appoint co-team leaders, one of whom is familiar with the strategic goals of the organization, the other an individual from the IT department who has a detailed working knowledge of its operations. One or more teams might necessary in large organizations, but if this route is chosen, it will be crucial to have a coordinator (who could also be the security officer) to ensure that all policies are harmonized and interoperable.

Although it is important to outline the structure of teams and identify the roles of members, it should be remembered that flexibility and informality are the keys to success. Rigidity and inflexible hierarchies can at best impede progress, or worse cause the project to languish. The composition of teams should reflect all interests of departments, divisions, or groups within an organization so that end users of the security policies—also the equivalent to all stakeholders—are not ignored. In some cases, the creation of meta-policies, with active direction from senior management might precede the creation of individual security policies in order to provide guidance on what is permissible.

In consideration of the content of security policies, while the overall accent is on the protection of assets, it is crucial not to be overly swayed by security incidents that have happened within the company. Such a view can produce bias. On the other hand, team members should be aware of incidents that have happened industrywide and have kept abreast of industry developments in order to achieve a balance. Case studies have shown that attitudes of "It can't happen here," or "We don't have the budget for that kind of security," or not uncommon. If consensus cannot be achieved within the company on what should be protected and to what degree, it might be useful to hire an outside expert to obtain a second opinion.

Drafts of security policies must be modeled or tested to ensure that they will work "as advertised." Assuming that a given procedure will work as written is likely to create a false sense of security, which is why the emphasis in this chapter has been on iterative processes in which review, feedback, and modification are important elements. Once the procedures have been tested, policies can be written and organized into manuals for dissemination.

The methods by which security policies are disseminated have been criticized as being insufficient and based too often on only one method (Fulford & Doherty, 2003). Consider not only using paper manuals but web-based applications, which have the option of being interactive to facilitate learning. For larger organizations pilot schemes can also be utilized in which security policies are implemented for small units to determine factors or modes of success or failure.

Other Factors

One of the essential factors to the success of security policies is training. Too many case studies have shown that failure was the result of lack of employee awareness. In addition, training can assist in building a security-conscious culture in which security of assets and data is considered a norm. Training should be thorough, companywide (which also includes all levels of management), and conducted during the implementation phase. Recurrent or refresher training is also smart as it keeps the skills of individuals better honed. Training after major configuration changes or the adoption of new infrastructure developments is also vital. The take-home message is that training should not be a one-time event. Most organizations are dynamic in structure, responding to new developments, and both security policies and the training associated with them should reflect this state.

Security policies must be enforced and individuals who willfully break security policies should be reprimanded. Without internal controls, it is unlikely that individuals will take security policies seriously, and will likely think that small transgressions are permissible. The majority of security breaches are caused by human error—that it to say from the failings of individuals rather than equipment or faulty procedures. If that error can be minimized, the security policies in place will succeed.

Even with internal controls present, errant human behavior will occur. Some individuals will perceive the security policy as too onerous, or "not applying to him or her." This kind of behavior is risky for the organization in that it can be contagious—"If she's doing it, so can I"—and can also facilitate attacks from outside the organization. However, the most dangerous individuals are those who have an axe to grind, and have the access authority to wreak havoc on security controls from within the company. Investing in monitoring equipment is a good idea, although if it is done with a heavy hand it might lead to resentment by individuals. The bottom line of an organization, however, is that the breaching of security policies should not be tolerated under any circumstances.

Finally, the issue of exception merits comment. Onerous processes—and security policies are no exception—often provoke an attitude of "that doesn't apply to me," particularly if the individual is at a high level within the organization, or commonly operates outside of the physical structures of the organization, such as a salesperson. Problems with security policy compliance should be reported to the individuals responsible for security and promptly, whether they are bona fide problems or gripes. It might be that a given procedure is poorly written, does not reflect original intention, or is simply too arduous, and is affecting a large group of individuals, in which case the procedure needs to be rethought. Individual or group exceptions to a stated policy should be decided upon by the security officer or other authority in a fair, rational manner without granting special status because of rank, power, or situation.

CONCLUSION

Security policies are a must for all organizations conducting business regardless of size or type. By protecting assets—human, physical, electronic, and digital—in a systematic way, organizations can focus most on what they do best: their business. Research shows that the creation, adoption, and implementation of security policies, however, is still lacking in many aspects. Issues of lack of management commitment, training, flexibility, and poor alignment with business strategic goals, as well as "knee-jerk" reflex action toward major security breaches are identified as the "usual suspects." Nevertheless, progress is being made in both the scope and execution of security policies in business today.

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KEY TERMS

Alignment: The degree to which strategic or corporate goals are in harmony with security policies.

Information Security (IS): The securing of information identified as confidential by computer-based and human-based procedures.

Information Security System (ISS): A framework that encompasses the methodology by which information will be identified as confidential and kept secure.

Information Security Policy (ISP): A written document specifying how the digital and electronic equipment assets of an organization will be protected through the use of individual procedures.

Information Technology (IT): The technology that supports access, processing, and dissemination of data (information).

Security Awareness: The perception by individuals within an organization that security is important to the conduct of business.

Security Meta-Policy: A policy that describes what is permissible in broad terms of security issues without specifying exact technological solutions.

Security Policy: A written document specifying how all assets of an organization will be protected through the use of individual procedures.

Strategic Information Systems Plan (SISP): A plan that describes how information will be collected, processed, and disseminated within and outside of an organization.

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Chapter 7.16

Privacy and Security in the Age of Electronic Customer Relationship Management

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ABSTRACT

This article presents a value exchange model of privacy and security for electronic customer relationship management within an electronic commerce environment. Enterprises and customers must carefully manage these new virtual relationships in order to ensure that they both derive value from them and minimize unintended consequences that result from the concomitant exchange of personal information that occurs in e-commerce. Based upon a customer's requirements of privacy and an enterprise requirement to establish markets and sell goods and services, there is a value exchange relationship. The model is an integration of the customer sphere of privacy, sphere of security, and privacy/security sphere of implementation.

INTRODUCTION

New technologies have fostered a shift from a transaction-based economy, through an Electronic Data Interchange (EDI) informational-exchange economy, to a relationship-based Electronic Commerce (EC) economy (Keen, 1999). We have moved from "*first order*" *transactional* value exchanges through "*second-order*" *informational* value exchanges to "*third-order*" *relational* value exchanges (Widmeyer, 2004). Three important types of EC relationships have been identified: between enterprises and customers (B2C); between enterprises (B2B); and between customers (C2C) (Kalakota & Whinston, 1996). Additional relationships between Governments (G2G), enterprises (G2B), and customers (G2C) have become more important as EC and e-government have matured, and legislation, regulation, and oversight have increased (Friel, 2004; Reddick, 2004); however, these are not the focus of this article. Relational value exchanges have become central to success and competitive advantage in B2C EC, and it is here that we focus on privacy and security in the age of virtual relationships.

Both enterprises and customers must carefully manage these new virtual relationships to ensure that they derive value from them and to minimize the possible unintended negative consequences that result from the concomitant exchange of personal information that occurs when goods and services are purchased through EC. The need to manage these relationships has resulted in the development of Electronic Customer Relationship Management (e-CRM) systems and processes (Romano & Fjermestad, 2001-2002). E-CRM is used for different reasons by enterprises and customers. It is important to understand how and why both of the players participate in "*relational value exchanges*" that accompany the economic transaction and informational value exchanges of EC.

Enterprises use e-CRM to establish and maintain *intimate virtual relationships* with their *economically valuable* customers to derive additional value beyond that which results from economic value exchanges to improve return-on-investment (ROI) from customer relationships.

Customers obtain goods, services and information (economic value) through EC for purposes such as convenience, increased selection and reduced costs. EC requires customers to reveal personal information to organizations in order for transactions to be completed. The exchange of information between customers and organizations leads to the possibility of privacy violations perpetrated against the customer. It is the responsibility of the organizations to provide privacy policies and security measures that will not endanger customer trust.

In this article, we present a series of models "*sphere of privacy model,*" "*sphere of security model,*" "*privacy/security sphere of implementation model,*" and then integrate them into the "*relational value exchange model*" to explain privacy and security in the context of e-CRM, from the perspective of both customers and enterprises, to provide guidance for future research and practice in this important area. It is important for both customers and firms to understand each others' vested interests in terms of privacy and security, and to establish and maintain policies and measures that ensure that both are satisfactorily implemented to minimize damage in terms of unintended consequences associated with security breaches that violate privacy and lead to relationship breakdowns.

The remainder of this article is structured as follows: First, we explain why privacy and security are critically-important issues for companies and customers that engage in EC, and the consequences that can result from failure to recognize their importance or poor implementation of measures to ensure both for the organization and its customers. Second, we define privacy and security and their interrelationship in the context of CRM. Third, we present our relational value exchange model for privacy and security in e-CRM.

Customer Relationship Management Privacy and Security: Who Cares?

The data contained within a CRM application is often a company's most critical asset, yet because of the pivotal role this information plays in day-to-day business activities, it is also often the most vulnerable to security breaches and disruptions (Seitz, 2006 p. 62).

Before we explain and define privacy and security in detail and present our models and the relational value exchange model, we will describe the costs associated with failure to understand these concepts and failure to effectively ensure that both are protected in terms that firms and customers can understand: dollars and lost customers.

Economic Cost of Customer Security Breaches

The economic cost of security breaches, that is, the release or loss of customers' personal information, has been studied in a number of surveys over the past decade; while some studies show declines in the total and average losses over time, the costs are still staggering for many firms. New threats and vulnerabilities have arisen in the recent past, and these lower costs are most likely offset by increased expenditures to implement security measures and training.

The Computer Security Institute (CSI) and the Federal Bureau of Investigation (FBI) have conducted eleven annual surveys of computer crime and security since 1995. Some of the results of the last seven are presented (Gordon, Loeb, Lucyshyn, & Richardson, 2004, 2005, 2006; Power, 2002; Richardson, 2003). The Ponemon Institute also conducted two surveys on the costs and effects of data security breaches (Ponemon, 2005a, 2005b), and we will also present a portion of their results as well.

The CSI/FBI surveys have tracked the costs (losses) associated with security breaches for thirteen years; we focus on summary data from the last seven years to illustrate trends and changes in the economic costs of security breaches for organizations that responded with loss data. Table 1 reveals some interesting aspects about security breach costs over the past seven years. Several types of costs have been reported across all the years of the survey; these include: theft of proprietary information, sabotage of data or networks, system penetration, insider abuse of network access, financial fraud, denial of service, viruses, unauthorized insider access, telecom fraud, and laptop theft.

Other types of losses were reported in early years of the period but not in later periods or were reported in only the last three or even only the final survey in 2006, indicating that some threats have been better managed and new ones have arisen or been identified and quantified. Specifically, losses from telecom eavesdropping were reported to be on average from a high of $1.2 million in 2002 to a low on $15,000 in 2003; however, there were no reported losses in 2004, 2005, or 2006. Active wiretapping is another loss that was reported as an average of $5 million in 2000 and $432,500 in 2003, but not reported in any of the other years. Theft of proprietary information was reported as the highest loss for the four years from 2000 to 2003; then viruses took over the top spot in 2004 and remained the highest loss in 2005 and 2006. The results also show that between 2002 and 2003, there is a 62% reduction in the reported losses and, between 2003 and 2004, there is a 90% reduction in the losses. Thus, the enterprises are responding to the need for privacy and security. In 2004, three new loss types were reported: Web site defacement, misuse of a public Web application, and abuse of wireless networks. All three of these losses were also reported in 2005 and 2006. Six new losses were reported in 2006: bots (zombies) within the organization; phishing in which your organization was fraudulently represented as sender; instant messaging misuse; password sniffing; DNS server exploitation; and a general category of other.

The time-series results reveal the dynamic nature of the security environment and the threats and costs over time as companies identify them and take actions to try to minimize or eliminate losses. Figure 1 reveals that losses from security breaches appear to be going down over time, which is a positive finding; however, they do not tell the whole story, because the same surveys from which the data in Table 1 are taken also found that budgets in terms of operating expenses and capitol investment for security and training also rose at the same time.

Figure 2 shows the reported average expenditure per employee for operations, capitol investment, and awareness training from 2004 to 2006 for four different-sized companies based on reported revenues. It is important to keep in

Table 1. Average loss per year per loss type

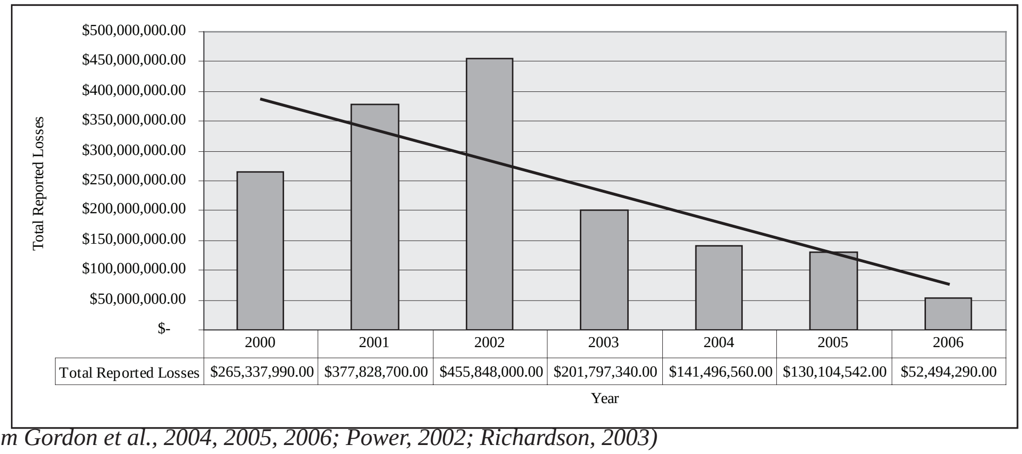
	2000	2001	2002	2003	2004	2005	2006
Theft of proprietary info.	$3,032,818	$4,447,900	$6,571,000	$2,699,842	$42,602	$48,408	$19,278
Sabotage of data or networks	$969,577	$199,350	$541,000	$214,521	$3,238	$533	$831
Telecom eavesdropping	$66,080	$55,375	$1,205,000	$15,200			
System penetration by outsider	$244,965	$453,967	$226,000	$56,212	$3,351	$1,317	$2,422
Insider abuse of Net access	$307,524	$357,160	$536,000	$135,255	$39,409	10,730	$5,910
Financial fraud	$1,646,941	$4,420,738	$4,632,000	$328,594	$28,515	$4,014	$8,169
Denial of service	$108,717	$122,389	$297,000	$1,427,028	$96,892	$11,441	$9,335
Virus	$180,092	$243,835	$283,000	$199,871	$204,661	$66,961	$50,132
Unauthorized insider access	$1,124,725	$275,636	$300,000	$31,254	$15,904	$48,878	$33,920
Telecom fraud	$212,000	$502,278	$22,000	$50,107	$14,861	$379	$4,033
Active wiretapping	$5,000,000	$-	$-	$352,500			
Laptop theft	$58,794	$61,881	$89,000	$47,107	$25,035	$6,428	$21,223
Web site defacement					$3,562	$180	$519
Misuse of public Web application					$10,212	$3,486	$861
Abuse of wireless network					$37,767	$852	$1,498
Bots (zombies) within the organization							$2,951
Phishing in which your organization was fraudulently represented as sender							$2,069
Instant messaging misuse							$931
Password sniffing							$515
DNS server exploitation							$288
Other							$2,827
Totals	$12,886,153	$10,688,458	$14,702,000	$5,557,491	$438,809	$203,661	$167712

(Data from Gordon et al., 2004, 2005, 2006; Power, 2002; Richardson, 2003)

mind that these are ***average*** expenditures ***per employee,*** so for any given company the total outlay would be calculated by multiplying the number of employees in the organization by their actual expenditures, which could be higher or lower than the average.

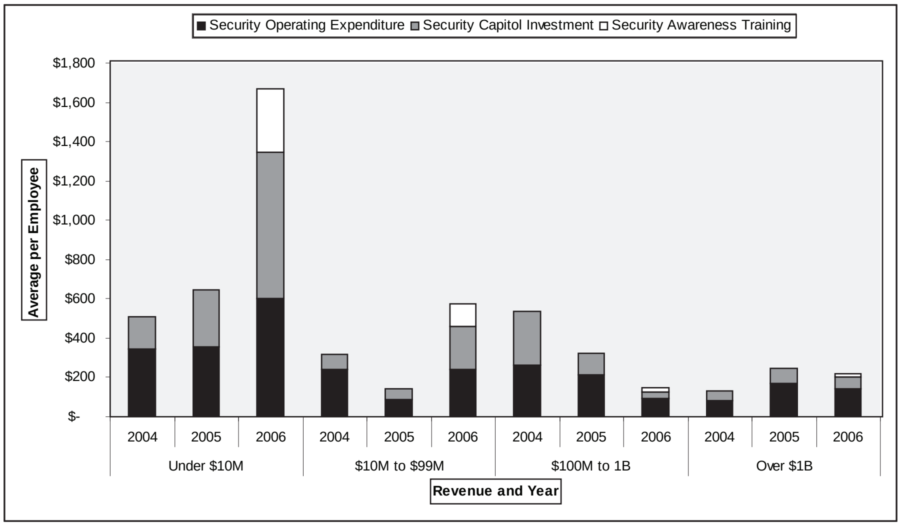
This time series of expenditures for security reveals interesting trends as well. One is that

Figure 1. Total reported losses per year across seven CSI/FBI surveys



(Data from Gordon et al., 2004, 2005, 2006; Power, 2002; Richardson, 2003)

Figure 2. Reported average expenditure per employee



(Data from Gordon et al., 2004, 2005, 2006; Power, 2002; Richardson, 2003)

there appears to be economies of scale for security measures, that is, organizations with higher revenue seem to have smaller expenditures per employee (Gordon et al., 2006), but that may not translate into smaller overall expenditures. A second similar trend is that lower revenue firms seem to have had increases in security expenditures while higher revenue firms have seen decreases. Regardless of these trends, the reduction in losses due to security breaches and attacks have been accompanied by increased investment in security software, hardware, and training; therefore, it is logical to conclude that either through losses or through increased defense expenditures, security continues to have a large economic impact on firms. Finally, it also reveals that in 2006, firms began to spend funds for security awareness training that were not reported in the previous years of the CSI/FBI surveys.

In November, 2005, the Ponemon Institute (Ponemon, 2005a) surveyed the costs incurred by 14 firms in 11 different industries that experienced security breaches. The size of the breaches in terms of customer records ranged from 900,000 to 1,500 for a total of 1,395,340 records and an average of 99,667 per breach.

Table 2 summarizes total average cost (including direct, indirect, and opportunity costs) for all 14 firms. The average total cost per company was $13,795,000 or $138 per lost customer record. These 14 firms had total losses of $193,103,545.

The economic cost of security breaches is still a staggering amount of money. Many enterprises have been able to reduce the losses by expending large amounts of resources. However, as shown in Table 1, new threats and vulnerabilities are being unleashed on enterprises every year. The lower costs are most likely offset by increased expenditures to implement new security measures and training. These economic costs are only part of the story, because there are also costs associated with lost customers, and opportunity costs associated with potential customers going elsewhere due to the security breach publicity. The next section discusses losses in these less tangible, but critically-important areas.

Cost of Security Breaches in Terms of Lost Customers

The Ponemon (2005a) survey found that security breaches have potentially severe costs to organizations in terms of lost customers and decreased customer trust in the organizations' ability to secure data and maintain the levels of privacy and confidentiality that customers expect. Ponemon also found that roughly 86% of security breaches involved loss or theft of customer information.

Ponemon (2005b), in "The National Survey on Data Security Breach Notification", polled 9,154 adult-aged respondents in all major U.S. regions, and found that damage to corporate reputation, corporate brand, and customer retention was very high among affected individuals:

- 1,109 (11.6%) reported that an organization had communicated to them a loss or theft of their personal information;
- upon receipt of a notification of a breach, nearly 20% of respondents reported that they had terminated their relationship with the firm;
- 40% of those that received notification reported that they might terminate the relationship due to the breach;
- 58% reported that they believed that the breach had lowered their confidence and trust in the organization that reported it;
- 92% of respondents blamed the company that notified them for the breach;
- only 14% of respondents that were notified of a breach were not concerned; and
- greater than 85% of all respondents reported they were concerned or very concerned about the effect that a data breach would have on them.

Table 2. Costs of security breaches for 14 firms in 2005

	Direct Costs	Indirect Costs	Lost Customer Costs	Total Costs
Total Cost for All Companies	$49,840,593	$123,262,952	(factored into indirect costs)	$193,103,545
Average Cost Per Company	$4,990,000	$1,347,000	$7,458,000	$13,795,000
Average Cost Per Lost Record	$50	$14	$75	$138

(Data from Ponemon, 2005a)

Furthermore, the National Survey on Data Security Breach Notification (Ponemon, 2005b) reported that the majority of respondents were not satisfied with the quality of the notification and communication processes. This is where CRM becomes important, and how enterprises communicate security breaches to their customers has an impact. The survey highlighted the following communication experiences:

- Companies that reported breaches to consumers were more than four times (417%) as likely to experience customer churn if they **failed** to communicate to the victim in a clear, consistent, and timely fashion;
- Companies that sent e-mails or form letters to communicate a breach of consumer data were more than three times (326%) as likely to experience customer churn than companies that used telephone or personalized letters (or a combination of both);
- Over 82% of respondents believed that it is always necessary for an organization to report a breach even if the lost or stolen data was encrypted, or there was no criminal intent. The type of information involved in the breach was also not a factor; and
- About 59% of respondents do not have confidence in U.S. state or federal regulations to protect the public from data security breaches by organizations.

The high cost of security breaches comes from efforts to prevent them and the cost of the aftermath of a breach. Customers appear to be more likely to terminate their relationship with an enterprise after a security breach. In addition, the timeliness and manner in which a breach notification is delivered is important. It appears that telephone calls immediately after (or at least before a public disclosure) followed up with a personal letter, is best to maintain trust and manage the relationship with the customer. Customers are concerned about protecting their privacy and identity, and they expect companies to be vigilant in securing any data they share. In the next two sections, we discuss and define both privacy and security within the context of EC and e-CRM.

PRIVACY DEFINED

The concept of privacy dates back into antiquity: For example, Aristotle (384–327 BCE) made explicit distinctions between a public sphere and political life, ‘πολιχ’ (*polis,* city) and one’s private sphere or family life, ‘οικοχ‘ (*oikos, home) that refers to a separate private domain (DeCew, 2002; Roy, 1999; Rykwert, 2001).*

DeCew (2002) explains that privacy does not have a single shared definition:

> *The term ‘privacy’ is used frequently in ordinary language as well as in philosophical, political and legal discussions, yet there is no single definition or analysis or meaning of the term. The concept of privacy has broad historical roots in sociological and anthropological discussions about how extensively it is valued and preserved in various cultures. Moreover, the concept has historical origins in well known philosophical discussions, most notably Aristotle’s distinction between the public sphere of political activity and the private sphere associated with family and domestic life. Yet historical use of the term is not uniform, and there remains confusion over the meaning, value and scope of the concept of privacy.*

DeCew (2002) further explains that there are several specific types or meanings of privacy that include control of information, human dignity (individual dignity and integrity, personal autonomy, and independence), degrees of intimacy, social relationships, and unwanted access by others. Each of these conceptualizations of privacy is important and meaningful; however, within the scope of this article, information systems (IS) research and practice in general, and EC specifically, we adopt the concept of "*informational privacy*" (DeCew, 2002). Privacy is an important issue for EC because new technologies have enabled personal information to be communicated in ways that were not possible in earlier time periods. Next we discuss the historical background of informational privacy and define privacy within the scope of this article.

Informational Privacy

Warren and Brandeis (*later Supreme Court Justice Brandeis*) (Warren & Brandeis, 1890) in their well-known essay "*The Right to Privacy*" cited "*political, social, and economic changes*" and recognized "*the right to be let alone*" to argue that extent law at the time did afford for protection of individual privacy. In 1890, technologies such as newspapers, photography, and others had led to privacy invasions through dissemination of details of peoples' private lives (Warren & Brandeis, 1890). They argued that the right to privacy is based on the general principle of "*the right to one's personality*" and the more specific principle of "*inviolate personality*" (Warren & Brandeis, 1890).

They asserted that the privacy principle was a part of the common law and the protection of a "*man's house as his castle*"; however, they also argued that new technologies had changed how private information was disseminated and thus required recognition of a separate and explicit protection of individual privacy (Warren & Brandeis, 1890). Their essay laid the foundation for what would become the idea of privacy as a person's control over information about themselves.

Two theories of privacy have stood the test of time and also have figured prominently in major privacy reviews in the 1970's, 1980's, and 1990's (Margulis, 2003): Westin's (1967) four states and four functions of privacy and Altman's five properties of privacy. We focus here on Westin's theory.

Westin (1967) defined four states of privacy; that is how privacy is achieved (Margulis, 2003) and four functions (purposes) of privacy; that is why one seeks privacy (Margulis, 2003):

States of Privacy

1. **Solitude**: an individual separated from the group and freed from the observation of other persons;
2. **Intimacy**: an individual as part of a small unit;
3. **Anonymity**: an individual in public but still seeks and finds freedom from identification and surveillance; and
4. **Reserve:** based on a desire to limit disclosures to others; it requires others to recognize and respect that desire.

Functions of Privacy

1. **Personal Autonomy**: desire to avoid being manipulated, dominated, or exposed by others or control over when information is made public;
2. **Emotional Release**: release from the tensions of social life such as role demands, emotional states, minor deviances, and the management of losses and of bodily functions. Privacy, whether alone or with supportive others, provides the "time out" from social demands, hence opportunities for emotional release;
3. **Self-Evaluation:** integrating experience into meaningful patterns and exerting individuality on events. It includes processing information, supporting the planning process (e.g., the timing of disclosures), integrating experiences, and allowing moral and religious contemplation; and
4. **Limited and protected communication**: limited communication sets interpersonal boundaries; protected communication provides for sharing personal information with trusted others.

Westin's (1967) definition is the one that we adopt for this paper and that we think is the one that should be adopted by IS researchers and practitioners as well as EC customers:

Privacy is the claim of individuals, groups, or institutions to determine for themselves when, how, and to what extent information about them is communicated to others. (p. 7)

Westin (1967) also pointed out that privacy is not an absolute but that:

Each individual is continually engaged in a personal adjustment process in which he balances the desire for privacy with the desire for disclosure and communication…. (p. 7)

With this definition in mind, we again turn to recent surveys of consumers and businesses to gain an understanding of how security breaches that violate privacy are perceived and handled. Ackerman, Cranor, and Reagle (1999) surveyed consumers to learn how comfortable they were with providing different types of personal information with businesses, while Ponemon (2005b) gathered data on actual breaches. Table 3 illustrates that data from the Ackerman et al. (1999) survey of consumer concerns and the Ponemon (2005b) survey of actual data breaches reveals that there may be a mismatch in terms of what information consumers would prefer not to have revealed and what has actually been lost or stolen. Ponemon (2005b) surprisingly found that some of the more sensitive information that consumers are most reticent to reveal and that could result in the most damage are the ones that are most often released.

Only 1% of consumers surveyed were comfortable always or usually with providing information such as their Social Security numbers (Ackerman et al., 1999), yet 38% of all breaches reported in another survey involved SSNs (Ponemon, 2005b). Similar types of mismatches can be seen for several other data types in Table 3. These results illustrate that companies may not secure the types of personal information that consumers are most concerned about well enough (SSNs, credit card numbers, and home telephone numbers) and may place too much emphasis on the security of information that consumers are more willing to share (i.e., e-mail addresses and mailing addresses). This leads us to question whether firms take into consideration the privacy expectations of consumers when they decide how to protect different types of data. We think that firms should take consumer expectations and willingness to reveal information into account when establishing security measures to protect different types of information, as this would focus resources in such a way as to engender trust from the consumer and also to minimize potential losses due to breaches.

Table 3. Comparison of actual data types released and consumer concern

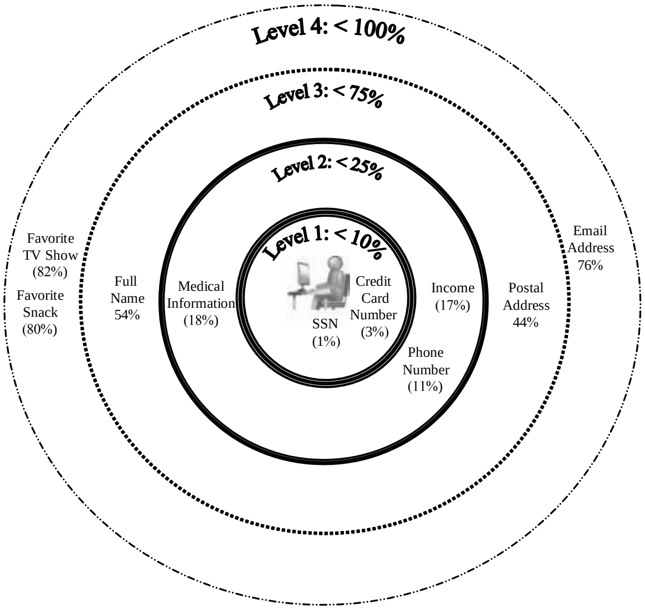
Data Type	Data Released	Consumer Comfort Level
Name	54%	54%
SSN	38%	1%
Credit Card Number	37%	3%
Home Telephone	36%	11%
Mailing address	23%	44%
E-mail Addresses	10%	76%

(Data from Ackerman et al., 1999 and Ponemon, 2005b)

Figure 3 presents our model of the personal "sphere of privacy" based on Ackerman's findings that illustrates how firms might establish levels of security that are consonant with both consumer willingness (comfort) to reveal information and also with the potential amount of damage that could occur from a breach of specific types of customer information.

We argue that firms should be most vigilant in securing information that consumers would

Figure 3. Model of the customer "sphere of privacy"



(Data from Ackerman et al., 1999)

most like to protect and should establish levels or zones of security of different strengths. Later in the paper we will tie this model to security strategies and technology implications.

Based on Ackerman et al. (1999) and Ponemon's (2005b) data (see Table 3), it is clear that consumers want their SSNs, credit card numbers, and telephone numbers kept private. In other words, consumers place maximum value on these data items in contrast to their mailing address and their e-mail address. Enterprises need to be sure and recognize what information is critical so as to protect it and ensure business continuity (Gordon & Loeb, 2002).

This leads us to the next section on security. Security is the technology and policies that an enterprise and consumer have to keep their valuable information secure.

SECURITY

Security breaches affect most enterprises and government agencies. A recent survey reports that 84% of all enterprises will be affected by a security breach, which is a 17% increase over the last three years (2004-2006) (Ferguson, 2006). Those enterprises and government agencies in the survey reported that when a security breach happened, 54% lost productivity, 20% reported lost revenue, and 25% claimed to have suffered some sort of public backlash with either damage to their reputation or loss of customer trust. Thirty-eight percent of these organizations reported that the breach was internal. Furthermore, according to the survey, many of them did not take the issue seriously enough. Only one percent of those surveyed thought IT security spending was too high, while 38% said it was much too low (Ferguson, 2006). The results suggest that even though organizations are investing in security technologies, they still are not achieving the results that they seek.

Security Defined

The term security can be used in reference to crime and accidents of all kinds. Security is a vast topic including security of countries against terrorist attack, security of computers against hackers, home security against burglars and other intruders, financial security against economic collapse, and many other related situations.

Following are four definitions that provide a narrower focus:

1. **Security**: a very general term covering everything;
2. **Computer Security**: "the discipline that helps free us from worrying about our computers" (Landwehr, 2001, p. 3). Computer security is the effort to create a secure computing platform, designed so that agents (users or programs) can only perform actions that have been allowed. This involves specifying and implementing a security policy. The actions in question can be reduced to operations of access, modification, and deletion. Computer security can be seen as a subfield of security engineering, which looks at broader security issues in addition to computer security;
3. **Information Security**: the protection of information systems against unauthorized access to or modification of information, whether in storage, processing, or transit, and against denial of service to authorized users, including those measures necessary to detect, document, and counter such threats (**NSTISSC,** 1999). IS security has previously concentrated on confidentiality of information stored electronically. The rapid growth in the volume of such information and the uptake of e-commerce within organizations have heightened the need for increased security to protect the privacy of this information and prevent fraudulent activities (Spinellis, Kokolakis, & Gritzalis, 1999); and
4. **Data Security**: the most important part of security - securing the data from unauthorized use.

From the point of view of e-CRM, the above definitions do not help us much. In the section on privacy, information such as SSN and credit card numbers were more critical to consumers than an e-mail address. Thus, we need to look at the security components.

Security Components

A recent meta-analysis of critical themes in electronic commerce research by Wareham, Zheng, and Straub (2005) identified security as an underserved area in IS research. They suggest and support Gordon and Loeb's (2002) assertion that information is an asset of value to an organization and consequently needs to be suitably protected in order to ensure business continuity, minimize business damage, and maximize ROIs and business opportunities (BSI, 1999). The purpose of information security could be characterized as the preservation of confidentiality, integrity, and availability for information assets to keep business value (BSI, 1999; Gordon & Loeb, 2002; Sheth, Sisodia, & Sharma, 2000). Then, in general, IS security is the effective implementation of policies to ensure the confidentiality, availability, and integrity of information and assets to protect from theft, tampering, manipulation, or corruption (Smith & Jamieson, 2006). This also follows from the International Standards Organization (ISO) 17999 Information Security Standard (ISO/IEC, 2005).

The ISO 17799 standard is an internationally-recognized information security management guidance standard (ISO/IEC, 2005). ISO 17799 is high level, broad in scope, and conceptual in nature. This approach allows it to be applied across multiple types of enterprises and applications. It has also made the standard controversial among those who believe standards should be more precise. In spite of this controversy, ISO 17799 is the only "standard" devoted to Information Security Management in a field generally governed by "Guidelines" and "Best Practices" (ISO/IEC, 2005).

ISO 17799 defines information as an asset that may exist in many forms and has value to an organization. Thus, the goal of information security is to suitably protect this asset in order to ensure business continuity, minimize business damage, and maximize return on investments. The objective of the standard is to safeguard:

- **Confidentiality** - ensuring that information is accessible only to those authorized to have access;
- **Integrity** - safeguarding the accuracy and completeness of information and processing methods; and
- **Availability** - ensuring that authorized users have access to information and associated assets when required.

Thus, our basic definition of security in the e-commerce environment is the necessary hardware, software, network controls, data encryption, policies, and procedures in place for an enterprise to ensure that a consumer's information is confidential, has integrity, and is available for e-commerce use.

Enterprise and Consumer Views of Security

Enterprises and consumers will view the security components somewhat differently. Table 4 shows the enterprise and the consumer view. For confidentiality, both the enterprise and consumer expect the security features to prevent unauthorized access to the data. For integrity, the enterprise must use the data supplied by the consumer only for business purposes and must not sell or release the personal data to other enterprises without authorization from the consumer. It is the consumer's obligation to assure that the data is correct. For availability, it is the enterprise's responsibility to assure that the data is available for the consumer and for e-commerce. From the consumer's point of view, the data needs to be available for modification (*i.e.*, change of address, change of preferences).

IS security has previously concentrated on confidentiality of information stored electronically. The rapid growth in the volume of such information and the uptake of e-commerce within organizations has heightened the need for increased security to protect the privacy of this information and prevent fraudulent activities (Spinellis et al., 1999).

Computer security is the effort to create a secure computing platform, designed so that agents (users or programs) can only perform actions that have been allowed. This involves specifying and implementing a security policy. The actions in question can be reduced to operations of access, modification, and deletion. Computer security can be seen as a subfield of security engineering, which looks at broader security issues in addition to computer security.

Table 4. Security components

Security Components	Enterprise/Organization	Consumers
Confidentiality	Prevent unauthorized access Secure all personal information	Prevent unauthorized access How my data is being protected
Integrity	Data used for only business purposes Data not sold without authorization	Data is correct
Availability	Data available for customer Data available for e-commerce	Data available for modification

Security Threats and Vulnerabilities

Table 5 highlights the major threats and vulnerabilities of enterprise networks and consumer use. Threats are any type of unwanted or unauthorized intrusions, attacks, or exploitations into the system (Volonino & Robinson, 2004). Vulnerabilities are twofold: from the consumer point of view - human error, using poor passwords, or participating in chat rooms; from the enterprise side - the complexity of the software which results in misconfigurations, programming errors, or other flaws. The major Internet security breaches are presented in Table 5 (Volonino & Robinson, 2004).

In a recent trade press article (August 29, 2006), AT&T revealed (Preimesberger, 2006) that an undisclosed number of unauthorized persons had illegally hacked into one of its computer systems and accessed the personal data, including credit card information, of about 19,000 customers who had purchased DSL equipment through the company's online store. The unauthorized electronic access took place over the weekend of August 26-27, 2006, and was discovered within hours, according to a company spokesperson. The electronic store was shut down immediately and remained off-line as we write this article. The cost of this security breach has not been disclosed; however, the company is also working with law enforcement to investigate the incident and pursue the perpetrators. The 19,000 customers are being notified by e-mail, phone calls, and letters. Furthermore, AT&T intends to pay for credit monitoring services for customers whose accounts have been impacted. Clearly breaches are still occurring, even to the largest companies that we would expect would have adequate security in place.

Security: No More than Managing Risk

Gordon and Loeb (2002) suggest that the optimal amount to spend on information security is an increasing function of the level of vulnerability of the information. However, the optimal amount to spend on information security does not always increase with the level of vulnerability of such information. They further suggest that managers should budget for security on information that is in a mid-range of vulnerability to security breaches. Furthermore, managers may want to consider partitioning information sets into low, middle, and high levels of security breach vulnerability. Some information may be difficult to protect at a high security level and thus is best defended at a more moderate level. Their findings suggest that the optimal amount to spend on information security never exceeds 37% of the expected loss resulting from a security breach.

Table 5. Security threats and vulnerabilities

Internal Threats		External Threats	
Organizations	**Consumers**	**Organizations**	**Consumers**
• Illness of personnel • Temporary staff • Loss of key personnel • Loss of network service • Disgruntled employees • Disgruntled consultants • Labor dispute • Malware • Software bugs	• User misuse • Malware • Software bugs • Poor passwords • Chat room participation	• Severe storms • Utility outage • Natural disasters • Theft of hardware • Software compromise • Hackers • Adversaries	• Severe storms • Utility outage • Natural disasters • Unauthorized access • Unauthorized sale • Theft of computer • Hackers • Denial of service

Smith and Spafford (2004) also suggest that security is managing risk. In addition, they suggest that the major security challenges are:

1. Stop epidemic-style attacks;
2. Build trustworthy large-scale systems;
3. Make quantitative information systems risk management as good as quantitative financial risk management; and
4. Give end users security that they can understand and privacy that they can control.

Kuper (2005) suggests that the sole reason that information technology exists is to leverage the critical asset of data. Thus, security is data and network integrity, the protection of and access to the data. Also, (Kuper, 2005) from 2000 to 2005, enterprises have spent $15 billion on perimeter level security (antivirus, firewal1s, and approximately $1.5 billion on encryption software,) one of the more obvious technologies for protecting the data. This supports Gordon and Loeb's (2002) assertion that the amount spent does not always match the required level of vulnerability.

Kuper (2005) suggests several new approaches to data security:

1. Data and network integrity - protecting access to data;
2. Inclusion/exclusion security - trusted, known users are handled differently than unknown users (nodes);
3. Embedded security - more security into all aspects of IT components (hardware, software, or service); and
4. Improved approaches - dynamic XML and Web service architectures.

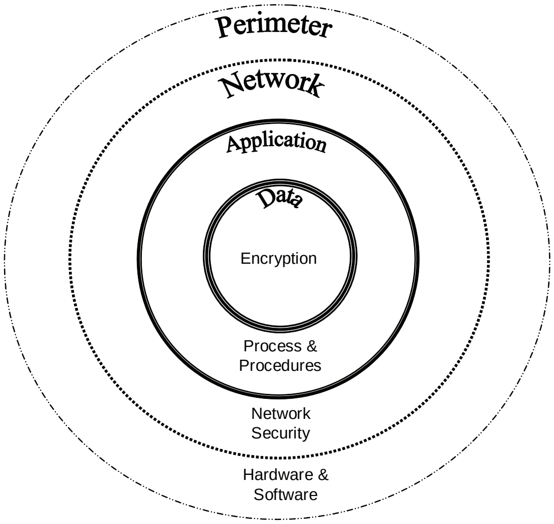
In this regard, enterprises need to work at the data level (using encryption) to secure the most critical data. The second element is that of trust; trusted consumers should be treated differently than unknown consumers. This is one of the objectives of CRM. Next, embedded security for the enterprise at the hardware/software and server level can help to minimize security breaches. Last, new dynamic approaches can be used.

Table 6 illustrates how privacy and security are interrelated in terms of the levels of data, security strategy, and technologies required to achieve appropriate vigilance. Our model of the sphere of privacy suggests that some information is not as critical to secure (i.e., e-mail address), while other information (consumer's SSN) is critical to secure. Kuper (2005) suggests that initially enterprises focused security at the perimeter, but as they learned from persistent attacks they moved from the edge down deeper, layer by layer, to secure the very data itself through encryption. We rename this as the Enterprise "Sphere of Security" model (see Figure 4). Different technologies are required at the different levels, and the most crucial-level data requires encryption to ensure that it is not released (Volonino & Robinson, 2004). At the perimeter (level 4), firewalls and malware

Table 6. Complementarity of privacy, security, and technology

Sphere of Privacy (Ackerman, 1999)	Sphere of Security (Kuper, 2005)	Technology (Volonino & Robinson, 2004)
Level 4: E-mail	Perimeter	Hardware/Software
Level 3: Full name	Network	Network Security
Level 2: Phone number	Application	Process and Procedures
Level 1: SSN	Data	Encryption

Figure 4. Model of the enterprise "sphere of security"



prevention software may offer enough protection for data that is not as sensitive.

Enterprise Privacy/Security Sphere of Implementation

There is an adage that you cannot ensure privacy if you do not first have security. Thus enterprises and consumers need to be prepared for an increasingly hostile public network. Both must provide the right (and updateable) hardware control, data and software controls, and encryption controls to ensure optimal security. Both must also consider the risks, costs, and possible consequences of releasing private information.

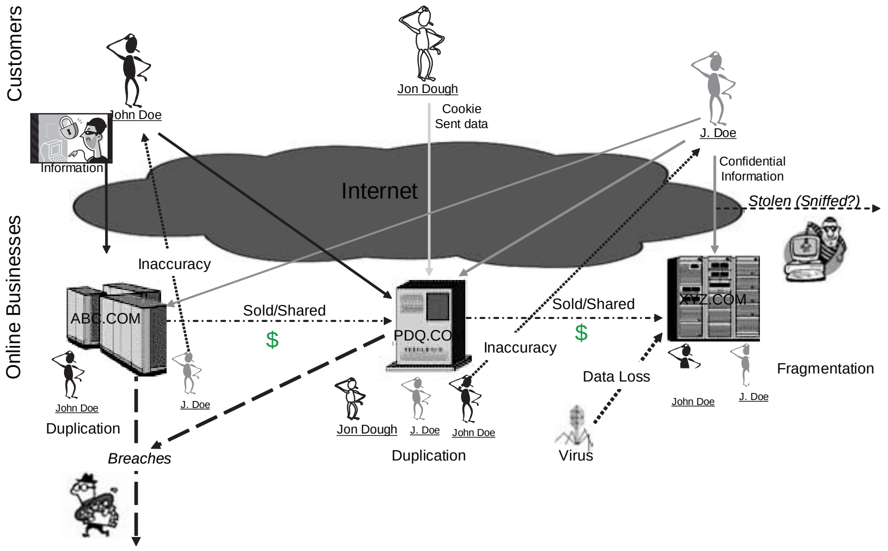
A complete solution to either the security or the privacy problem requires the following three steps which become our privacy/security sphere of implementation model:

- **Policy**: The first step is to develop a security or privacy policy. The policy precisely defines the requirements that are to be implemented within the hardware and software of the computing system and those that are external to the computing system, including physical, personnel, and procedural controls. The policy lays down broad goals without specifying how to achieve them.
- **Mechanism**: The security or privacy policy is made more concrete with the mechanism necessary to implement the requirements of the policy. It is important that the mechanism perform the intended functions.
- **Assurance:** The last step deals with the assurance issue. It provides guidelines for ensuring that the mechanism meets the policy requirements with a high degree of assurance. Assurance is directly related to the effort required to subvert the mechanism. Low-assurance mechanisms are easy to implement, but also relatively easy to subvert; on the other hand, high-assurance mechanisms are notoriously difficult to implement.

CONDITIONAL RELATIONAL "VALUE EXCHANGE" MODEL

Figure 5 illustrates customer data flow and some privacy and security issues related to e-CRM.

Figure 5. Customer dataflow and privacy and security issues



The Figure shows that each customer has their own personal identity as well as personal and confidential information that they may choose to share, or unknowingly (unwittingly) share with online businesses with which they interact, or with others that obtain the information through some other mechanism than a known direct transfer. The Figure illustrates both intentional and unintentional information transfer from customers to other entities. Three representative customers interact with one or more of three online businesses, as well as other players. Several different scenarios that can affect privacy and security are depicted in the Figure.

Scenarios for Customer John Doe: Mr. Doe interacts with online businesses ABC.COM and PDQ.COM and reveals “some” personally-identifiable information to both, but not necessarily the same information. Once this data is revealed, ABC.COM and PDQ.COM have a responsibility to keep it secure and accurate; however, both may fail in these responsibilities. If they share or sell the information to other companies, there will then be duplicate copies of the information in multiple systems, each of which has different levels of security and protection, and the risk that John Doe’s information may be used for purposes other than he intended increases. Additionally, duplicate copies may not be updated if Mr. Doe changes his address, e-mail, or phone number, and thus inaccuracies due to redundant data that is not synchronized can and do multiply. Another possible security and privacy issue is that data from other customers with similar names to John Doe may be inaccurately associated with him, or he may be inaccurately associated with their data. This can result in unwanted offers being sent, invalid information being released, or even inaccurate information that changes the customers’ status and affects their credit score, ability to purchase, or reputation. The complex data exchange environment and the increase in the number and types of attacks and threats makes it very hard for customers to be confident that their data will be secured and their privacy not violated.

Figures 6 and 7 present our conditional relational “value exchange” model. The basic value exchange model (Figure 6) integrates our customer sphere of privacy with our sphere of security model and the enterprise privacy/security sphere of implementation. If an enterprise is to succeed in

Figure 6. Conditional relational "value exchange" model

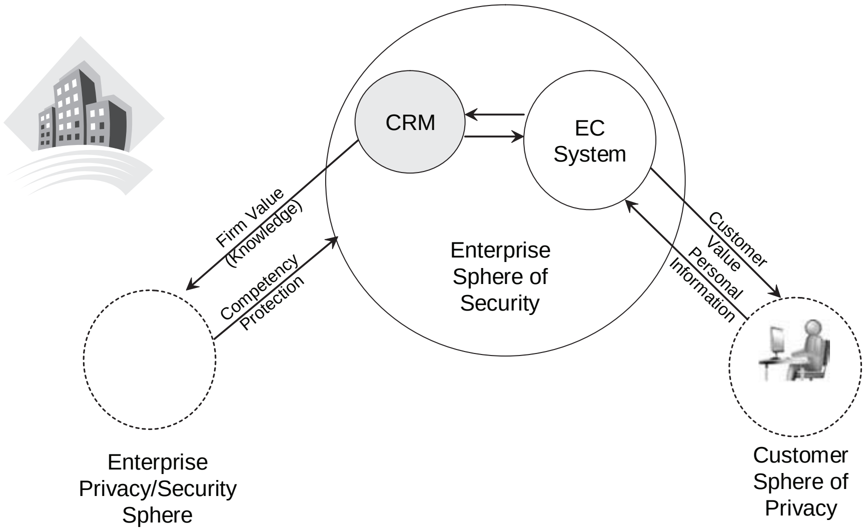
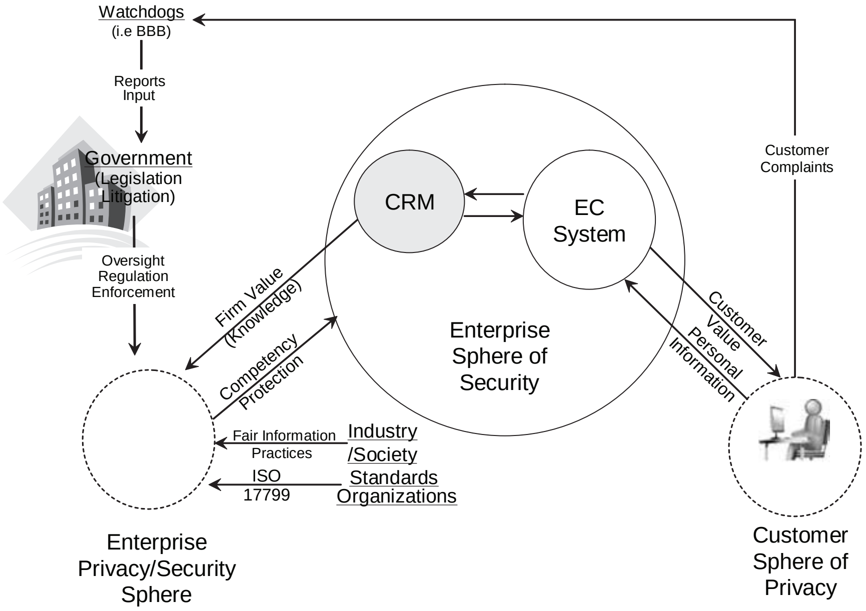


Figure 7. Extended model with watchdogs, government, society, and standards organizations



the EC environment, it must provide the necessary security to attract and retain customers. Surveys have shown that (Ackerman et al., 1999; Ponemon, 2005a) customers will churn if they feel that their privacy has been or may be violated.

The value exchange model works through the EC system. The customer interested in obtaining information, evaluating a product or service, or even buying a product or service connects with the EC system and then provides the information that is required from their sphere of privacy. Simultaneous with the customer's inquiry or purchase (the customer's value exchange) the e-CRM system is updated. This in turn becomes the enterprise's value exchange. Then, based upon detailed internal and external analysis, the enterprise's privacy/security policies, assurances, and mechanisms should be modified.

Clearly this is a value exchange model. Prabhaker (2000) suggests that businesses can add value to their EC offerings by leveraging Internet technology (the sphere of security) in coordination with proactive measures (privacy/security sphere of implementation) to preserve consumer privacy (the customer sphere of privacy). This is further supported by Schoder and Madeja (2004), who suggest that e-CRM built upon knowledge about their customers and their ability to serve their customers based on that knowledge has proven to be a key success factor in EC. They also suggest that the most effective way to collect customer data online is through an interactive, feature-rich environment that matches the customers' expectations of an enterprise. In other words, there should be a match between the enterprise's sphere of security and the customer's sphere of privacy.

Figure 7 is the extended value exchange model. This model adds in the interrelationships between the customers, the enterprise, the government, standards organizations, industry and society, and watchdog agencies (i.e., the Better Business Bureau, or BBB). This is a very complex open model. Fletcher (2003) suggests that consumer backlash to perceived invasions of privacy is causing government agencies, standards organizations, industry, and other watchdogs to be more proactive in developing guidelines and policies. Most major EC companies have a detailed privacy statement on their home page. For example, Amazon.com has 11 major items from "What personal information about customers does Amazon.com gather?" to "Examples of information collected". Their objective is to assure that the information that they collect from customers helps them personalize and continually improve the customer's shopping experience at Amazon.com (2006).

IMPLICATIONS FOR ENTERPRISES AND CUSTOMERS

Enterprises continue to collect more and more personal information from online transactions and are using this data to improve sales and service effectiveness (Fletcher, 2003; Romano & Fjermestad, 2003); this is e-CRM in the e-commerce environment. This has become one of the most significant issues confronting enterprises in the electronic age. The issues are securing privacy and security of consumer data while using advanced information systems technology (i.e., e-CRM, business intelligence, data warehousing, and data mining) to sell more goods and services to the consumer.

Consumers, on the other hand, want to get benefits (i.e., reduced time and reduced costs) from e-commerce; however, they are not willing to sacrifice data items such as SSN and credit card number to achieve these benefits. Consumers require that the enterprises safeguard their data.

CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

The objective of this article was to develop an integrated value exchange model for enterprises and consumers in an e-commerce environment. Enterprises want to attract and retain economically-valuable customers (Romano & Fjermestad, 2001-2002). Typically this is through e-CRM. However, the prime ingredient is customer data. Thus, an enterprise must employ the right levels of privacy, security, and policy spheres to enable the continued collection and use of consumer data. Gordon and Loeb (2002) suggest that information is an asset of value to an organization and consequently needs to be suitably protected in order to ensure business continuity, minimize business damage, and maximize ROIs and business opportunities. Information security is then characterized as the preservation of confidentiality, integrity, and availability of this information asset to maintain business value (BSI 1999; Gordon & Loeb, 2002; Sheth et al., 2000). IS security is the effective implementation of policies to ensure the confidentiality, availability, and integrity of information and assets to protect it from theft, tampering, manipulation, or corruption (Smith & Jamieson, 2006).

Enterprises can lose customers if they do not respond quickly enough and through the right communication channel after a security breach. Research suggests that this is best handled with personal telephone calls and follow-up personal letters (Ponemon, 2005b). The use of spam e-mail will not be effective and can, in fact, make customers more upset due to feeling disrespected in addition to their personal information being lost.

Our contributions are fourfold. First is our model of the customer sphere of privacy adapted from Ackerman et al.'s (1999) survey findings. This model presents the idea of levels of privacy for a consumer in terms of how willing they are to reveal personal information of different types. The highest level, level 1, corresponds to any personal information that consumers are almost never comfortable revealing, such as their Social Security Number or credit card numbers. Consumers will not reveal such information unless they fully trust the recipient. The lowest level, level 4, corresponds to personal information that many consumers are very comfortable revealing, such as their e-mail address. These levels also correspond with the potential seriousness of consequences from the consumers' information getting into the wrong hands. Release of an SSN or credit card number can result in identity theft or monetary losses, while release of an e-mail address may only result in additional spam e-mail. Both are negative consequences, but clearly the former is much more serious than the latter.

The second contribution is our enterprise sphere of security derived from Kuper's (2005) levels of security. This model represents the level of security required to support customer privacy ranging from the deepest internal data level to the externally-focused perimeter level. Accompanying this model is the technology required to support it. At the perimeter level, hardware and software (i.e., routers and firewalls) provide a modest level of protection, while at the data level more secure technologies such as encryption or perturbation are required to more vigilantly ensure protection of consumer privacy. The third contribution is the enterprise privacy/security sphere of implementation. These are the policies, mechanisms, and assurances to support privacy and security. Many enterprises provide such a policy statement on their Web site.

Our fourth contribution is the integrated value exchange model and the extended model. This model is built upon the interrelationships among the three spheres. The model proposes that both the enterprise and the customer exchange information when they transact via EC. The customer exchanges personal information in order to obtain customer value (reduced time and cost, as well as the goods, services, or information purchased). The enterprise gains customers and, via aggregation and data mining, competitive advantage from the knowledge about their customers. In order to keep their customers, the enterprise must provide competent protection for the customers' information. The extended model shows that there is substantial input from industry, standards organizations, the government, and other watchdog organizations.

In many cases, the major asset of an enterprise is its customers and data about them. There is a delicate balance (as the value exchange model illustrates) that must be maintained. The customers are only a mouse click away from an enterprise's competitors. Customers also have responsibilities to be careful and vigilant in that they must give up personal information in order to receive the benefits of EC. They must provide accurate and reliable information and also verify that a firm is trustworthy and employing adequate levels of security before revealing personal information. They should also think carefully about what information is required for a given transaction and not provide additional information that is not necessary. This can assist customers to make more informed queries and purchases and, at the same time, helps the enterprise market to them and to other customers more effectively through new mechanisms such as recommender systems, cross-selling, and preference discounts.

In the age of e-CRM, Enterprises and Customers have vast new opportunities to exchange value more quickly and effectively than ever before; however, along with these come new vulnerabilities and responsibilities to secure and protect privacy. Enterprises that fail to protect the privacy of their customers may find that many leave for the competition that will do so. E-CRM is about establishing and maintaining intimate relationships with customers to generate additional value and long-term loyalty; enterprises cannot do this if they do not provide the security required to protect their customers' privacy at the level of vigilance they expect. It may be necessary to provide personalized levels of security for the very best customers if they demand it. Just as investors can choose the level of risk they are willing to take for a potential return on investment, consumers will also choose which firms to do business with via EC based on the level of perceived risk they associate with them. Future research and practice in Information Assurance (Security and Privacy) will have to take the consumer's perspective more into account than at present.

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Section VIII
Emerging Trends

This section highlights research potential within the field of strategic information systems while exploring uncharted areas of study for the advancement of the discipline. Chapters within this section highlight advancements in enterprise resource planning, strategic technology planning, and strategic decision making for Green IT. These contributions, which conclude this exhaustive, multi-volume set, provide emerging trends and suggestions for future research within this rapidly expanding discipline.

Chapter 8.1

Patterns for Organizational Modeling

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ABSTRACT

Organizational modeling is concerned with analyzing and understanding the organizational context within which a software system will eventually function. This paper proposes organizational patterns motivated by organizational theories intended to facilitate the construction of organizational models. These patterns are defined from real world organizational settings, modeled in i* and formalized using the Formal Tropos language. Additionally, the paper evaluates the proposed patterns using desirable qualities such as coordinability and predictability. The research is conducted in the context of Tropos, a comprehensive software system development methodology.

INTRODUCTION

Analyzing the organizational and intentional context within which a software system will eventually operate has been recognized as an important element of the organizational modeling process also called early requirements engineering (see e.g., Anton, 1996; Dardenne, van Lamsweerde, & Fickas, 1993; Yu, 1995). Such models are founded on primitive concepts such as those of actor and goal. This paper focuses on the definition of a set of organizational patterns that can be used as building blocks for constructing such models. Our proposal is based on concepts adopted from organization theory and strategic alliances literature. Throughout the paper, we use i* (Yu, 1995) as the modeling framework in terms of which the proposed patterns are presented and accounted for. The research reported in this paper is being conducted within the context of the Tropos project (Giorgini, Kolp, Mylopoulos, & Pistore, 2004; Giorgini, Kolp, Mylopoulos, & Castro, 2005), whose aim is to construct and validate a software development methodology for agent-based software systems. The methodology adopts ideas from multi-agent system technologies, mostly to define the implementation phase of our methodology. It also adopts ideas from Requirements Engineering, where actors and goals have been used heavily for early requirements analysis. The project is founded on the premise that actors and goals are used as fundamental concepts for modeling and analysis during all phases of software development, not just early requirements, or implementation. More details about Tropos can be found in Giorgini, et al., 2005. The present work continues the research in progress about social abstractions for the Tropos methodology. In Kolp, Giorgini and Mylopoulos (2002a), we have detailed a social ontology for Tropos to consider information systems as social structures all along the development life cycle. In Giorgini, Kolp, and Mylopoulos (2002); Kolp, Giorgini, and Mylopoulos (2002b); and Kolp, Giorgini, and Mylopoulos (2006), we have described how to use this Tropos social ontology to design multi-agent systems architectures, notably for e-business applications (Kolp, Do, & Faulkner, 2004). As a matter of fact, multi-agent systems can be considered structured societies of coordinated autonomous agents. In the present paper, which is a extended and revised version of Kolp, Giorgini, and Mylopoulos (2003), we emphasize the use of organizational patterns based on organization theory and strategic alliances for early requirements analysis, with the concern of modeling the organizational setting for a system-to-be in terms of abstractions that could better match its operational environment (e.g., an enterprise, a corporate alliance, etc.).

The paper is organized as follows: The second section describes organizational and strategic alliance theories, focusing on the internal and external structure of an organization. The third section details two organizational patterns—the structure-in-5 and the joint venture—based on real world examples of organizations. These patterns are modeled in terms of social and intentional concepts using the i* framework and the Formal Tropos specification language. The fourth section identifies a set of desirable non-functional requirements for evaluating these patterns and presents a framework to select a pattern with respect to these identified requirements. The fifth section overviews the *Tropos* methodology. Finally, The sixth section summarizes the contributions of the paper and provides an overview of related work.

STRUCTURING ORGANIZATIONS

Organizational structures are primarily studied by *organization theory* (e.g., Mintzberg, 1992; Scott, 1998; Yoshino & Rangan, 1995), that describes the structure and design of an organization and *strategic alliances* (e.g., Dussauge & Garrette, 1999; Gomes-Casseres, 1996; Morabito, Sack, & Bhate, 1999; Segil, 1996), that model the strategic collaborations of independent organizational stakeholders who have agreed to pursue a set of agreed upon business goals.

Both disciplines aim to identify and study organizational patterns that describe a system at a macroscopic level in terms of a manageable number of subsystems, components, and modules interrelated through dependencies.

In this article, we are interested in identifying, formalizing and applying organizational modeling patterns that have been already well-understood and precisely defined in organizational theories. Our purpose is neither to categorize them exhaustively nor to study them on a managerial point of view. The following sections will thus only insist on patterns that have been found, due to their nature, interesting candidates, also considering the fact that they have been studied in great detail in the organizational literature and presented as fully-formed patterns.

Organization Theory

"An organization is a consciously coordinated social entity, with a relatively identifiable boundary, that functions on a relatively continuous basis to achieve a common goal or a set of goals" (Morabito et al., 1999). Organization theory is the discipline that studies both structure and design in such social entities. Structure deals with the descriptive aspects, while design refers to the prescriptive aspects of a social entity. Organization theory describes how practical organizations are actually structured, offers suggestions on how new ones can be constructed, and suggests how old ones can change to improve effectiveness. To this end, since Adam Smith, schools of organization theory have proposed models and patterns to try to find and formalize recurring organizational structures and behaviors.

In the following, we briefly present organizational patterns identified in Organization Theory. The structure-in-5 will be studied in detail in the next section.

The Structure-in-5

An organization can be considered an aggregate of five substructures, as proposed by Minztberg (1992). At the base level sits the *Operational Core*, which carries out the basic tasks and procedures directly linked to the production of products and services (acquisition of inputs, transformation of inputs into outputs, and distribution of outputs). At the top lies the *Strategic Apex* which makes executive decisions ensuring that the organization fulfils its mission in an effective way and defines the overall strategy of the organization in its environment. The *Middle Line* establishes a hierarchy of authority between the Strategic Apex and the Operational Core. It consists of managers responsible for supervising and coordinating the activities of the Operational Core. The *Technostructure* and the *Support* are separated from the main line of authority and influence the operating core only indirectly. The Technostructure serves the organization by making the work of others more effective, typically by standardizing work processes, outputs, and skills. It is also in charge of applying analytical procedures to adapt the organization to its operational environment. The Support provides specialized services at various levels of the hierarchy, outside the basic operating workflow (e.g., legal counsel, R&D, payroll, and cafeteria). We describe and model examples of structures-in-5 in the next section.

The Pyramid Pattern

A well-known hierarchical authority structure. Actors at lower levels depend on those at higher levels. The crucial mechanism is the direct supervision from the Apex. Managers and supervisors at intermediate levels only route strategic decisions and authority from the Apex to the operating (low) level. They can coordinate behaviors or take decisions on their own, but only at a local level.

The Chain of Values

The chain of values merges, backward or forward, several actors engaged in achieving or realizing related goals or tasks at different stages of a supply or production process. Participants who act as intermediaries, add value at each step of the chain. For instance, for the domain of goods distribution, providers are expected to supply quality products, wholesalers are responsible for ensuring their massive exposure, while retailers take care of the direct delivery to the consumers.

The Matrix

The matix proposes a multiple command structure: vertical and horizontal channels of information and authority operate simultaneously. The principle of unity of command is set aside, and competing bases of authority are allowed to jointly govern the workflow. The vertical lines are typically those of functional departments that operate as ”home bases” for all participants, the horizontal lines represent project groups or geographical arenas where managers combine and coordinate the services of the functional specialists around particular projects or areas.

The Bidding Pattern

The bidding pattern involves competitive mechanisms, and actors behave as if they were taking part in an auction. An auctioneer actor runs the show, advertises the auction issued by the auction issuer, receives bids from bidder actors and ensures communication and feedback with the auction issuer who is responsible for issuing the bidding.

Strategic Alliances

A strategic alliance links specific facets of two or more organizations. At its core, this structure is a trading partnership that enhances the effectiveness of the competitive strategies of the participant organizations by providing for the mutually beneficial trade of technologies, skills, or products based upon them. An alliance can take a variety of forms, ranging from arm’s-length contracts to joint ventures, multinational corporations to university spin-offs, and franchises to equity arrangements. Varied interpretations of the term exist, but a strategic alliance can be defined as possessing simultaneously the following three necessary and sufficient characteristics:

- The two or more organizations that unite to pursue a set of agreed upon goals remain independent, subsequent to the formation of the alliance.
- The partner organizations share the benefits of the alliances and control over the performance of assigned tasks.
- The partner organizations contribute on a continuing basis in one or more key strategic areas, e.g., technology, products, and so forth.

In the following, we briefly present organizational patterns identified in strategic alliances. The joint venture will be studied in detail in the third section.

Joint Venture Pattern

The joint venture pattern involves agreement between two or more intra-industry partners to obtain the benefits of larger scale, partial investment, and lower maintenance costs. A specific joint management actor coordinates tasks and manages the sharing of resources between partner actors. Each partner can manage and control itself on a local dimension and interact directly with other partners to exchange resources, such as data and knowledge. However, the strategic operation and coordination of such an organization, and its actors on a global dimension, are only ensured by the joint management actor in which the original actors possess equity participations. We describe and model examples of joint ventures in the third section.

Arm’s-Length Pattern

The arm’s-length pattern implies agreements between independent and competitive, but partner, actors. Partners keep their autonomy and independence but act and put their resources and knowledge together to accomplish precise common goals. No authority is lost or delegated from one collaborator to another.

Hierarchical Contracting Pattern

The hierarchical contracting pattern identifies coordinating mechanisms that combine arm’s-length agreement features with aspects of pyramidal authority. Coordination mechanisms developed for arm’s-length (independent) characteristics involve a variety of negotiators, mediators, and observers at different levels handling conditional clauses to monitor and manage possible contingencies, negotiate and resolve conflicts, and finally deliberate and take decisions. Hierarchical relationships, from the executive apex to the arm's-length contractors, restrict autonomy and underlie a cooperative venture between the parties.

Co-Optation Pattern

The co-optation pattern involves the incorporation of representatives of external systems into the decision-making or advisory structure and behavior of an initiating organization. By co-opting representatives of external systems, organizations are, in effect, trading confidentiality and authority for resource, knowledge assets, and support. The initiating system has to come to terms with the contractors for what is being done on its behalf; each co-optated actor has to reconcile and adjust its own views with the policy of the system it has to communicate.

MODELING ORGANIZATIONAL PATTERNS

We will define an organizational pattern as a metaclass of organizational structures offering a set of design parameters to coordinate the assignment of organizational objectives and processes, thereby affecting how the organization itself functions. Design parameters include, among others, goal and task assignments, standardization, supervision and control dependencies, and strategy definitions.

This section describes two of the organizational patterns presented in the second section: the structure-in-5 and the joint-venture.

Structure-in-5

To detail and specify the structure-in-5 as an organizational pattern, this section presents two case studies: LDV Bates (Bates, 2006) and GMT (GMT, 2006). They will serve to propose a model and a semi-formal specification of the structure-in-5.

LDV Bates

Agate Ltd. is an advertising agency located in Belgium that employs about fifty staff, as detailed in Table 1.

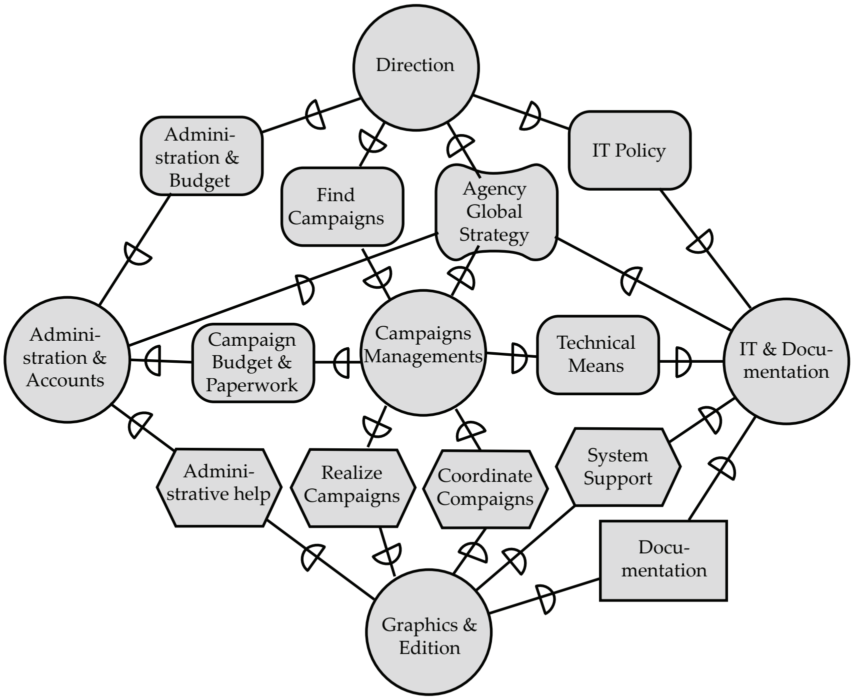
The *Direction*—four directors responsible for the main aspects of LDV Bates's *Global Strategy* (advertising campaigns, creative activities, administration, and finances)—forms the *Strategic Apex*. The *Middle Line*, composed of the *Campaigns Management* staff, is in charge of finding and coordinating advertising campaigns (marketing, sales, edition, graphics, budget, etc.). It is supported in these tasks by the *Administration and Accounts* and *IT and Documentation* departments. *Administration and Accounts* constitutes the *Technostructure* handling administrative tasks and policy, paperwork, purchases, and budgets. The Support groups the IT and Documentation departments. It defines the *IT policy* of Agate, provides *technical means* required for the management of campaigns, and ensures services for *system support* as well as information retrieval (*documentation* resources). The *Operational Core* includes the *Graphics and Edition* staff in charge of the creative and artistic aspects of realizing *campaigns* (texts, photographs, drawings, layout, design, and logos).

Figure 1 models LDV Bates in structure-in-5 using the i* strategic dependency model. i* is a framework for organizational modeling (Yu, 1995), which offers goal-and-actor-based notions, such as *actor, agent, role, position, goal, softgoal, task, resource and belief, as well as* different kinds of social dependency between actors. Its strategic dependency model describes the network of social *dependencies* among actors. It is a graph, wherein each node represents an actor, and each link between two actors indicates that one actor

Table 1. Organization of LDV Bates

Direction	***Edition***	
1 Campaigns Director	2 Editors	***IT***
1 Creative Director	4 Copy writers	1 IT manager
1 Administrative Director		1 Network administrator
1 Finance Director	***Documentation***	1 System administrator
	1 Media librarian	1 Analyst
Campaigns Management	1 Resource librarian	1 Computer technician
2 Campaign managers	1 Knowledge worker	
3 Campaign marketers		
1 Editor in Chief	***Administration***	***Accounts***
1 Creative Manager	3 Direction assistants	1 Accountant manager
	4 Manager Secretaries	1 Credit controller
Graphics	2 Receptionists	2 Accounts clerks
6 Graphic designers	2 Clerks/typists	2 Purchasing assistants
2 Photographers	1 Filing clerk	

Figure 1. LDV Bates as a Structure-in-5

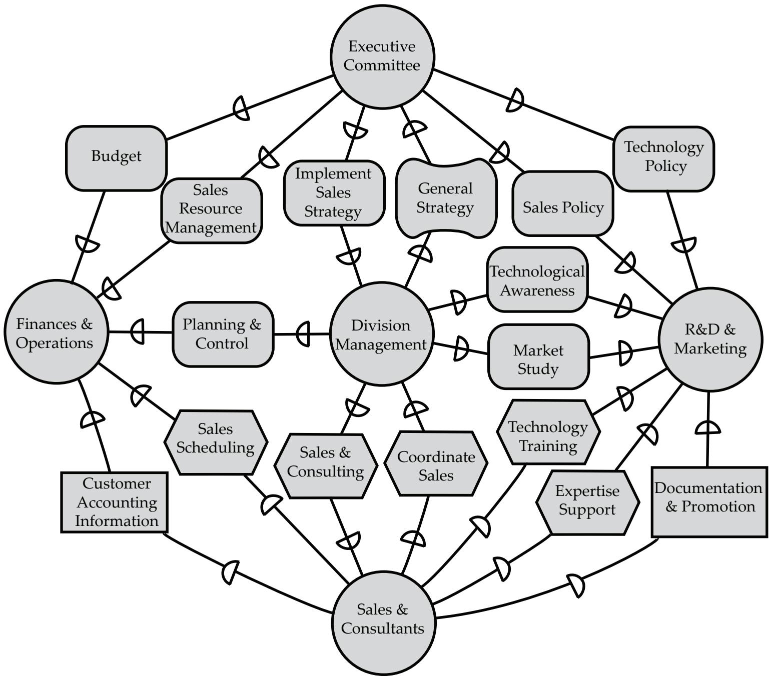


depends on the other for some goal to be attained. A dependency describes an "agreement" (called *dependum*) between two actors: the *depender* and the *dependee*. The depender is the depending actor, and the dependee, the actor who is depended upon. The type of the dependency describes the nature of the agreement. *Goal* dependencies represent delegation of responsibility for fulfilling a goal; *softgoal* dependencies are similar to goal dependencies, but their fulfillment cannot be defined precisely (for instance, the appreciation is subjective or fulfillment is obtained only to a given extent); *task* dependencies are used in situations where the dependee is required to perform a given activity; and resource dependencies require the dependee to provide a resource to the depender. As shown in Figure 1, actors are represented as circles; dependums–goals, softgoals, tasks, and resources–are represented as ovals, clouds, hexagons, and rectangles, respectively, and dependencies have the form *depender → dependum → dependee*.

GMT is a company specialized in telecom services in Belgium. Its lines of products and services range from phones & fax, conferencing, line solutions, internet & e-business, mobile solutions, and voice & data management. As shown in Figure 2, the structure of the commercial organization follows the structure-in-5. An *Executive Committee* constitutes the *Strategic Apex*. It is responsible for defining the *general strategy* of the organization. Five chief managers (*finances*, *operations*, *divisions management*, *marketing*, and *R&D*) apply the specific aspects of the *general strategy* in the area of their competence: *Finances & Operations* is in charge of *Budget* and Sales *Planning & Control*, *Divisions Management* is responsible for *Implementing Sales Strategy*, and *Marketing* and *R&D* define *Sales Policy* and *Technological Policy*.

The *Divisions Management* groups managers that coordinate all managerial aspects of product and service sales. It relies on *Finance & Operations* for handling *Planning* and *Control* of

Figure 2. GMT's sales organization as a structure-in-5



products and services, it depends on *Marketing* for accurate *Market Studies*, and on R&D for *Technological Awareness.*

The *Finances & Operations* departments constitute the *technostructure* in charge of management *control* (financial and quality audit) and sales *planning,* including *scheduling* and *resource management.*

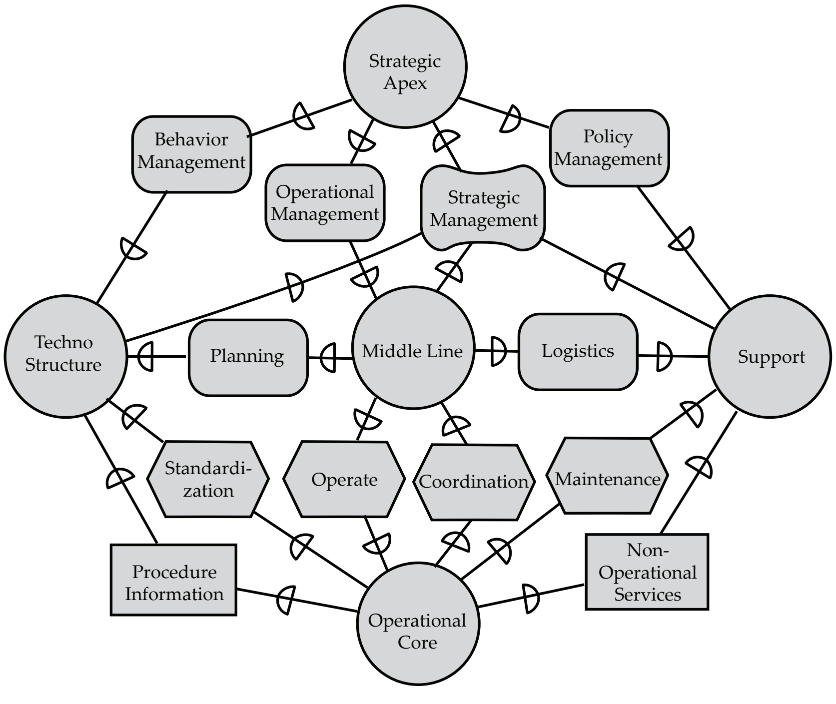
Support involves the staff of *Marketing* and *R&D*. Both departments jointly define and support the *Sales* Policy. The Marketing department coordinates *Market Studies* (customer positioning and segmentation, pricing, sales incentive, etc.) and provides the *Operational Core* with *Documentation* and *Promotion* services. The *R&D* staff is responsible for defining the technological policy, such as *technological awareness* services. It also assists *Sales people* and *Consultants* with *Expertise Support* and *Technology* Training.

Finally, the *Operational Core* groups *the Sales people* and *Line consultants* under the supervision and coordination of *Divisions Managers.* They are in charge of selling products and services to actual and potential customers.

Figure 3 abstracts the structures explored in the case studies of Figures 1 and 2 as a structure-in-5 pattern composed of five actors. The case studies also suggested a number of constraints to supplement the basic pattern:

- Dependencies between the *Strategic Apex* as depender and the *Technostructure*, *Middle Line,* and *Support* as dependees must be of type goal
- A softgoal dependency models the strategic dependence of the *Technostructure, Middle Line,* and *Support* on the *Strategic Apex*
- Relationships between the *Middle Line* and *Technostructure* and *Support* must be of goal dependencies
- *Operational Core* relies on the *Technostructure* and *Support* through task and resource dependencies

Figure 3. The structure-in-5 pattern



- Only task dependencies are permitted between the *Middle Line* (as depender or dependee) and the *Operational Core* (as dependee or depender)

To specify the formal properties of the pattern, we use *Formal Tropos* (Fuxman, Liu, Mylopoulos, Roveri, & Traverso, 2004), which extends the primitives of *i** with a formal language comparable to that of KAOS (Dardenne, et al., 1993). Constraints on *i** specifications are thus formalized in a first-order linear-time temporal logic. *Formal Tropos* provides three basic types of metaclasses: *actor, dependency, and entity* (Giorgini, Kolp, & Mylopoulos, 2002). The attributes of a *Formal Tropos* class denote relationships among different objects being modeled.

Metaclasses

Actor : = **Actor** name[attributes] [creation-properties] [invar-properties][actor-goal]
With subclasses:
Agent(with attributes occupies: Position, play: Role)
Position(with attributes cover: Role)
Role
Dependency : =**Dependency** name type mode **Depender** name **Dependee** name [attributes] [creation-properties] [invar-properties] [fulfill-properties]
Entity:=**Entity** name [attribute] [creation-properties][invar-properties]
Actor-Goal := (**Goal**|**Softgoal**) name mode **FulFillment**(actor-fulfill-property)

Classes: Classes are instances of Metaclasses.

In Formal Tropos, constraints on the lifetime of the (meta)class instances are given in a first-order linear-time temporal logic (see Fuxman et al., 2004 for more details). Special predicates can appear in the temporal logic formulas: predicate *JustCreated*(*x*) holds in a state if element *x* exists in this state but not in the previous one; predicate *Fulfilled*(*x*) holds if *x* has been fulfilled; and predicate *JustFulfilled*(*x*) holds if *Fulfilled*(*x*) holds in this state, but not in the previous one.

In the following, we only present some specifications for the *Strategic Management* and *Operational Management* dependencies.

Actor StrategicApex
Actor MiddleLine
Actor Support
Actor Technostructure
Actor OperationalCore

Dependency StrategicManagement
Type SoftGoal
Depender te: Technostructure, ml: MiddleLine, su: Support
Dependee sa: StrategicApex
Invariant

$$\forall dep : Dependency\ (JustCreated(dep) \rightarrow Consistent(self, dep))$$

$$\forall ag : Actor - Goal\ (JustCreated(ag) \rightarrow Consistent(self, ag))$$

Fulfillment

$$\forall dep : Dependency\ (dep.type = goal \wedge dep.depender = sa \wedge (dep.dependee = te\ dep.dependee = ml\ dep.dependee = su)) \wedge Fulfilled(self) \rightarrow \blacklozenge Fulfilled(dep)$$

[Invariant properties specify, respectively, that the strategic management softgoal must be consistent with any other dependency of the organization and with any other goal of the actors in the organization. The predicate Consistent depends on the particular organization we are considering and it is specified in terms of goals' properties to be satisfied. The fulfillment of the dependency necessarily implies that the goal dependencies between the Middle Line, the Technostructure, and the Support as dependees, and the Strategic Apex as depender have been achieved some time in the past]

Dependency OperationalManagement **Type** Goal
Mode achieve
Depender sa: StrategicApex
Dependee ml: MiddleLine
Invariant
$Consistent(self, StrategicManagement)$
$\exists\, c : Coordination\ (c.type = task \wedge c.dependee = ml \wedge c.depender = OperationalCore \wedge ImplementedBy(self, c))$

Fulfillment
$\forall ts : Technostructure, dep : Dependency\ (dep.type = goal \wedge dep.depender = ml \wedge dep.dependee = ts) \wedge Fulfilled(self)) \rightarrow \blacklozenge Fulfilled(dep)$

[The fulfillment of the Operational management goal implies that all goal dependencies between the Middle Line as depender and the Technostructure as dependee have been achieved some time in the past. Invariant properties specifies that the Operational Management goal has to be consistent with Strategic Management softgoal and that there exists a coordination task (a task dependency between MiddleLine and Operational Core) that implements (ImplementedBy) the OperationalManagaemnt goal.]

In addition, the following structural (global) properties must be satisfied for the Structure-in-5 pattern:

- $\forall inst1, inst2 : StrategicApex \rightarrow inst1 = inst2$

[There is a single instance of the Strategic Apex (the same constraint also holds for the Middle Line, the Technostructure, the Support, and the Operational Core)]

- $\forall sa : StrategicApex, te : Technostructure, ml : MiddleLine, su : Support, dep : Dependency\ (dep.dependee = sa \wedge (dep.depender = te \vee dep.depender = ml \vee dep.depender = su) \rightarrow dep.type = softgoal)$

[Only softgoal dependencies are permitted between the Strategic Apex as dependee and the Technostructure, the Middle Line, and the Support as dependers]

- $\forall sa : StrategicApex, te : Technostructure, ml : MiddleLine, su : Support, dep : Dependency : (dep.depender = sa \wedge (dep.dependee = te \vee dep.dependee = ml \vee dep.dependee = su) \rightarrow dep.type = goal)$

[Only goal dependencies are permitted between the Technostructure, the Middle Line, and the Support as dependee, and the Stategic Apex as depender]

- $\forall su : Support, ml : MiddleLine, dep : Dependency\ ((dep.dependee = su \wedge dep.depender = ml) \rightarrow dep.type = goal)$

  [Only task dependencies are permitted between the Middle Agency and the Operational Core]

- $\forall te : Technostructure, oc : OperationalCore, dep : Dependency\ ((dep.dependee = te \wedge dep.depender = oc) \rightarrow (dep.type = task \vee dep.type = resource))$

[Only resource or task dependencies are permitted between the Technostructure and the Operational Core (the same constraint also holds for the Support)]

- $\forall a : Actor, ml : MiddleLine, (\exists dep : Dependency(dep.depender = a \wedge dep.$

$$\begin{aligned}&dependee = \\ &ml) \vee (dep.dependee = a \wedge dep.depender = ml) \rightarrow \\ &((\exists sa : StrategicApex(a = sa)) \vee (\exists su : Support(a = su) \vee \\ &(\exists te : Technostructure(a = te)) \vee (\exists op : OperationalCore \\ &(a = op))\end{aligned}$$

[No dependency is permitted between an external actor and the Middle Agency (the same constraint also holds for the Operational Core)]

This specification can be used to establish that a certain *i** model does constitute an instance of the structure-in-5 pattern. For example, the *i** model of Figure 1 can be shown to be such an instance, in which the actors are instances of the structure-in-5 actor classes (e.g., *Direction* and *IT&Documentation* are instances of the *Strategic Apex* and the *Support*, respectively), dependencies are instances of structure-in-5 dependencies classes (e.g., *Agency Global Strategy* is an instance of the *Strategic Management*), and all above global properties are enforced (e.g., since there are only two task dependencies between *Campaigns Management* and *Graphics&Edition*, the fourth property holds).

Joint Venture

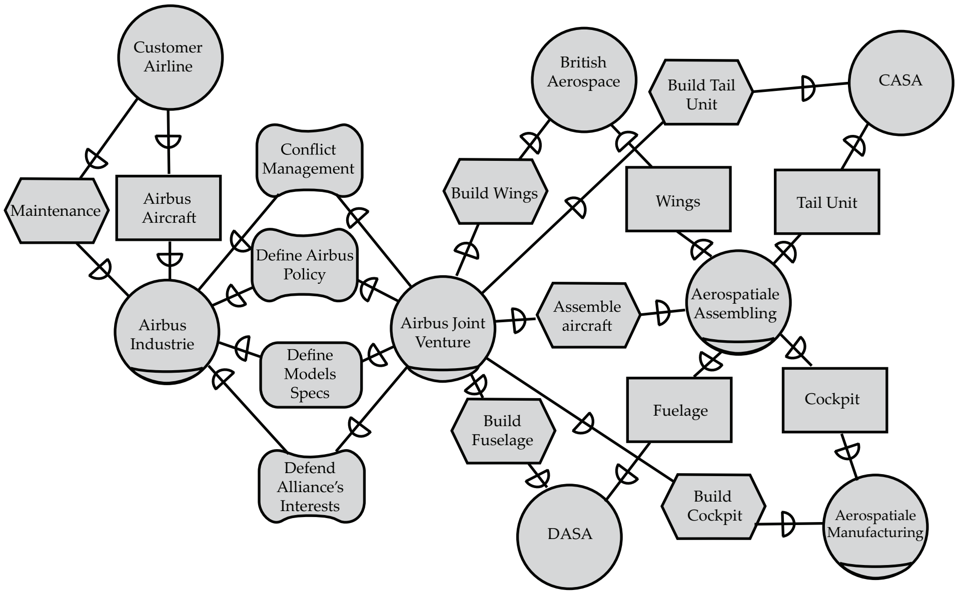
We describe here two alliances—Airbus (Dussauge & Garrette, 1999) and a more detailed one, Carsid (Wautelet, Kolp, & Achbany, 2006)—that will serve to model the joint venture structure as an organizational pattern and propose a semi-formal specification.

Airbus. The Airbus Industrie joint venture coordinates collaborative activities between European aeronautic manufacturers to build and market airbus aircraft. The joint venture involves four partners: British Aerospace (UK), Aerospatiale (France), DASA (Daimler-Benz Aerospace, Germany), and CASA (Construcciones Aeronauticas SA, Spain). Research, development, and production tasks have been distributed among the partners, avoiding any duplication. Aerospatiale is mainly responsible for developing and manufacturing the cockpit of the aircraft and for system integration. DASA develops and manufactures the fuselage, British Aerospace the wings, and CASA the tail unit. Final assembly is carried out in Toulouse (France) by Aerospatiale. Unlike production, commercial and decisional activities have not been split among partners. All strategy, marketing, sales, and after-sales operations are entrusted to the Airbus Industrie joint venture, which is the only interface with external stakeholders, such as customers. To buy an Airbus, or to maintain their fleet, customer airlines could not approach one or another of the partner firms directly, but have to deal with Airbus Industrie. Airbus Industrie, which is a real manufacturing company, defines the alliance's product policy and elaborates the specifications of each new model of aircraft to be launched. Airbus defends the point of view and interests of the alliance as a whole, even against the partner companies themselves when the individual goals of the latter enter into conflict with the collective goals of the alliance.

Figure 4 models the organization of the Airbus Industrie joint venture using the *i** strategic dependency model. Airbus assumes two roles: Airbus Industrie and Airbus Joint Venture.

Airbus Industrie deals with demands from customers, *Customer* depends on it to receive airbus aircrafts or maintenance services. The *Airbus Joint Venture* role ensures the interface for the four partners (*CASA*, *Aerospatiale*, *British Aerospace*, and *DASA*) with *Airbus Industrie* defining Airbus strategic policy, managing conflicts between the four Airbus partners, defending the interests of the whole alliance, and defining new aircraft specifications. *Airbus Joint Venture* coordinates the four partners, ensuring that each of them assumes a specific task in the building of Airbus aircrafts: wings building for *British Aerospace*, tail unit building for *CASA*, cockpit building and

Figure 4. The Airbus Industrie joint venture



aircraft assembling for *Aerospace*, and fuselage building for *DASA*. Since Aerospatiale assumes two different tasks, it is modeled as two roles: *Aerospatiale Manufacturing* and *Aerospatiale Assembling. Aerospatiale Assembling* depends on each of the four partners receiving the different parts of the planes.

Carsid (Carolo-Sidérurgie) is a joint venture that has recently arisen from the global concentration movement in the steel industry. The alliance, physically located in the steel basin of Charleroi in Belgium, has been formed by the steel companies Duferco (Italy), Usinor (France)—that also partially owns Cockerill-Sambre (Belgium) through the Arcelor group—and Sogepa (Belgium), a public investment company representing the Walloon Region Government. Usinor has also brought its subsidiary Carlam into the alliance.

Roughly speaking, the aim of a steel manufacturing company like CARSID is to extract iron from the ore and to turn it into semi-finished steel products. Several steps compose the transformation process, each step is generally assumed by a specific metallurgic plant:

- **Sintering plant:** Sintering is the preparation of the iron ore for the blast furnace. The minerals are crushed and calibrated to form a sinter charge.
- **Coking plant:** Coal is distilled (i.e., heated in an air-impoverished environment in order to prevent combustion) to produce coke.
- **Blast furnace:** Coke is used as a combustion agent and as a reducing agent to remove the oxygen from the sinter charge. The coke and sinter charge are loaded together into the blast furnace to produce cast iron.
- **Steel making plant:** Different steps (desulphuration, oxidation, steel adjustment, cooling, etc.) are necessary to turn cast iron into steel slabs and billets. First, elements other than iron are removed to create molten steel. Then, supplementary elements (e.g., titanium, niobium, and vanadium) are added to make a more robust alloy. Finally, the result—finished steel—is solidified to produce slabs and billets.
- **Rolling mill:** The manufacture of semi-finished products involves a process known as hot rolling. Hot-rolled products are of two

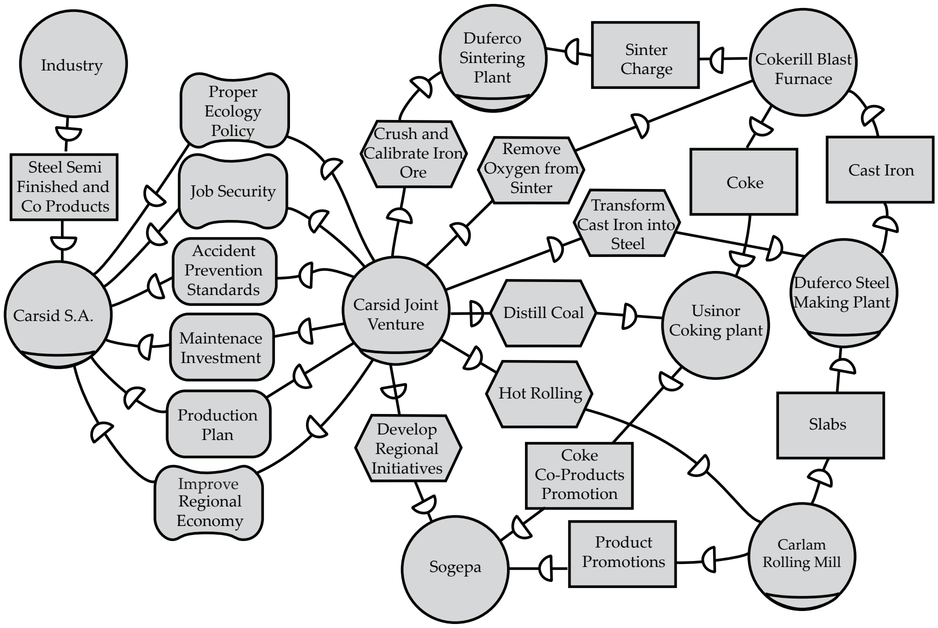
categories: flat (plates, coiled sheets, sheeting, strips, etc.) produced from steel slabs and long (wire, bars, rails, beams, girders, etc.) produced from steel billets.

Figure 5 models the organization of the Carsid joint venture in *i**. Carsid assumes two roles: Carsid S.A. ("Société Anonyme"–the English equivalent is "Ltd") and Carsid Joint Venture.

Carsid S. A. is the legal and contractual interface of the joint venture. It handles the sales of *steel semi-finished products* (bars, plates, rails, sheets, etc., but also slabs and billets) and *co-products* (coke that does not meet blast furnace requirements, rich gases from the different plants, godroon, naphtalin, etc.) to external *industries* such as vehicle manufacturers (e.g., automobiles, trains, and boats), foundries, gas companies, and building companies. It is also in charge of the *proper environment policy*, a strategic aspect for steelworks that are polluting plants. Most important, Carsid has been set up with the help of the Walloon Region to guarantee *job security* for about 2000 workers in the basin of Charleroi. Indeed, the steel industry in general and the Walloon metallurgical basins in particular are sectors in difficulty with high unemployment rates. As a corollary, the joint venture is committed to *improve regional economy* and maintain work in the region. Carsid has then been contractually obliged to plan *maintenance investment* (e.g., blast furnace refection, renovation of coke oven batteries, etc.) and develop *production plans* involving regional subcontractors and suppliers. Since steelmaking is a hard and dangerous work sector, Carsid, like any other steelworks, is legally committed to respect, develop, and promote *accident prevention standards.*

The *Carsid joint venture* itself coordinates the steel manufacturing process. The sintering phase to *prepare iron ore* is the responsibility of *Duferco Sintering Plant* while *Usinor Coking Plant, distills coal* to turn it onto *coke*. The *sinter charge* and *coke* are used by the Cokerill Blast Furnace to produce *cast iron* by *removing oxygen from sinter.* The *Duferco Steel Making Plant transforms cast iron into steel* to produce slabs and billets for the *Carlam Rolling Mill* in charge

Figure 5. The Carsid joint venture



of the *hot rolling* tasks. Carlam (Carolo-Laminoir). *Sogepa*, the public partner, has the responsibility to *develop regional initiatives* to promote Carsid activities, particularly in the Walloon Region and in Belgium.

Figure 6 abstracts the joint venture structures explored in the case studies of Figures 4 and 5. The case studies suggest a number of constraints to supplement the basic pattern:

- Partners depend on each other for providing and receiving resources
- Operation coordination is ensured by the joint manager actor, which depends on partners for the accomplishment of these assigned tasks
- The joint manager actor must assume two roles: A private interface role to coordinate partners of the alliance and a public interface role to take strategic decisions, define policy for the private interface, and represent the interests of the whole partnership with respect to external stakeholders

Part of the Joint Venture pattern specification is in the following:

Role JointManagerPrivateInterface Goal CoordinatePatterns

Role JointManagerPublicInterface
Goal TakeStrategicDecision
SoftGoal RepresentPartnershipInterests
Actor Partner

and the following structural (global) properties must be satisfied:

- $\forall$jmpri1, jmpri2 : J ointManagerPrivateInterface
  (jmpri1 = jmpri2)

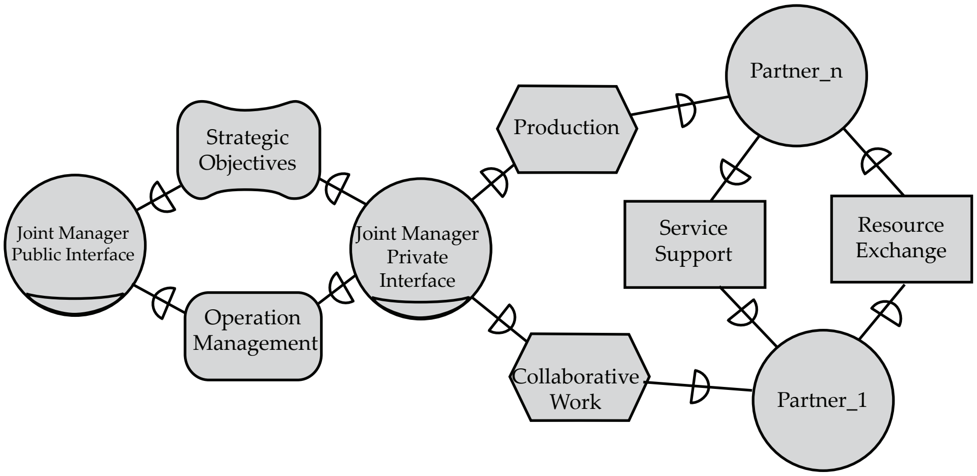
  [Only one instance of the joint manager]

- *$\forall$p1, p2 : P artner, dep : Dependency (((dep.depender = p1 $\wedge$dep.dependee = p2)$\vee$(dep.depender =
  p2 $\wedge$ dep.dependee = p1)) $\rightarrow$ (dep.type = resource))*

  [Only resource dependencies between partners]

- *$\forall$jmpri : JointManagerPrivateInterface, p : Partner, dep : Dependency((dep.dependee = p $\wedge$ dep.depender = jmpri)
  $\rightarrow$dep.type = task)*

Figure 6. The joint venture pattern



[Only task dependencies between partners and the joint manager, with the joint manager as depender]

- $\forall jmpri : JointManagerPrivateInterface, jmpui : JointManagerPublicInterface, dep : Dependency\ ((dep.depender = jmpri \wedge dep.dependee = jmpui) \rightarrow (dep.type = goal \vee dep.type = softgoal))$

[Only goal or softgoal dependencies between the joint manager roles]

- $\forall dep : Dependency, p1 : Partner\ ((dep.depender = p1 \vee dep.dependee = p1) \rightarrow ((\exists p2 : Partner(p1 \neq p2 \wedge (dep.depender = p2 \vee dep.dependee = p2)) \vee (\exists jmpi : JointManagerPrivateInterface\ ((dep.depender = jmpi \vee dep.dependee = jmpi))))$
  [Partners only have relationships with other partners or the joint manager private interface]
- $\forall dep : Dependency, jmpi : JointManagerPrivateInterface\ ((dep.depender = jpmi \vee dep.dependee = jpmi) \rightarrow ((\exists p : Partner((dep.depender = p \vee dep.dependee = p))) \vee (\exists jmpui : JointManagerPublicInterface\ ((dep.depender = jmpui \vee dep.dependee = jmpui))))$
  [The joint manager private interface only has relationships with the joint manager public interface or partners]

EVALUATION

Patterns can be compared and evaluated with quality attributes (Shaw & Garlan, 1996), also called non-functional requirements (Chung, Nixon, Yu, & Mylopoulos, 2000). For instance, the requirements seem particularly relevant for organizational structures (Do, Faulkner, & Kolp, 2003; Kolp, et al., 2006):

- **Predictability** (Woods & Barbacci, 1999): Actors can have a high degree of autonomy (Wooldridge & Jennings, 1995) in the way that they undertake action and communication in their domains. It can be then difficult to predict individual characteristics as part of determining the behavior of the system at large. Generally, predictability is in contrast with the actors' capabilities to be adaptive and responsive: Actors must be predictable enough to anticipate and plan actions while being responsive and adaptive to unexpected situations.
- **Security:** Actors are often able to identify their own data and knowledge sources and they may undertake additional actions based on these sources (Woods & Barbacci, 1999). Strategies for verifying authenticity for these data sources by individual actors are an important concern in the evaluation of overall system quality since, in addition to possibly misleading information acquired by actors, there is the danger of hostile external entities spoofing the system to acquire information accorded to trusted domain actors.
- **Adaptability:** Actors may be required to adapt to modifications in their environment. These may include changes to the component's communication protocol or possibly the dynamic introduction of a new kind of component previously unknown or the manipulations of existing actors.

Generally, adaptability depends on the capabilities of the single actors to learn and predict the changes of the environments in which they act (Weiss, 1997), and also their capability to make a diagnosis (Horling, Lesser, Vincent, Bazzan, & Xuan, 1999), that is, being able to detect and determine the causes of a fault based on its symptoms. However, successful organization environments tend to balance the degree of reactivity and predictability of the single actors with their capabilities to be adaptive.

- **Coordinability:** Actors are not particularly useful unless they are able to coordinate with other agents. Coordination is generally (Jennings, 1996) used to distribute expertise, resources, or information among the actors (actors may have different capabilities, specialized knowledge, different sources of information, resources, responsibilities, limitations, charges for services, etc.), solve interdependencies between actors' actions (interdependence occurs when goals undertaken by individual actors are related), meet global constraints (when the solution being developed by a group of actors must satisfy certain conditions if is to be deemed successful), and to make the system efficient (even when individuals can function independently, thereby obviating the need for coordination, information discovered by one actor can be of sufficient use to another actor that both actors can solve the problem twice as fast).

Coordination can be realized in two ways:

1. **Cooperativity:** Actors must be able to coordinate with other entities to achieve a common purpose or simply align their local goals. Cooperation can either be communicative in that the actors communicate (the intentional sending and receiving of signals) with each other in order to cooperate or it can be non-communicative (Doran, Franklin, Jennings, & Norman, 1997). In the latter case, actors coordinate their cooperative activity by each observing and reacting to the behavior of the other. In deliberative organizations, actors jointly plan their actions so as to cooperate with each other.
2. **Competitivity:** Deliberative negotiating organization (Doran et al., 1997) are like deliberative ones, except that they have an added dose of competition. The success of one actor implies the failure of others.

- **Availability:** Actors that offer services to other actors must implicitly or explicitly guard against the interruption of offered services.
- **Fallibility-tolerance:** A failure of one actor does not necessarily imply a failure of the whole organization. The organization then needs to check the completeness and the accuracy of information and knowledge transactions and workflows. To prevent failure, different actors can have similar or replicated capabilities and refer to more than one actor for a specific behavior.
- **Modularity:** (Shehory, 1998) increases efficiency of service execution, reduces interaction overhead, and usually enables high flexibility. On the other hand, it implies constraints on inter-organization communication.
- **Aggregability:** Some actors are parts of other actors. They surrender to the control of the composite entity. This control results in efficient workflow execution and low interaction overhead. However, it prevents the organization to benefit from flexibility.

As an illustration, we evaluate the patterns with respect to coordinativity, predictability, fallibility-tolerance, and adaptability. The evaluation can be done in a similar way for the other non-functional requirements. Due to the lack of space, we refer the author to the bibliography for the other attributes.

The structure-in-5 improves coordinativity among actors by differentiating the data hierarchy (the support actor) from the control hierarchy—supported by the operational core, technostructure, middle agency, and strategic apex. The existence of three different levels of abstraction (1) Operational Core; (2) Technostructure, Middle Line, and Support; (3) Strategic Apex addresses the need for managing predictability. Besides, higher levels are more abstract than lower levels: Lower levels only involve resources and task dependencies while higher ones propose intentional (goal and soft-goal) relationships. Checks and control mechanisms can be integrated at different levels of abstraction assuming redundancy from different perspectives and considerably increase fallibility-tolerance. Since the structure-in-5 separates data and control hierarchies, integrity of these two hierarchies can also be verified independently. The structure-in-5 separates independently the typical components of an organization, isolating them from each other and allowing them dynamic adaptability. But since it is restricted to no more than five major components, more refinement has to take place inside the components themselves.

The joint venture supports coordinativity in the sense that each partner actor interacts via the joint manager for strategic decisions. Partners indicate their interest, and the joint manager either returns the strategic information immediately or mediates the request to some other partners. However, since partners are usually heterogeneous, it could be a drawback to define a common interaction background. The central position and role of the joint manager is as a means for resolving conflicts and preventing unpredictability. Through its joint manager, the joint-venture proposes a central communication controller. It is less clear how the joint venture pattern addresses fallibility-tolerance, notably reliability. However, exceptions, supervision, and monitoring can improve its overall score with respect to these qualities. Manipulation of partners can be done easily to adapt the structure by registering new ones to the joint manager. However, since partners can also exchange resources directly with each other, existing dependencies should be updated as well. The joint manager cannot be removed due to its central position. Table 2 summarizes the strengths and weaknesses of the reviewed patterns.

Table 2. Strengths and weaknesses of some patterns

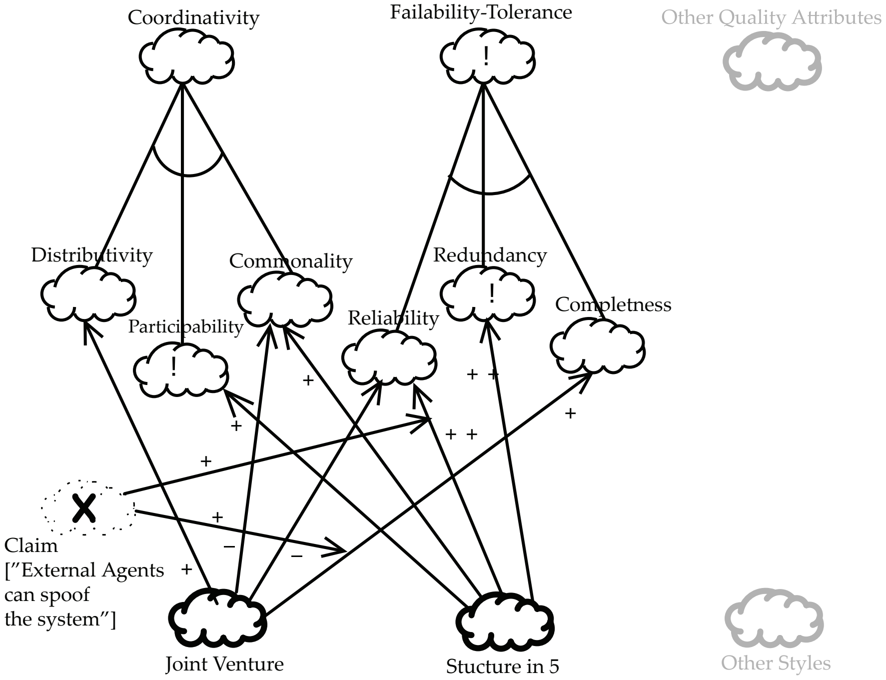
	Structure-in-5	Joint-Venture
Coordinativity	++	+
Predictability	+	+
Fallibility-Tolerance	++	+
Adaptability	+	+

To cope with non-functional requirements and select the pattern for the organizational setting, we go through a means-ends analysis using the non functional requirements (NFRs) framework (Chung et al., 2000). We refine the identified requirements to sub-requirements that are more precise and evaluates alternative organizational patterns against them, as shown in Figure 7. The analysis is intended to make explicit the space of alternatives for fulfilling the top-level requirements. The patterns are represented as operationalized requirements (saying, roughly, “model the organizational setting of the system with the *pyramid, structure-in-5, joint venture, arm’s-length* ... pattern”).

The evaluation results in contribution relationships from the patterns to the non-functional requirements, labeled “+”, “++”, “–”, “– –”. Design rationale is represented by claims drawn as dashed clouds. They make it possible for domain characteristics (such as priorities) to be considered and properly reflected into the decision making process, e.g., to provide reasons for selecting or rejecting possible solutions (+, –). Exclamation marks (! and !!) are used to mark priority requirements while a check-mark “√” indicates an accepted requirements and a cross “ X ” labels a denied requirement.

Relationships types (AND, OR, ++, +, –, and – –) between NFRs are formalized to offer a tractable proof procedure. AND/OR re-

Figure 7. Partial evaluation for organizational patterns



lationships correspond to the classical AND/OR decomposition relationships: if requirement R0 is AND-decomposed (respectively, OR-decomposed) into *R*1,*R*2,...,*Rn,* then all (at least one) of the requirements must be satisfied for the requirement R0 to be satisfied. So, for instance, in Figure 7 Coordinativity is AND decomposed into Distributivity, Participability, and Commonality. Relationships "+" and "–" model respectively a situation where a requirement contributes positively or negatively towards the satisfaction of another one. For instance, in Figure 7 Joint Venture contributes positively to the satisfaction of Distributivity and negatively to the Reliability. In addition, relationships "++" and "– –" model a situation where the satisfaction of a requirement implies the satisfaction or denial of another goal. In Figure 7 the satisfaction of structure-in-5 implies the satisfaction of requirements Reliability and Redundancy.

The analysis for selecting an organizational setting that meets the requirements of the system to build is based on propagation algorithms presented in Giorgini, Mylopoulos, Nicchiarelli, and Sebastiani (2002). Basically, the idea is to assign a set of initial labels for some requirements of the graph, about their satisfiability and deniability, and see how this assignment leads to the labels propagation for other requirements. In particular, we adopt from Giorgini, Mylopoulos, Nicchiarelli and Sebastiani (2002) both qualitative and a numerical axiomatization for goal (requirements) modeling primitives and label propagation algorithms that are shown to be sound and complete with respect to their respective axiomatization. The following is a brief description of the qualitative algorithm.

To each requirement *R*, we associate two variables. $Sat(R)$, $Den(R)$, ranging in $\{F, P, N\}$ (full, partial, none) such that $F > P > N$, represents the current evidence of satisfiability and deniability of the requirement *R*. For example, $Sat(R_i) >= P$ states there is at least partial evidence that A_i is satisfiable. Starting from assigning an initial set of input values for $Sat(R_i)$, $Den(R_i)$ to (a subset of) the requirements in the graph, we propagate

Table 3. Propagation rules for satisfiability in the qualitative framework. A dual table is given for deniability propagation.

	+ $G2 \rightarrow G1$	- $G2 \rightarrow G1$	++ $G2 \rightarrow G1$	-- $G2 \rightarrow G1$
$Sat(G1)$ $Den(G1)$	$min\{ Sat(G2), P \}$ N	$min\{ Sat(G2), P \}$	$Sat(G2)$ N	N $Sat(G2)$

the values through the propagation rules of Table 3. Propagation rules for AND (respectively OR) relationships are min-value function for satisfiability (max-value function) and max-value function (min-value function) for deniability. A dual table is given for deniability propagation.

The schema of the algorithm is described in Figure 8. *Initial*, *Current*, and *Old* are arrays of pairs $Sat(R_i)$, $Den(R_i)$, one for each R_i of the graph, representing respectively the initial, current, and previous labeling status of the graph.

The array *Current* is first initialized to the initial values *Initial* given in input by the user. At each step, for every requirement R_i, $Sat(R_i)$, $Den(R_i)$ is updated by propagating the values of the previous step. This is done until a fixpoint is reached, that is, no updating mode is possible (*Current* == *Old*). The updating of $Sat(R_i)$, $Den(R_i)$ works as follows. For each relation Rel_i incoming in G_i, the satisfiability and deniability values $sati_i$ and $deni_i$ derived from the old values of the source requirements are computed by applying the rules of Table 3. Then, it returns the maximum value between those computed and the old values.

Figure 8. Schema of the label propagation algorithm

```
Current=Initial;
do
    Old=Current;
    for each $R_i$ do
        Current[i] = Update label(i, Old);
until not (Current==Old);
return Current;

for each $Rel_i$ s.t. target($Rel_i$) == Ri do
    satij = Apply Rules Sat(i, $Rel_i$, Old);
    denij = Apply Rules Den($R_i$, $Rel_i$, Old);
return max($max_i$ ($sati_i$), Old[i].sat),
            max($max_i$ ($deni_i$), Old[i].den);
```

A REQUIREMENTS-DRIVEN METHODOLOGY

This research is conducted in the context of the *early requirements* phase of *Tropos* (Giorgini et al., 2004; Giorgini et al., 2005), a software development methodology for building multi-agent systems founded on the concepts of actor and goal.

The *Tropos* methodology adopts ideas from multi-agent systems technologies, mostly to define the detailed design and implementation phase, and ideas from requirements engineering and organizational modeling, where agents/actors and goals have been used heavily for early requirements analysis (Dardenne et al., 1993; Yu, 1995). In particular, the *Tropos* project adopts Eric Yu's *i** model which offers actors (agents, roles, or positions), goals, and actor dependencies as primitive concepts for analyzing an application during organizational modeling. The key assumption which distinguishes *Tropos* from other methodologies is that actors and goals are used as fundamental concepts for analysis and design during *all phases of software development*, not just requirements analysis. That means that, in the light of this paper, *Tropos* describes the organizational environment within which a system will eventually operate, as well as the system itself in terms of the same concepts and patterns. *Tropos* spans four phases of software development:

- Organizational modeling, concerned with the understanding of a problem by studying an organizational setting; the output is an organizational model which includes relevant actors, their goals and dependencies.
- Requirements analysis, in which the system-to-be is described within its operational environment, along with relevant functions and qualities.
- Architectural design, in which the system's global architecture is defined in terms of subsystems, interconnected through data, control, and dependencies.
- Detailed design, in which behavior of each architectural component is defined in further detail.

CONCLUSION

Modelers need to rely on patterns, styles, and idioms to build their models, whatever the purpose. We argue that, as with other phases of software development, organizational modeling can be facilitated by the adoption of organizational patterns. This paper focuses on two such patterns and studies them in detail through examples, a formalization using Formal Tropos and an evaluation with respect to desirable requirements. There have been many proposals for software patterns (e.g., Kolp, Do, & Faulkner, 2005) since the original work on design patterns (Gamma, Helm, Johnson, & Vlissides, 1995). Some of this work focuses on requirements patterns. For example, Konrad and Cheng (2002) propose a set of requirements patterns for embedded software systems. These patterns are represented in UML and cover both structural and behavioral aspects of a requirements specification. Along similar lines, Fowler (1997) proposes some general patterns in UML. In both cases, the focus is on requirements analysis, and the modeling language used is UML. On a different path, Gross and Yu (2002) propose a systematic approach for evaluating design patterns with respect to non-functional requirements (e.g., security, performance, and reliability). Our approach differs from this work primarily in the fact that our proposal is founded on ideas from organization theory and strategic alliances literature. We have already described organizational patterns, but to be used for designing multi-agent system architectures (Kolp et al., 2006) and e-business systems (Kolp et al., 2004). Considering real world organizations as a metaphor, systems involving many software actors, such as multi-agent systems, could benefit from the same organizational models. In the present paper we have focused on patterns for modeling organizational settings rather than software systems, and emphasized the need for organizational abstractions to better match the operational environment of the system-to-be during organizational modeling.

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Chapter 8.2

Enterprise Resource Planning Under Open Source Software

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ABSTRACT

Open source software is becoming more prevalent in businesses today, and while still a relatively immature offering, open source enterprise resource planning (OS-ERP) systems are becoming more common. However, whether or not an OS-ERP package is the right software for a given organization is a little researched question. Building on the current real options thinking about platform acquisitions, this chapter proposes the five most critical factors to consider when evaluating an OS-ERP package. To adequately do this, a great deal of detail about the current offerings in OS-ERP software is presented, followed by a review of the real options theory and thinking behind using these factors to evaluate OS-ERP options. The international implications of OS-ERP are presented in the "Future Trends" section.

INTRODUCTION

Open source software (OSS) is becoming a prominent part of the business infrastructure landscape. However, open source application software is still in its infancy. Success of open source enterprise resource planning (OS-ERP) systems will signify a coming of age of open source applications. There are many factors that will determine if OS-ERP systems are a valuable option for corporations, and thus whether OS-ERP systems will become as prominent as other open source offerings like Linux or JBOSS. This chapter will inform the reader of the current state of OS-ERP in the global context, and explain to potential adopters of OS-ERP the important factors to consider in evaluating an OS-ERP option.

First, a common language for defining OS-ERP systems will be developed. Second, the current state of OS-ERP software will be explored. Third, the business models of OS-ERP vendors will be exposed. Fourth, the advantages and disadvantages of customization of OS-ERP software will be explained. Fifth, the factors for valuing OS-ERP options using real options theory (Fichman, 2004) are defined. Finally, the global adoption of ERP software is explored.

BACKGROUND

The first necessary requisite for understanding OS-ERP systems is to define a common language for talking about OS-ERP applications. This includes defining exactly what an OS-ERP application entails and whether the software meets the definition of open source software. There is much ambiguity in the popular press about what is and is not OSS; this is only confounded when ERP systems claim to be open source. To clarify these issues, the next section will explain historical context of OSS. Secondly, open source licensing issues are explained. Then, the issue of open source ERP functionality is addressed. Lastly some examples of OS-ERP software are provided.

History of Open Source Software

Open source software has a rich history, from an initial chaotic beginning out of a hacker culture (Raymond, 1999) to its current manifestation as a foundation for profit-seeking corporations such as JBOSS (Watson, Wynn, & Boudreau, 2005), Compiere Inc., and Red-Hat Linux. As open source has evolved, the definition of open source software has changed and the open source ecosystem has grown. Previously, open source software was defined in terms of two characteristics: (1) licenses that give programmers the ability to view, change, enhance open source code, and distribute the source code without discrimination (Feller & Fitzgerald, 2000; Open Source Initiative, 2005); and (2) the software is free of cost. While this definition was sufficient, for pure open source initiatives of the past, it does not adequately cover all that "open source" includes today. This is in contrast to proprietary software where the license generally does not allow for distribution of the source code and is not free of cost. Evolution and commercialization of OSS have led to many products being labeled "open source" that are not free of cost. As well, proprietary software (software controlled and offered by vendors for a price) that give access to the code are termed open source, while there is no licensing to support the open source model of software development. Proprietary software that allows access to the source code still leaves the control of the source code, what is included in the source code in future versions, in the hands of the vendor, who may be less accepting of contributions of code than an open source community.

However, even under the most stringent of open source (OS) definitions, there have been many great open source successes. For example, MySQL is an open source database server that has grown phenomenally since its inception in 1995. MySQL AB is the company that supports the MySQL product. This product is free and the source code is available to everyone under the GNU General Public License (GPL). Licensing will be discussed in more detail in the next section.

MySQL is currently backed by several venture capitalists and is without debt (MySQL, 2007). There were over 12 million downloads of MySQL in 2006, and 2,500 new customers started using MySQL to power Web sites, critical applications, packaged software, and telecommunications infrastructure. MySQL is just one example of the success of OS software in the infrastructure space. Other examples in infrastructure offerings include JBOSS and Linux.

In terms of business applications, there are fewer major success stories. SugarCRM, however, is one of the most successful open source business applications. SugarCRM is a customer relationship management software package (packaged software is that which offers a "set of functionality" in a complete state that does not require programming) that is available under a "custom" open source license.[1] SugarCRM has over a million downloads and about 1,000 customers (SugarCRM, 2007). ERP systems—large packaged integrated business applications that include intensive functionality in the following areas: marketing and sales, accounting and finance, production and materials management, and human resources[2]—are relatively less prolific than these major success stories in the open source space. However, as the rest of this chapter outlines, there are several open source ERP offerings becoming available. It waits to be determined which of these applications will become widely used in businesses.

Open Source Licenses

Licensing plays a big role in definitions of OSS. As of 2006, the Open Source Initiative (OSI) recognizes nearly 60 different open source licenses (Open Source Initiative, 2006). Given this number of licenses, and that OSI is not the only organization that provides accreditation of licenses,[3] it is understandable that the definition of open source is not stable. Many companies have turned to a dual-licensing strategy, making their code available under general public license (GPL) but also offering a commercial license (Rist, 2005). Given this large number of licensing options and business models, it is understandable that there is confusion as to what software really is open source software.

Open source software still must allow access to the source code, as mentioned above. So, OS-ERP systems are defined to allow access to the code. However, under what terms this is available, including for what cost, is a question. For the purposes of understanding OS-ERP software, one must assume that the cost is not necessarily free. For the OS-ERP packages in this chapter, three general license types are utilized:

1. **Apache License Version 2.0:** "Subject to the terms and conditions of this License, each Contributor hereby grants to You a perpetual, worldwide, non-exclusive, no-charge, royalty-free, irrevocable copyright license to reproduce, prepare Derivative Works of, publicly display, publicly perform, sublicense, and distribute the Work and such Derivative Works in Source or Object form." As with all licenses, it is recommended that a full review of the license is conducted before working with any open source software (Apache, 2007).
2. **Mozilla Public License 1.1:** This license allows for access to the source code for review and modification. This is a copyleft license, meaning that all modifications involving the original source code are sent back to the originator of the software. As with all licenses, it is recommended that a full review of the license is conducted before working with any open source software (Mozilla, 2007).
3. **GNU GPL:**"GNU is a recursive acronym for 'GNU's Not Unix'; it is pronounced *guh-noo*, approximately like *canoe*…the GNU General Public License is intended to guarantee your freedom to share and change free software—to make sure the software is free for all its users." Users of software under the GNU GPL can use, modify, improve, and redistribute such software. As with all licenses, it is recommended that a full review of the license is conducted before working with any open source software (GNU, 2007a, 2007b).

However, some software companies create their own licenses with their own implications for what "open source" means to their software. In the OS-ERP space, examples include:

1. **OpenMfg:**"…the license OpenMFG uses allows companies to view and modify

source code, as well as make contributions to the source code" (Caton, 2006). However, this license does not allow for distribution of the source code. So, by definition, this is not what is generally meant by "open source" software. As with all licenses, it is recommended that a full review of the license is conducted before working with any software.

2. **avERP:** This license includes no license fees, no charge for updates, no fees charged for own programming, no obligation to pay or purchase anything at anytime, no obligation for use of services, and it is possible to alter all program modules if wished and includes source code (HK-Software, 2007). It does not appear that redistribution of the software is allowed. As with all licenses, it is recommended that a full review of the license is conducted before working with any software.
3. **OpenPro:** This is software built on open source technologies that allows access to the source code. However, there is a license fee involved, and the right to distribute the software is not explained on the Web site (OpenPro, 2007). As with all licenses, it is recommended that a full review of the license is conducted before working with any open software.

Table 1 outlines current OS-ERP offerings, licensing, and Web sites where more can be learned about the software.

The popular press has referred to all of the software listed in Table 1 as OS-ERP, even those with cost. ERP systems are the backbone of an organization, and the cost of the initial license is

Table 1. Open source ERP licensing

Open Source Offering	**License**	**Web Sites**
Compiere	GNU GPL	http://www.compiere.org/
OpenMFG	Custom	http://www.openmfg.com/
OfBiz	Apache License Version 2.0	http://ofbiz.apache.org/
Tiny ERP	GNU GPL	http://sourceforge.net/projects/tinyerp
OpenPro	Undisclosed Cost Structure	http://www.openpro.com/
WebERP	GNU	http://www.weberp.org/
ERP5	GPL	http://www.erp5.org/
Adempiere	GNU GPL	http://www.adempiere.com/
avERP	Custom	http://www.hk-software.net/h-k.de/content/doc_138099-3-5-0.php
Fisterra	GNU GPL	http://community.igalia.com/twiki/bin/view/Fisterra
OpenBravo	Mozilla Public License 1.1	http://www.openbravo.com/
GNUe	GNU GPL	http://www.gnuenterprise.org/
Value ERP	GNU	http://www.valueerp.com/

only part of the total cost of ownership (TCO) of an ERP system or any software package. Organizations cannot rely on vendors and analysts to provide accurate TCO estimates. One practitioner notes, "…no matter how honest they try to be, neither vendor nor analyst can ever fill in all the variables of the TCO formula…The unique combination of resources, both machine and human, at work within your organization is something only you can fully understand" (McAllister, 2005). One estimate of the costs that make up TCO includes hardware and software, technical services, planning and process management, finance and administration, training, user support, peer support, and application development (DiMaio, 2004). However, migration costs, testing, system integration, and so forth must be included in determining the total cost of switching to any software package. For a breakdown of some of the costs to consider, please see the cost comparison provided by Nolan (2005). The comparison of costs between proprietary ERP and OS-ERP systems is not readily known, as "the lack of large-scale implementations (of OS-ERP) eliminate a direct comparison with enterprise solutions, such as mySAP Business Suite or Oracle E-Business suite" (Prentice, 2006). However, even getting an accurate TCO is not adequate when deciding whether to use open source software (DiMaio, 2004, 2007). For OS-ERP software, the decision is more complex because this decision crosses the bounds of the entire organization. Decision makers involved in evaluating ERP systems are aware that even for proprietary systems, the cost estimates vary wildly (Cliff, 2003), and thus when considering OS-ERP solutions, TCO (as complex as it is) will be but one evaluative criterion. ERP evaluative criteria are often handled by complex request for proposal processes involving outside experts. Beyond this expertise, this chapter proposes factors for valuing OS-ERP options (see the "Real Options Value of OS-ERP" section) that should be considered in addition to these complex TCO estimates.

As well, the business model (see the "Open Source Vendor Models" section) behind open source offerings will explain why cost is not as much of an issue in the definition of OS-ERP systems. However, a pure definition of OS-ERP would not include AvERP, OpenPro, or OpenMFG because, although all allow access to modify and change the code, these packages either charge a license fee or do not allow for re-distribution of the software (as mentioned above).

Functionality of OS-ERP

For those interested in understanding the OS-ERP phenomena, a solid foundation of understanding the functionality of each ERP application is also important. The maturity of the proprietary ERP market has allowed convergence as to what constitutes ERP functionality. For most, an acceptable general definition of ERP systems is as follows: ERP systems are complex, modular software integrated across the company with capabilities for most functions in the organization. As mentioned in the "History of Open Source" section, ERP systems include functionality in the following areas: marketing and sales, accounting and finance, production and materials management, and human resources. Many times supply chain management and customer relationship management are also included in ERP packages. It is beyond the scope of this chapter to list and define whether each open source system that claims to be ERP actually contains ERP functionality. For practitioners looking to acquire OS-ERP software and academicians looking to do OS-ERP research, a thorough assessment of whether a particular system contains full ERP functionality is required. This is more of an issue in OS-ERP systems since most of these systems are fairly new and a consensus has not been achieved as to what is actually an OS-ERP system. In the OS-ERP market, many of the claims of what functionality constitutes an OS-ERP system is blurry:

One characteristic of open source is that different projects define their category's feature sets in different ways. This is especially true of ERP packages. Linux-Kontor, for example, defines ERP without accounting, focusing instead on customer management, order entry, invoicing, and inventory. TUTOS, on the other hand, calls itself ERP but more closely resembles a groupware suite. Clearly, some research is needed to make sure you're really getting what you expect in this category. (Rist, 2005)

Another concern with open source software is that the offerings are changing rapidly, so for up-to-date and complete information, the Web sites listed in Table 1 are the best sources for information about the offerings and the platforms on which the software is built/supports. However, just to provide a flavor of the offerings, Table 2 provides a cursory look at the functionality being offered by these software products (OS-ERP) at the time of this work. Again, since functionality is hard to pin down, (for example, if a package only lists "HR" as its offering, does this mean benefits administration is included?), those interested in this software should contact the company directly for the most accurate and up-to-date information.

OS-ERP Examples

There are many different flavors of OS-ERP packages, mostly because each package grew from a particular need (as OSS offerings often do). For example, Fisterra grew from a custom application built for an automotive glass replacement and repair company (Fisterra, 2007). Versions of the Fisterra product specifically intended for this industry are now called Fisterra Garage. This new name allows distinction from Fisterra 2—a generic ERP released in 2004. In this case, proprietary ERP definitions apply, in that the package has what most would define as full ERP functionality. However this is not always the case (as noted above).

The industry origins of the ERP package are important, as many times these are industry solutions that work best for the original industry. This is akin to SAP providing excellent manufacturing functionality because of its origins in the manufacturing industry. Another example of OS-ERP starting in a specific industry is OfBiz, which started with an emphasis on the retail industry (Adamson, 2004).

ASSESS THE OS-ERP LANDSCAPE

In the OSS arena, infrastructure products like Linux, Perl scripting language, and My SQL database management systems have been very successful and thus very prominent. Given that the developers of open source software were many times the users of open source software, this success is predictable. Less predictable is the success of open source software when used to develop applications. Most of the time, developers are developing the application for users that are very different from themselves. The users of applications are not technical, and their requirements are very different from those of technical users—thus the criticism that open source software is not "user friendly" or has a usability problem (Nichols & Twidale, 2003). This issue is important to OS-ERP, as possibly the entire organization will interface with the OS-ERP application, rather than only IT people directly working with infrastructure products.

OS-ERP is a quickly changing environment. For example, Compiere, one of the most well-known open source ERP companies, announced Andre Boisvert as chairman of the board and chief business development officer in May 2006. Jorg Janke (founder of Compiere) noted that Boisvert's success in "applying the open source business model to markets traditionally monopolized by proprietary software vendors is definitely a plus" (Compiere, 2006a). Then, in July 2006, Compiere added Larry Augustin to its board of directors. Mr.

Table 2. OS-ERP platform and functionality

Software	Platform	Functionality
Compiere	Independent	Quote to Cash, Requisitions to Pay, Customer Relations, Partner Relations, Supply Chain, Performance Analysis, Web Store/Self Service
OpenMFG	Linux, Apple Mac OS X, Windows	Manufacturing, Materials Management, Supply Chain (Sales Order, Purchase Order, CRM), Accounting
OfBiz	Linux, Berkeley Software Distribution	Supply Chain Management, E-Commerce, Manufacturing Resource Planning, Customer Relationship Management, Warehouse Management, Accounting
Tiny ERP	Independent	Finance and Accounting, CRM, Production, Project Management, Purchasing, Sales Management, Human Resources
OpenPro	Linux, Windows	Financials, Supply Chain, Retail and Manufacturing, CRM and E-Commerce, Warehousing, EDI
WebERP	Independent	Order Entry, Accounts Receivable, Inventory, Purchasing, Accounts Payable, Bank, General Ledger
ERP5	Linux, Windows (coming soon)	Customer Relationship Management, Production Management, Supply Chain Management, Warehouse Management, Accounting, Human Resources, E-Commerce
Adempiere	Independent or Linux on its site	Point of Sale, Supply Chain Management, Customer Relationship Management, Financial Performance Analysis, Integrated Web Store
avERP	Linux	Sales, Manufacturing, Purchasing, Human Resource Management, Inventory Control, CAD Management, Master Data Management, Business Analyses
Fisterra	GNU/Linux	Point of Sale, Other Business Processes Specific to Automotive Glass Repair Businesses
OpenBravo	Linux, Windows	Procurement, Warehouse, Project Management, Manufacturing, Sales and Financial Processes, Customer Relationship Management, Business Intelligence
GNUe	Linux, Microsoft Windows	Human Resources, Accounting, Customer Relationship Management, Project Management, Supply Chain, E-Commerce
Value ERP (Project Dot ERP) http://www.valueerp.net/catalog/index.php	Linux, Solaris, Berkeley Software Distribution, Microsoft Windows	General Ledger, Payable and Receivable, Invoicing, Purchase and Receiving, Time Sheet Management for HR, Inventory Management and Manufacturing

Augustin is founder of VA Linux (VA Software) and launched SourceForge.net, the largest open source development site on the Internet (Compiere, 2006b). These new additions to the board indicate an interest in growth by Compiere.

However, Compiere faces many challenges, for example a group of developers decided to "fork"[4] and created Adempiere ERP, CRM, & SCM Bazaar (commonly referred to as Adempiere). Forking (Raymond, 1999) is not unusual in the open source community. OFBiz also has a forked version called Sequoia. Sequoia in February 2006 was renamed Opentaps, meaning Open Source Enterprise Application Suite. The issue of forking is not new in open source software and thus is an issue in open source ERP applications as well. As mentioned earlier, forking usually occurs when a group of developers decides that the current direction of the project is not as they would like; take for example what happened with Compiere's fork Adempiere. Adempiere was started in September 2006 after "a long running disagreement between Compiere and the community that formed around the project" (Adempiere, 2006). The developers behind Adempiere felt that Compiere was focusing on "commercial/lock-in" aspects of the project, and decided to create a new version that could focus more on the community and the "sharing/enriching" aspects of the project. Jorg Janke refutes these allegations, nonetheless forking has occurred.

Geographic Origins, Age, and Networks of OS-ERP Projects

At this time, there is very little research (academic or practitioner) into the global status of open source ERP. It is clear that there are many vendors out there offering open source packages in multiple languages—indicating an international audience. Also, the packages analyzed for this research have geographically dispersed locations, if any location is listed at all. Many times in an open source ERP project, the Web serves as the primary location for the project, and there is no real geographic orientation associated with the project, as is indicated by "Web" in Table 3.

Most of the open source ERP companies are relatively new (see Table 3), though many have formidable numbers of partners (see Table 4). Part-

Table 3. Geographic origins of OS-ERP projects

Open Source Company	**Project Founded**	**Where**
Compiere Inc.	2001	Santa Clara, CA
OpenMFG	2001	Norfolk, VA
OfBiz	2001 (2003 migrated to java.net)	Web
Tiny ERP	2002	Belgium
OpenPro	1998 (1999 first release)	Fountain Valley, CA
WebERP	2001 (2003 first release)	Web
ERP5	2002	Web
Adempiere	2006	Web
avERP	1998 (2001 first installation)	Bayreauth, Germany
Fisterra	2002 (2003 first release)	Web
Openbravo	2001	Pamplona, Spain
GNUe	2003 (first release)	Web
Value ERP	2005	Sparta, NJ

ners are important in sustaining an open source project. Partners have some monetary interest in sustaining a viable open source offering, as they are often offering consulting services, implementation services, maintenance, or training. The number of customers is also important in assessing the maturity of the OS-ERP. As can be seen from Table 4, Compiere currently has more the three times the number of customers as any other OS-ERP application. However, it is hard to assess the number of customers because many of these open source projects have no central repository for keeping track of this information. Although partners that provide services for OS-ERP systems have some count of how many customers they currently have, they do not necessarily share this information. For assessing the value of OS-ERP software, the number of partners, customers, and developers provides a strong network and thus should provide greater value. More will be discussed on this topic in the "Real Options Value of OS-ERP" section.

Another important consideration in assessing the landscape of OS-ERP offerings is that most of these packages are targeted to specific audiences and may only be proven for specific sizes of organizations. Table 5 outlines the size of organization targeted by OS-ERP packages according to their Web sites.

From Table 5, it can be gleaned that most OS-ERP projects are targeting small and medium enterprises, with some targeting large organizations. With this target audience, the question of multinational implementation success with OS-ERP systems is raised. At this time, the limited and varying functionality (see Table 2), and lack of large-scale implementations precludes direct comparison with solutions like mySAP Business suite or Oracle E-Business suite (Prentice, 2006).

Venture Capital Funding and Project Activity in OSS and OS-ERP

The open source market is heavily funded by venture capital firms, Guth and Clark (2005) in the *Wall Street Journal* estimated that $290 million was invested in open source in 2004. However, open source ERP companies are lagging in maturity and thus their numbers for VC funding are much lower. Currently, two open source ERP companies are funded by venture capitalists: OpenBravo (Serrano & Sarriegi, 2006) and Compiere (Hoover, 2006). Both companies are funded with $6 million.

Given the importance of the community to open source project value, SourceForge.com tracks the most active projects daily. As of November

Table 4. OS-ERP network (partners, customer, and developers)

	Customers	Partners	Developers	Data Collected From
OpenBravo	15	*	*	Serrano & Sarriegi, 2006
Compiere Inc.	240	70	50	Ferguson, 2006
ERP5	10	8	*	Serrano & Sarriegi, 2006; *www.erp5.org*
avERP	60	*	*	*http://de.wikipedia.org/wiki/AvERP*
OpenMfg	35	20	100	Ferguson, 2006; www.openmfg.com
OFBiz	59	21	*	www.ofbiz.org
TinyERP	*	34	*	http://tinyerp.com
OpenPro	*	Over 75	*	www.openpro.com
WebERP	*	9	*	www.weberp.org

** not available at time of data gathering, no information could be found for those not listed*

Table 5. OS-ERP

Software	Size of Organization Targeted
Compiere	Small, Medium
OpenMFG	Small, Medium Manufacturers
OfBiz	*
Tiny ERP	*
OpenPro	Small, Medium, Large (1-1,000+ users)
WebERP	*
ERP5	Small, Medium, Large
Adempiere	Small, Medium
avERP	Small, Medium (1-300 employees)
Fisterra	Small, Medium
OpenBravo	Small, Medium
GNUe	Small, Medium, Large
Value ERP	Small, Medium, Large

** not available at time of data gathering*

5, 2006, three OS-ERP projects fall in the top 15 most active: Openbravo ERP at #7; Adempiere ERP, CRM, & SCM Bazaar at #11; and Compiere at #14. There is clearly activity happening at the site that hosts these projects (http://sourceforge.net/top/mostactive.php?type=week). This is a sign of strength for these OS-ERP projects. Also, in trying to assess the value of OS-ERP options, VC funding and project activity would certainly positively impact the prospect for network dominance of the OS-ERP. More will be discussed on this topic in the "Real Options Value of OS-ERP" section of this chapter.

OPEN SOURCE VENDOR BUSINESS MODELS

Open source vendors have many different business models. When working with a piece of open source software, it is important to understand which type of organization/business model is in use by any particular vendor. Table 4 defines the business models that have been used to describe what is happening with open source firms in general. The most simple understanding of these models can be drawn from Bonaccorsi, Giannangeli, and Rossi (2006) with Pure OS and Hybrid business models. The Pure OS model includes firms that only offer OS products or OS solutions. The Hybrid business model includes all the others that play and profit in the OS space. Hybrid business models mix products, types of licenses, and sources of revenues. As academicians and practitioners, it is important to understand what type of vendor is included in any OS project undertaken. As can be seen from the plethora of business model types, the objectives and goals of each type of business will differ and may impact the quality of service or the types of products that the vendor offers. Organizations should consider the business model of any OS vendor with whom they engage in business, as the model and the viability of the vendor will impact the value of the OS-ERP option. Proprietary vendors do not have this range of business models, so this is not an issue with proprietary ERP systems. OS-ERP option value and its relation to business model will be discussed

Table 6. Open source business models

Business Models	Definition	Source
FOSS	Value-added service-enabling—sell support services and complementary software products Loss-leader/market creating—goal is enlarging the market for alternative closed source products and services	Fitzgerald, 2006
OSS 2.0	Includes FOSS, adds the following: Dual product/licensing—can download for free, small percentage of downloads purchase a commercial license Cost reduction—proprietary companies offer OS as part of their solution Leveraging the open source brand—as government agencies mandate that open source be a priority option for software solutions, the open source brand becomes more valuable	Fitzgerald, 2006
Software Producer GPL Model	Entirely open source offerings	Krishnamurthy, 2005
Software Producer Non-GPL Model	Incorporate source code into a larger code base and create a new product or take an entire open source product and bundle it with existing products	Krishnamurthy, 2005
The Distributor	Derives benefits by providing it on CD, providing support services to enterprise customers, upgrade services only to open source product	Krishnamurthy, 2005
Third-Party Software Provider	Provide services for all types of products	Krishnamurthy, 2005
Pure OS Business Model	Firms that offer only OS products and OS solutions	Bonaccorsi et al., 2006
Hybrid Business Model	"They (hybrids) distribute OS products but also develop customized solutions using OS software, for which they presumably offer installation, support, and maintenance. The large majority also actively supply complementary services such as consulting, training, and to a lesser extent research and development." (p. 1090)	Bonaccorsi et al., 2006
Professional Open Source (POS)	"POS combines the benefits of open source (OS) with the development of methodologies, support, and accountability expected from enterprise software vendors." (p. 329) Three features of POS: (1) separation of product adoption and purchase, (2) seed and harvest marketing strategy, and (3) dual growth of firm and ecosystem	Watson et al., 2005
Proprietary	Inability to view and modify the source code (regardless of price)	Watson, Boudreau, York, Greiner, & Wynn, 2006

continued on following page

Table 6. continued

Open Community	Volunteers develop and support code with limited or no commercial interest	Watson et al., 2006
Corporate Distribution	Organizations create value by providing complementary services such as: interacting with the community for support, supporting the software for customers, identifying appropriate OSS for customers	Watson et al., 2006
Sponsored OSS	Corporations act as primary sponsors of OSS projects. These corporations provide funding and/or developers to the project.	Watson et al., 2006
Second-Generation OSS (OSSg2)	This is a combination of corporate distribution and sponsored OSS (the OSSg2 company provides complementary services around the products, but OSSg2 companies also provide the majority of the resources needed to create and maintain their products). These types of corporations strive to provide accountability, talented programmers, and a healthy ecosystem.	Watson et al., 2006

more in the "Real Options Value of OS-ERP" section of this chapter.

CUSTOMIZATION OF OS-ERP

Proprietary ERP system customization has been explored extensively in the ERP literature (Gattiker & Goodhue, 2004; Levin, Mateyaschuk, & Stein, 1998; Nah & Zuckweiler, 2003; Soh & Sia, 2004, 2005; Soh, Siew, & Tay-Yap, 2000). OS-ERP applications are different from proprietary ERP applications in that they are closer to custom applications than to packaged software. For example, packaged software has limitations in terms of customization because the source code is not available. The issues with packaged software, as described by Gross and Ginzberg (1984) of "uncertainty about package modification time and cost, vender viability, and the ability of the package to meet the user needs," will apply differently to open source applications. Open source software has the code available, so the user is free to change (and many times is encouraged to change) the code as needed. Therefore, the issue of uncertainty about package modification time and cost depends solely on the skill of the programmers, not on some constraint that the modification may not be allowed by the proprietary software vendor. However, the ability to change source code raises a new set of problems. The efficiencies that we reap from packaged software (standards, easy maintenance, and upgrades) will not necessarily be available with open source software. Thus customization of OS-ERP is a double-edged sword. Although it is beneficial to adopters from a flexibility of the software perspective, maintenance, upgrades, and version control become new issues with which the adopting organization must contend.

Another issue that comes with OS-ERP is that the quality of the code will not always be similar to the acceptable quality of code required by the implementing organization (Spinellis, 2006). With proprietary code this is not as much of an issue, as you do not usually have access to all that code, and maintenance is definitely the duty of the vendor. In the OSS industry, it is many times expected that the skill for maintaining the code resides in the adopter's organization. Code of questionable quality will be harder to modify and maintain.

REAL OPTIONS VALUE OF OS-ERP

Much research has been done on real options theory as a way of evaluating platform change decisions (Fichman, 2004; Fichman, Keil, & Tiwana, 2005; McGrath, 1997; McGrath & MacMillan, 2000). In fact, a switch from SAP R/2 to SAP R/3 was considered a platform decision and evaluated in terms of real options (Taudes, 2000). These models and methods are useful, but seem to be missing some key variables that would influence the option value of OS-ERP.

Real options theory rests on the belief that limited commitment can create future decision rights. Real options theory has a rich history borne from the finance and economics literature, and has been applied to technology in a variety of ways. Real options theory, in terms of technology positioning projects, proposes that technologies are desirable if they provide opportunities for future rent creation. These investments require less commitment than if a full plan was created that did not allow for quitting midstream. Beyond the specific real options literature that supports the logic of committing to software with the intent of exercising some future option, the project management literature on management information systems (MIS) also supports this notion. In the case of ERP systems and large systems in general, organizations implementing technology have decided that a “staged” or incremental approach is preferable to “big bang” implementations. The staged approach allows for less radical change introduction in the organization. A logical extension of this trend in project implementation approaches to valuing technologies in the selection decision seems clear. If companies can commit to a technology, and yet have the option to proceed, as well as options for future rents, the technology is more valuable to the organization. ERP systems—and more specifically, OS-ERP systems—tend to allow for future options.

Option valuation will be performed multiple times throughout the life of a project. This is not a one-time pre-implementation exercise. This is important: as implementation techniques have changed, so have the options that are afforded by technology positioning investments. For example, a company may look at the option value of implementing specific modules of an ERP system. Future options may be to continue to implement other modules of this system, to implement an integrated best-of-breed addition, to use these modules as a stand-alone part of their system, to integrate this module back to existing legacy systems, and so forth. This approach would be in congruence with current project management practices, where the project is analyzed at different steps to ensure the project is proceeding satisfactorily. Likewise, the option value of investment should be analyzed periodically to determine how to proceed with the option[5]—the emphasis being here that option value does change with time and thus should be examined over time.

Most of the studies of real options in a technology context have used a rigorous finance-influenced quantitative methods for evaluating the value of real options (Benaroch, 2000, 2002; Benaroch & Kauffman, 1999; Clemons & Gu, 2003; Santos, 1991; Taudes, 1998, 2000). Table 7 provides important background information about these studies.

For valuing the option of OS-ERP, I propose thinking more in line with the thinking behind McGrath (1997), McGrath and MacMillian (2000), Chen and Chen (2005), and Fichman (2004). These studies apply real options thinking to a qualitative options valuation method. For example, McGrath (1997) provides factors that influence the option value of a technology positioning option. This framework was expanded with explicit items to characterize each factor in later work (McGrath & MacMillan, 2000). This theory of real options for technology positioning focuses on the factors that are necessary for specific domains: new product development and R&D type research. Although there are many similarities in R&D investments and IT platform investments, there are also many differences (Fichman, 2004).

Table 7. Finance-based studies of IT platform decisions as real options

Authors	Major Theme	Context	Case or Conceptual
Clemons & Gu, 2003	Strategic options in IT infrastructure	Credit card rates for Capital One (industry level)	Case
Benaroch, 2002	Manage IT investment risk that that helps to choose which options to deliberately embed in an investment	Internet sales channel	Case
Benaroch & Kauffman, 2000	Investment timing	POS debit market	Case
Taudes, 2000	Evaluates ERP platform change	SAP R/2 to SAP R/3	Case
Benaroch & Kauffman, 1999	Investment timing	POS debit market	Case
Taudes, 1998	Evaluates software growth options	EDI growth option	Case
Dos Santos, 1991	Applies real options theory to IT investments using two stages, where the first stage creates the option for the second stage	None	Conceptual

These differences are explained by drawing from four complementary perspectives: technology strategy, organizational learning, innovation bandwagons, and technology adaptation to develop 12 factors identified as antecedents of option value in IT platform investments (Fichman, 2004). As the focus of this book chapter is on option value of OS-ERP systems, the original factors proposed to explain option value of platform decisions (Fichman, 2004) are pared down to the most influential in this context, and the short definition is contextualized to OS-ERP option valuation. Then, several factors (see Table 8) are added based on the previous discussion of OS-ERP systems.

According to real options theory, options are valued more highly if limited commitment is required to take advantage of the option. In terms of OS-ERP options, less commitment will be required if the organization already possesses the resources to customize, maintain, and upgrade the OS-ERP software. Future rents may be created by customizing and upgrading the OS-ERP software. Less resources are required if the quality of the source code is high. As well, a fit between the business model of the OS vendor and the type of services and future solutions the organization might need would require less commitment in terms of gaining acceptance of the vendor. Future rents will be created if the business model of the vendor proves to be viable and the vendor is able to survive. This phenomenon is not unlike the dot.com era where the business model was as important as the technology. As was discussed earlier, these factors cannot be ignored in evaluation of an OS-ERP software option.

FUTURE TRENDS

Global Adoption of Open Source ERP

International research on open source firms is scarce (Bonaccorsi et al., 2006). Research in the area of OS-ERP packages is scarcer. Even scarcer still is international OS-ERP research. For that reason, some generalizations about the current state of "adoption of open source" research are attempted based on what is happening in open source software in general. As well, several open source ERP participants were asked their opinions of the international open source ERP market.

Table 8. Factors for valuing OS-ERP options

Factor	Short Definition
Susceptibility to network externalities (Fichman, 2004)	The extent to which a technology increases in value to individual adopters with the size of the adoption network. In the case of OS-ERP, this is particularly relevant as future versions of the software depend on the adoption network, the partners, and developers.
Prospects for network dominance of the technology instance (Fichman, 2004)	The extent to which the technology instance being adopted is likely to achieve a dominant position relative to competing technology instances within the same class. In the case of OS-ERP, a dominant position may be achieved by a large network of adoption, partners, and developers, as well as venture capitalists.
Customization	The extent to which an organization possesses the resources to customize, maintain, and upgrade OS-ERP software.
Quality of Source Code	The extent to which the source code associated with an OS-ERP is of high quality.
Business Model of OS Vendor	The extent to which the business model of the OS vendor is acceptable and viable to the organization.

There is clearly international activity in the open source arena, as is evidenced by a study performed by Lancashire (2001) where he showed that contributors to open source software development were shifting to an international origin. However, even this study had a very small sample (two projects) and there are questions as to the generalizability of these findings. More recently, evidence of the activity internationally in open source projects comes from the samples taken for some open source research. Bonaccorsi et al. (2006) performed a survey of 175 partners and system administrators of Italian open source[6] firms. Their sample was drawn using a snowballing technique where initial contacts refer other potential participants. This sample hints at the breadth of OSS in European countries.

Currently, several open source ERP participants based in the United States see potential for international growth. One open source ERP company estimates that about 15% of their business is from outside the United States and the CEO sees "enormous growth opportunity internationally." Another participant involved with an open source ERP package based in the United States reports that in 2005 about 80% of his income came from international sources. Then there are open source vendors that are based all over the world. The small sample of ERP vendors studied for this research shows that the base country for these organizations varies greatly (see Table 3).

There are many reasons that open source ERP is being developed internationally and development services sold internationally. The requirements of ERP systems vary from country to country. For example, China has different requirements of ERP packages than the U.S. (Liu & Steenstrup, 2004) . So, where certain packages dominate the U.S. ERP market, they are less diffused in the Asian market. Similar considerations will occur with open source ERP applications internationally. There is more room for competition from open source ERP packages in countries where the requirements are not as mainstream. This observation helps explain the proliferation of open source ERP developments around the world.

As for the services of U.S. developers being sold around the world, some U.S.-based open source

ERP participants feel that the international opportunity is greater because the dollar is weaker, and so development by U.S. programmers is more affordable to those outside the U.S. The economics of this assumption also work in the reverse. There are many instances of international partners to U.S.-based ERP projects that are called on to develop customizations for U.S.-based users of the software because this international labor is more affordable.

CONCLUSION

This chapter outlines the current state of several OS-ERP packages (see Table 1) along the dimensions of licensing, geographic origins, number of customers, number of partners, targeted organization size, and functionality. Then the several factors that are important to decision making about OS-ERP packages are discussed: susceptibility to network externalities, prospects for network dominance, customization, quality of the source code, and business model of the OS vendor.

These factors will be important to OS-ERP packages crossing the credibility gap. Currently, as companies scour the landscape looking for an ERP package, there are very few open source offerings that have established credibility as reliable, maintainable, and scalable. Once several OS-ERP packages cross this hurdle, more widespread use of OS-ERP can be expected. As well, since the cost of ownership of an ERP package is so complex, marketing OS-ERP packages as more affordable is probably not going to gain much traction or gain the attention of major decision makers in the ERP space. Other features of OS-ERP, like customizability (given an adequate upgrade path) and a strong OS-ERP network, most specifically customers and consulting partners, will be desirable to decision makers.

This chapter hopes to enlighten practitioners and academia about the growing field of OS-ERP systems and their role in the international ERP community. There are significant differences in the offerings of open source ERP packages, and theoretically grounded evaluation techniques of OS-ERP are little researched or published. The aforementioned topics are important for creating a clear picture of what is currently on the market and the future directions of the OS-ERP market. Given the data presented in this chapter, it is clear that while OS-ERP is entering the ERP market, OS-ERP is far from a strong player. Also, OS-ERP is currently marketed as a small and medium enterprise option, with some governmental agencies also considering its use. Future research should attempt to explore the value gained and experiences of organizations actually using OS-ERP systems.

FUTURE RESEARCH DIRECTIONS

OS-ERP is a very little researched area. Future research should be performed that rigorously interviews OS-ERP participants about motivation, as this will add to the current literature about OSS motivation (several motivation articles are listed in the Additional Reading section). Many open source software initiatives fill a gap in functionality and thus are interesting to programmers. ERP systems are mature enough to lack such gaps, and thus figuring out what interests programmers that take part in OS-ERP projects could shed more light on the issue of motivation. Also, OS-ERP in the global context is an area ripe for research. Case study research of a large multinational implementation of OS-ERP would inform academia as to how large organizations work with open source communities and whether the functionality offered by OS-ERP systems is adequate in such a setting. Survey research with global companies might shed light on the differences in companies that adopt OS-ERP solutions and those that choose proprietary solutions. Global public sector research is also needed, as the motivations and evaluation criteria for public sector organizations is noted in the popular press to be different from private companies.

To build on the ideas in this chapter, the five factors should be included in a survey of those that have adopted and not adopted open source research to determine how these factors impacted the decision, and whether there were future implications of any of these factors on the success of the OS-ERP implementation. Each factor should be further researched in terms of options evaluation in the OS-ERP domain. For example, the author has posited that OS-ERP is closer to custom software than to packaged software. This assertion should be tested through rigorous research. This could be done by looking at how much customization is actually done to OS-ERP packages, and how upgrades and maintenance are handled on these customized systems. ERP customization literature would benefit from such research. This is a partial list of possible future research directions. All of the topics covered in this chapter: factors for evaluating options, global OS-ERP systems, and OS-ERP organizations require much more research for academia to build a complete and coherent picture of OS-ERP and its impacts.

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ENDNOTES

[1] http://www.sugarcrm.com/crm/SPL—The SugarCRM Public License Version (SPL) consists of the Mozilla Public License Version 1.1, modified to be specific to SugarCRM. Please see the actual license to understand the terms of this license.

[2] Intensive and complete functionality for ERP vendors includes the aforementioned

functional areas, though the specifics of what is included in each functional area may be termed differently by different vendors (i.e., Oracle and SAP); however, both offer much of the same functionality and this base functionality is what is intended by the author when discussing ERP systems. For details about this functionality, see SAP.com or Oracle.com.

[3] See the Free Software Foundation Web site at http://www.fsf.org/licensing/licenses/ for another source for OSS licensing resources.

[4] "Forking" is not unusual in open source communities. Forking refers to taking the code in a separate direction, usually a direction not intended by those managing the open source project. There are dissenting opinions as to whether this is cause for alarm for the original open source project.

[5] For a review of potential option outcomes, see Fichman et al. (2005).

[6] Open source is defined as firms that supply OS-based offerings, even if the offering includes proprietary solutions.

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Chapter 8.3

The Dynamics and Rationality of Collective Behavior within a Global Information System

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ABSTRACT

The scope of interests in the area of information systems (IS) has focused mainly on technological aspects so far. If the human component were taken into account, it has been analyzed from the level of an individual. So have all new concepts of rationality. This chapter argues that collective behavior, which is a basic determinant of the global IS dynamics, does not proceed in a planned manner, but is adaptive and follows certain patterns found in nature. It follows that this behavior can be expressed in a model form, which enables to structure it. A model exemplification of a global information system is a modern, electronic, stock exchange. The identification of quantitative attributes of a social subsystem can provide substantial theoretical and methodological premises for the extension of the optimizing and individualistic notion of rationality by the social and adaptive aspects.

INTRODUCTION

General Perspective

One of the main issues, both in the theory and practice, of social and economic sciences is the question of integration, that is, how actions and interactions of individuals lead to the emergence of phenomena that characterize social entireties. This topic acquires particular importance in light of the dynamic integration processes of societies, for example, the recent enlargement of the European Union, when, in 2004, 15 new member states joined this commonwealth. The integration processes, aided with the most recent achievements in information technology (IT), harmonize with globalization and virtualization of human activity, from social to political to a business one.

The outlined issue is the background of two basic research threads proposed in this chapter.

The first part refers to the question of human behavior within an information system (IS). A fully integrated society of the future will make a fundamental, subjective element of a global information system. That global IS will be either a ubiquitous and wireless Internet, or some totally different, unknown yet, technological platform. And it is crucial that so far interests in the area of IS have concentrated mainly on technological aspects. The issue of human behavior within an IS has been generally omitted as one belonging to other disciplines. Admittedly, since the mid-1990s we have observed some growth of interest in the domain of social aspects of the IS development (Avison & Fitzgerald, 2003), but those interests have concentrated on the specificity of individual behavior. However, the nature of global phenomena and the features of dispersed collectivities denote a necessity of a new perspective on the society and organization. No longer can we perceive the human component of an IS as independent individuals. The users of local, regional and global telecommunications networks create a specific form of a *virtual crowd*, accessing the same sources of information and reacting to the same sets of stimuli. These users, through their interactions, compose the phenomenon of an IS dynamics. The dynamics not understood as one referring to the flow of energy (e.g., electrical impulses), but dynamics based on the collective information processes, reflected in collective actions. A phenomenon that was called by Simon (1955) "a collective mind."

And here we find the other research thread of this chapter: the issue of human rationality. The Western organizational culture still is based on three main determinants: individualism, competition, and a mechanistic-reductionist perspective. As a result, the essential body of scientific achievements in the area of human behavior concerns individuals (Nelson & Quick, 2005), and this is reflected in the paradigm of rationality. This depiction, known as rational choice theory (Alingham, 2006), assumes that individuals are perfectly rational, with clearly defined preferences, and optimizing their behavior at all levels of a decision-making process. Reductionism, which is related to it, postulates that collective behavior is composed of the sum of rational behavior of all individuals. Since this *sum* is purely theoretical and abstract, it generally is accepted that all phenomena concerning a collectivity are exclusively qualitative and cannot be structured.

The deficiencies of the traditional, idealistic approach to rationality have been known and discussed for a long time. Admittedly, since Simon's idea of "bounded rationality" it has been allowed that human actions can be more "satisficing" than "optimizing," but all new concepts of rationality still refer only to individual behavior (Halpern & Stern, 1998). At the same time, it has been emphasized that there is a need for such a formulation of the rationality principle so that it can take into account the specificity of collective behavior, so different from the individual one.

This chapter tries to briefly explore the existing possibilities of an effective modeling of collective information processes, and of structuring this phenomenon through the identification of its quantitative dimension. The potential findings should help formulate a new, wider, approach to rationality, which could respond to the integration and globalization trends of modern societies.

Objectives

The main objective of this chapter is a presentation of an innovative approach to the analysis and modeling of collective information processes and the mechanisms of collective behavior within a model global IS. This is the first such attempt in relation to the above-mentioned social aspects of information systems. Extensive literature studies helped formulate the following research questions:

1. Are information processes of collectivity and the resulting collective behavior, which

constitute the dynamics of an information system, phenomena of exclusively qualitative nature, impossible to structure?
2. Does irrationality or non-rationality, and unpredictability of individual actions determine irrationality and unpredictability of the whole social system within a Global IS?
3. Is there a research method allowing to identify and analyze a phenomenon of "social rationality," from its theoretical to methodological to empirical dimension?

These research questions produced the following theses:

1. Collective behavior, which is a basic determinant of the IS (global IS) dynamics, does not proceed in a planned and intended manner, but is adaptive and follows certain patterns found in the world of nature.
2. Collective behavior can be expressed in a model form, which enables to structure this phenomenon, otherwise considered purely qualitative so far.
3. The identification of quantitative attributes of collective behavior can provide substantial theoretical and methodological premises for the extension of the optimizing and individualistic notion of rationality by the social and adaptive aspects.

THEORETICAL BACKGROUND

Electronic Exchange as a Global Information System

The Notion of Information System (IS)

There are very many definitions of an information system. Some, such as the following example, emphasize the use of information and communication technology (ICT): "Any telecommunications and/or computer related equipment or interconnected system or subsystems of equipment that is used in the acquisition, storage, manipulation, management, movement, control, display, switching, interchange, transmission, or reception of voice and/or data, and includes software, firmware, and hardware" (National Information Systems Security Glossary, 1999, p. 31).

Others narrow it down to systems that support management decision making. This is typical for more recent approaches, which generally adopt a broader view. It goes well beyond the integration of hardware and software, and considers an information system to be any system that has collection, processing, dissemination, and use of information as a major component in terms of its purpose and the activities it carries out. Most modern information systems with any degree of complexity will, in practice, almost always incorporate ICT, but the technology is not the defining aspect. The significant issues are the generation, processing, and use of information.

For example, according to Vigden et al. (2002, p. 2), an information system is a set of interacting components—people, procedures, and technologies—that together collect, process, store, and distribute information to support control, decision making, and management in organizations. This definition stresses the mutual relation between an organization's management system and its information system.

Benson and Standing (2002, p. 5) identify the basic components of an information system: people, data/information, procedures, software, hardware, and communications.

Pearlson and Saunders (2004, p. 14), in turn, define an information system as the combination of people (the "who"), technology (the "what"), and processes (the "how") that an organization uses to produce and manage information. They also refer to information technology as the technical devices and tools used in the system.

The scope of this analysis makes one more definition of an IS especially useful for further considerations. Buckingham et al. (1987) define an information system as: "A system which assembles, stores, processes and delivers information relevant to an organization (or to society), in such a way that the information is accessible and useful to those who wish to use it, including managers, staff, clients and citizens. An information system is a human activity (social) system which may or may not involve the use of computer systems."

This definition is useful in that it emphasizes the human and organizational aspects of information systems. The definition also makes clear that not all information systems use information technology, and that an information system is in essence a human activity system situated in an organizational context—technology is important to information systems but must be considered jointly with human and organizational dimensions.

There are two clear examples of information systems, at somewhat different ends of the spectrum. A payroll system is an information system. This was one of the first applications to be computerized. Today, payroll systems are not simple, there exists a wealth of legislation with which the system has to cope and comply. A payroll system also must be flexible and maintainable, for almost every few days there are changes. It does not provide any competitive advantage to an organization, it is just a necessary system for an organization to have to enable it to be in business. It is what is termed, a mature application. There are many such mature systems in organizations, for example, invoicing systems, billing systems, order processing systems, inventory systems, and personnel systems.

The next example system is very different. It is an electronic auction house, such as eBay. It is relatively new (eBay started in 1995) and uses the World Wide Web as its user interface. Yet, essentially, it is just an information system. It matches buyers with sellers utilizing an auction concept. This concept is not new, there have been auctions for hundreds of years, but the electronic auction enables buyers and sellers to be geographically distributed across the world, whereas, the traditional auction required the buyers and sellers, and the product being auctioned, to be together in a particular place at a particular time. The electronic auction breaks the tradition in terms of both time and space. The auction house usually provides payment, insurance, delivery, security, and other services to its clients if required and, in general, provides an environment that enables people to participate easily and securely in an auction from the comfort of their home or workplace. So, the electronic auction is an information system, comprising people, rules, procedures, technology, software, communications and allied services.

IS Categories

There are different typologies and different levels of analysis within the area of information systems. Most generally, there are three basic categories of information systems:

- Simple manual (paper-and-pencil) IS
- Informal (word-of-mouth) IS
- Computer-based IS

Our concern in research today is with computer-based information systems. We must remember, however, that many information systems in organizations are informal—the office grapevine and conversations at the water-cooler are typical examples of these. Although the informal aspects of information systems are difficult to manage and are not amenable to an engineering approach, their influence should not be under-estimated.

This is consistent with the system's view presented by Thompson (1976, pp. 2-26) three decades ago. He argued that the organization consisted of two systems. The artificial system is the tool designed by the owner, managers, or both to accomplish a particular goal. The informal organization of social relationships constitutes a natural system whose goal is not entirely compatible with the artificial system's goal. The result is that the effectiveness of the artificial system is always limited by the natural one.

Thus, there are other forms of information systems. Organizations have always needed information systems, although the formal aspects of these information systems would have been implemented using paper-based filing systems (paper-and-pencil) in the pre-IT era.

One of the many ways to identify the development of IS/IT is using a three-era model (Ward & Peppard, 2002, p. 23). The prime objective of using IS/IT in the eras differs:

1. **Data processing:** To improve operational efficiency by automating information-based processes (from the 1960s onward—the DP era).
2. **Management information systems:** To increase management effectiveness by satisfying their information requirements for decision making (from the 1970s onward—the MIS era).
3. **Strategic information systems:** To improve competitiveness by changing the nature or conduct of business—from the 1980s onward (the SIS era).

Next, focusing, for example, on management information systems, they sit on the boundary between information and knowledge—MIS are really support tools providing management with the information needed to do the job. In essence, different kinds of information are able to be accessed and analyzed, and summarized reports produced. The reports are used at the highest levels of management to produce long-term strategic plans, and in middle management to improve the quality of service and employee efficiency, or for simple operational matters. MIS can be divided into five basic categories (Benson & Standing, 2002, p. 87):

- Management reporting systems (MRS)
- Decision support systems (DSS)
- Expert systems (ES)
- Executive information systems (EIS)
- Groupware

To conclude this brief overview of IS categories, let us concentrate on another important criterion. It is the range of applicability, and there are micro- and macro-economic information systems. In light of the dynamic growth of a global telecommunications network, we can complete this typology with a relatively new category of global information systems. Turban et al. (2005, p. 277) define global information systems as inter-organizational systems that connect companies located in two or more countries. There are three main categories of organizations that use global information systems: multinational, international, and virtual organizations. Companies that have global operations usually use the Internet. The major benefits of global information systems for such organizations include:

1. Effective communication at a reasonable cost.
2. Effective collaboration to overcome differences in distance, time, language, and culture.
3. Access to databases of business partners and ability to work on the same projects while their members are in different locations.

Global systems involve multiple organizations in multiple countries. Examples include: airline reservation systems such as Travelocity (www.travelocity.com) or Expedia (www.expedia.com), police and immigration systems, electronic funds transfer (EFT) systems (including networks of ATMs), and many commercial and educational systems for international organizations such as the European Union (http://cordis.europa.eu).

Also, the electronic auction house, described earlier, belongs to this category. We may posit, then, that a modern, electronic exchange (stocks, commodities, currencies) also constitutes a good example of a certain category of global information systems. Besides, the performance of capital markets is a typical example of group (crowd) reactions (Plummer, 1998), which will be especially useful in further analysis.

Another important observation from this brief analysis points to a certain structural characteristic of an information system. Regardless of different definitions and approaches, people constitute the basic component of any information system. We may assume, then, that the most important element of each information system is its social subsystem, which complies with the basic categorization of IS, and with the notion that IS do not have to use modern technologies.

The social subsystem of an electronic and virtual stock exchange will be the subject of further analysis.

IS Dynamics

Dynamics (Latin: *dynamikos,* "strong," "possessing strength") according to *Webster's Unabridged Dictionary* (2005, p. 564), refers to "that branch of mechanics which treats of the motion of bodies (kinematics) and the action of forces in producing or changing their motion."

According to Eden and Spender (2003), the dynamics of an organization represents changes in the various types of knowledge, in the learning and unlearning processes. The basic determinants of this phenomenon are thus:

- Knowledge
- Learning
- Unlearning

Organizational learning is a metaphor indicating the way an organization adapts to the constantly changing environment. Organizational learning occurs as knowledge, acquired and developed by individual members, is embedded in *organizational memory.* At the same time, collective knowledge cannot be understood without paying attention to the communication processes going on among the group's members (Weick, 2000). It follows that information and decision processes flowing in the social subsystem of a given IS condition the phenomenon of the IS dynamics, and learning and unlearning are a specific category of these processes. Decision processes usually precede taken actions, therefore, collective behavior, as a consequence of collective information and decision processes, is the next determinant of the IS dynamics.

The IS dynamics, generally understood as the systems ability to act, refers directly to a phenomenon defined as the "activity system" (Eden & Spender, 2003). The notion of activity system, jointly with the notion of the *organization's culture* point to the next determinant of the IS dynamics. It is the *collective mind,* which can only be identified in the practice of the activity system, and for many analysts the terms organizational culture and collective mind are scarcely separable.

As early as 1895, Le Bon (2006) in his classic "The Crowd: A Study of the Popular Mind" posited that a crowd is primarily a *psychological* phenomenon rather than a physical one (although the two concepts are not necessarily mutually exclusive). He considered that any number of otherwise independent and spatially separate individuals could form a crowd, provided that the members had a *common cause.* This implies that *crowd-type* pressures can be found in a large range of groupings. We can identify the occurrence of this phenomenon during football games, manifestations, and revolutions, in schools (peer pressure) and religious cults. We also can find it in many organizations, especially those, where the identification of an employee with the company is very strong. Le Bon argued that "whoever be the individuals, the fact that they have been transformed into a crowd puts them in possession of a sort of collective mind" (2006, p. 53).

A crowd is, then, something other than the sum of its parts—in particular, a crowd has an effective mind of its own, and each individual's behavior is altered by membership of a crowd. Generally, this phenomenon reveals how strongly a group influences its members and is described more precisely by the "social laws" (Pring, 1993). According to these laws:

- A group of people, or "crowd," is subject to instincts that individuals acting on their own would never be.
- People involuntarily follow the impulses of the crowd, that is, they succumb to the herd instinct.
- Contagion and imitation of the minority make individuals susceptible to suggestion, commands, customs, and emotional appeals.
- When gathered as a group or crowd, people rarely reason but, instead, follow blindly and emotionally what is suggested or asserted to them.

Today, it is assumed that an organism does not even need a brain in order to be intelligent. Intelligence is a property that emerges when a certain level of organization is reached that enables the system to process information. The greater the ability to process information, the greater the intelligence. If a system has the capacity to process information, to notice and respond, then that system possesses the quality of *intelligence* (Wheatley, 2005, p. 98). Any entity that has capacities for generating and absorbing information, for feedback, for self-regulation, possesses mind. This approach offers us a means to contemplate *organizational intelligence*.

The issue of human behavior within an information system is the most recent research trend in the area of information systems development (ISD). In 1994, Morita, the founder of Sony Corp., pointed to the constantly growing gap between the world of business, and generally a society, and the new world of information technology, and called it the "IT/business gap." Arguably, it was the first human aspect within the area of IS that was detected so clearly. The problem identified by Morita a decade ago concerned individual attitudes and actions. Today, the Internet revolution and an unprecedented growth of dispersed collectivities denote a necessity of a new perspective on the society and organization. No longer can we perceive the social subsystem of an IS as a set of independent individuals. The users of the global information system create a specific form of a *virtual crowd*, accessing the same sources of information and reacting to the same sets of stimuli.

The idea that behavior in financial markets is essentially a crowd phenomenon is the basis of this analysis. At one extreme, a self-aware individual is potentially unpredictable except within the very broadest of guidelines. However, at the other extreme, people as a group are predictable. This is the essence of the crowd phenomenon, and the main challenge is to find a quantitative measure of this phenomenon. It follows that the individualistic and optimizing approach to rationality has become insufficient in that new, virtual environment, and the next big challenge in the discussed area is an attempt to adapt the traditional paradigm of rationality to the new reality.

Rationality of Human Behavior

Traditional Approach to Rationality

Battram and Battram (2002, p. 94) argue that modern management thinking is underpinned by three myths. These are: the myth of the rational person, the myth of the economic person, and the myth of the scientific person.

The rational person is characterized by the property of perfect knowledge, and the ability to obtain and retain perfect information. Also it is assumed that people are always rational and logical, and all else being equal, decisions are always about selecting the best alternative. The myth of the economic person is that the market is perfect, free and open, and everyone behaves perfectly within it. Similarly, the myth of the scientific person tells us that our decisions are always logical, perfectly quantified, based on an understanding of cause and effect, and carried out in our mind, without any influence from emotions, and other distractions.

The key word of those three myths is "rationality." Rationality (Latin: *rationalis,* "reasonable"), according to *Webster's Unabridged Dictionary* (2005, p. 1193), refers to the "possession of," "agreeableness to," or "exercise of reason." Reason, in turn, is a "basis or cause;" or a "statement in justification or explanation of a belief or action" (2005, p. 1197).

Rational behaviors follow stable, consistent, and coherent beliefs or rules that enable individuals to understand what they are doing and why. The most clearly elucidated rules of rational behavior are based on self-interest. As early as the late 1800s, Edgeworth (1881/1974), in *Mathematical Psychics* asserted that the "first principle of Economics is that every agent is actuated only by self-interest." And so, Edgeworth's *first principle* of self-interest came to define the core of economic and political models.

Today, the notion of positive science is premised on a rational method, and social scientists have struggled continually with the concept of rationality, both in defending their methods and in describing human behavior. One side in the debate argues that the classical economists' model of rational decision making offers the best way to understand decision behavior. This model focuses on the value, or utility, of the decision outcome. And since the publication of Von Neumann and Morgenstern's (1944) seminal work, the concept of maximizing expected utility became synonymous with rationality. This axiomatic single-person decision theory considers only rational outcomes, those made based on maximization of expected utility, unencumbered by external pressures or cognitive limitations.

The second group of researchers, those concerned with decision processes, advocate identifying specific behaviors or concerns that characterize humans and incorporating their influences into the classical models.

A third approach to the debate advocates the inclusion of context, particularly social context, as an additional element influencing the decision maker (Halpern, 1997; Mele & Rawling, 2004). As this third, more recent, approach develops, it may either extend or repudiate the classic model.

Within economics a theory of rational choice developed, adding to the self-interest argument the notion of "revealed preferences" (Halpern & Stern, 1998). The theory assumes that people are capable of expressing both consistent preferences (evaluative judgments) and consistent beliefs (predictive judgments concerning cause and effect). This individual choice model combining self-interest with preference simplifies our understanding of decision making by offering maximization of expected utility as the sole criterion of a rational choice.

The economists' preference for investigating rationality in a vacuum emerged from their tendency to study an ideal market with perfect competition, which functions without prolonged human or social contact. As a result, the central assumptions of rational choice theory are powerful simplifications. Arrow (1990, p. 25), a Nobel-prize winning economist, argues that: "[The rationality assumptions] . . . imply an ability at information processing and calculation that is far beyond the feasible and that cannot well be justified as the result of learning and adaptation."

The critics of the classical rational choice structure, including anthropologists and some psychologists and sociologists, long have argued that decision making, even economic decision making, tends to occur in a social setting (e.g., Lichbach, 2003; Coleman, 1998). Recently, researchers, including some economists have agreed that rationality has a social component (e.g., Shi, 2002; Sato, 2006). The social context creates pressures of its own, influencing the decision process and outcome. Arrow (1990, p. 25) acknowledged the importance of context in this observation: "Rationality is not a property of the individual alone, although it is usually presented that way. Rather, it gathers not only its force but also its very meaning from the social context in which it is embedded." Recent laboratory work, based on these earlier empirical observations, suggests that the social context exerts its effects even when there is no communication between transactors (Halpern, 1997). This observation has a particular significance for further analysis, which concerns the rationality of collective behavior of investors taking actions in the virtual environment of present-day capital markets.

Alternative Notions of Rationality

The first response to Von Neumann and Morgenstern's formulation of rationality as maximization was Simon's (1955) idea of *satisficing*. Simon observed that human decision making is "boundedly rational": it is limited by our inability to process all the information that is available as well as by our inability to be consistent in our preferences. As a result, people tend to "satisfice" or use a variety of heuristics (shortcuts) in their decision-making process.

Simon's critique of the maximization principle was based on two issues. First, in order to maximize one has to have all the relevant information, and this usually is not the case. Second, people are limited in their ability to process information; hence, the chance that people would be able to maximize is rather small. According to this model, people select a subsample of the space of total relevant alternatives and search until they find a *good enough* alternative. Search is terminated when an alternative gets selected, and since the process does not continue to ensure the selection of the optimal alternative, it is defined as satisficing, which differs from maximizing.

Simon's analysis of bounded rationality treated individual and organizational decision making similarly. The development of behavioral decision theory over the last 30 years, however, has focused more on the individual level of analysis. Recent attempts have been made to link the two and over the last decade relationships between these two levels of analysis have been explored (e.g., Kahneman & Lovallo, 1993; Shapira, 2002).

In 1978 March proposed variants on the classical notion of rationality. In addition to the notion of *bounded rationality*, he suggested several alternatives. *Limited rationality*, describes the features of a process where decision makers try to simplify a decision problem because of problems associated with considering or anticipating all the alternatives and all the needed information. *Contextual rationality* highlights the effects of a social context where there are multiple other claims on decision makers' attention. *Game rationality* highlights the degree to which self-interests and calculation guide the behavior of a decision maker, while *process rationality* is the extent to which decision makers focus on the process of making choices, rather than on the decision outcomes. *Selected rationality* refers to the process of selection through survival or growth, while *posterior rationality* refers to the discovery of intentions after actions have been taken.

Last but not least, *adaptive rationality* was supposed to emphasize the experiential learning of individuals and the way experience affects learning. This was the first case of a usage of the term "adaptive rationality." This concept, however, related to individuals only and remained in the area of theoretical proposals. This chapter explores the possibilities of an extension of the notion of adaptive rationality to the whole social system within a given IS, and supports it with a practical case study.

In 1992, Mumby and Putnam unshackled rationality and expanded it to embrace emotionality. Their concept of *bounded emotionality* fuses the emotional foundations of the social phenomenon, rationality, with the currently reified perspectives. The boundedness stems from each party's mutual respect for the other's space and dignity (a choice that a person makes) rather than the boundedness of rationality that is treated as a constraint without choice. Originally, this approach was supposed to unite the concepts of *bounded rationality* and *emotionality*. The authors suggested acknowledging the *emotionality of rationality*, in order to create an appreciation of "intersubjective understanding, community, and shared interests" (1992, p. 480), recognizing not only the cognitive, instrumental dimensions, but also the social dimensions of human behavior, in which emotions play an important role.

Similarly to March's adaptive rationality, bounded emotionality still remains a theoretical concept, without any empirical achievements.

Finally, in 1998, the concept of *bonded rationality* was introduced (Halpern & Stern, 1998). Just as human cognitive limitations on our ability to process and use information lead us to have "bounded rationality," so also do our shared limitations on information processing and on our understanding of the evaluation of alternatives lead us to a "bonded rationality" based on our need to interact effectively with other people.

Bonded rationality is a model of human interaction that argues first, that we share ways of evaluating alternatives that may not be objectively optimal, and second, that we reason rationally about these shared evaluations. It follows that we should study evidence of suboptimal transaction behavior as elucidating shared ways of valuing alternatives rather than as evidence of nonrational reasoning.

Bonded rationality derives from the fact that our personalizations (individual acts of understanding alternatives) can be understood by others, and that we wish these personalizations to be understood by others. The decision maker who is bondedly rational usually is understood (although not necessarily agreed with) by peers because his or her personalized perceptions share common cognitive bounds and contextual references. Bonded rationality thus both derives from, and facilitates, social interaction.

What is important, bonded rationality argues that individuals reason rationally about alternatives as they personalize these alternatives, but this rational reasoning proceeds in terms of the axioms of rational choice theory. Nevertheless, the concept of bonded rationality explicitly adds social and cultural context to considerations of psychological influences in rational decision making. It is thus both more realistic than theories of rationality that ignore context, and a fertile source of research questions. By emphasizing the importance of how decision makers personalize alternatives, bonded rationality focuses attention on the influences of psychology, sociology, and anthropology on rational decision making.

This cursory survey of alternative notions of rationality shows that in spite of the development of diverse concepts, and a general consensus about the existence of many possible ways to describe rational behavior, still dominates the classic, single-person and optimizing, version of rationality. This creates a need to both continue research in the area of social and organizational aspects of rationality and search for empirical evidence for proposed theoretical concepts.

METHODOLOGICAL BACKGROUND

The Paradigm Shift

Most of today's organizations are designed and managed according to the assumptions taken from 17th century physics, from Newtonian mechanics. This machine imagery leads to the belief that studying the parts is the key to understanding the whole. These assumptions also are the base from which we do research in all of the social sciences. Intentionally, or not, we work from a world view that has been derived from the natural sciences. Even to this day, many scientists keep searching for the "building blocks" of matter, the physical forms from which everything originates.

However, we need to expand our search for principles of organization to include what is presently known about the universe. Only this can help us explain how to create structures that move with change, that are flexible and adaptive, even boundaryless, that enable rather than constrain.

One of the first differences between new science and Newtonianism is a focus on holism rather than parts. Organizations are understood as whole systems, and attention is given to relationships within those networks. When we view systems from this perspective, we enter an entirely new field of connections, of phenomena that cannot be reduced to simple and linear cause and effect, or explained by studying the parts as isolated contributors. In this new land, it becomes critical to sense the constant working of dynamic processes, and then to notice how these processes materialize as visible behaviors and forms. The most recent trend even goes as far as assuming that a system is a set of processes that are made visible in temporary structures (Wheatley, 2005, p. 23).

The new science research referred to in this chapter comes from the disciplines of quantum physics, biology, chemistry, theories of evolution and co-evolution, theories of complexity and chaos. They span several disciplines, so the proposed research approach is, by definition, multidisciplinary, and interdisciplinary.

For example, in physics, the search for radically new models is characterized by the major discoveries in quantum mechanics. In the quantum world, relationship is the key determiner of everything. In a homologous process, described as *relational holism*, whole systems are created by the relationships among subatomic particles. Subatomic particles come into form and are observed only as they are in relationship to something else. Electrons are drawn into these intimate relations as they cross paths with one another, overlapping and merging; their own individual qualities become indistinguishable. There are no *building blocks.* Many physicist nowadays describe elementary particles as, in essence, a set of relationships that reach outward to other things.

A new understanding of change and disorder also has emerged from chaos theory. Work in this field has led to a new appreciation of the relationship between order and chaos. These two forces are now understood as mirror images, two states that contain the other. A system can descend into chaos and unpredictability, yet, within that state of chaos the system is held within boundaries that are well-ordered and predictable. Chaos is necessary to new creative ordering.

In chemistry, Prigogine's and Nicolis's (1977) work confirmed that disorder can be the source of new order. Prigogine coined the term "dissipative structures" for these newly discovered structures. In a dissipative structure, anything that disturbs the system plays a crucial role in helping self-organize into a new form of order. Whenever the environment offers new and different information, the system chooses whether to accept it and respond. If the system brings the information inside, the information grows and changes. If the information becomes such a large disturbance that the system can no longer ignore it, then real change is at hand. At this moment, far from equilibrium, the system will fall apart. In its current form, it cannot deal with the disturbance, so it dissolves. But this disintegration does not mean the end of the system. If a living system can maintain its identity, it can self-organize to a higher level of complexity.

In this way, dissipative structures demonstrate that *disorder* can be a source of new *order,* and that growth appears from disequilibrium, not balance. The things we try to avoid in organizations-disruption, confusion, chaos-are thus necessary to awaken creativity. And so, our concept of organizations is moving away from the mechanistic creations that were useful in the age of bureaucracy. We now speak of more fluid, organic structures, of boundaryless and seamless organizations. We are beginning to recognize organizations as whole systems, construing them as *learning organizations* or as *organic* and noticing that people possess self-organizing capacity. Most importantly, however, organizations are living systems, possessing the same capacity to adapt and grow that is common to all life. And fluctuation and change are essential to the process by which order is created.

Scientists of chaos study shapes in motion. Wholeness is revealed only as shapes, not facts. Systems reveal themselves as patterns, not as isolated incidents or data points. Wheatley (2005, p. 125) raises a question: "If we were to understand organizations in a similar way, what would constitute the shapes in motion of an organization?" This chapter makes an attempt at answering, at least partially, this question.

Collectivity of Investors as a Complex Aadaptive System

The flow of collective information processes determines organizational learning, which is a useful metaphor describing the way an organization, including a virtual and global one, adapts to its environment. The research on collective mind and collective behavior can be conducted within a social subsystem of an electronic stock exchange, which was recognized as a model representation of a global information system. The performance of capital markets is a typical example of crowd reactions. After the memorable crash of world financial markets in August 1998, Alan Greenspan, chair of the U.S. Federal Reserve Bank, affirmed that "markets are an expression of the deepest truths about the human nature" (Ramo, 1999).

Financial markets are fast-moving, continually oscillating, reflections of the processes of transformation and change. Unlike any other crowd, the behavior of financial market crowds is clearly reflected in simple, and specific, indicators. These are the price movements themselves, and certain mechanical indexes of the underlying activity and energy of the crowd, such as trading volumes. Financial markets are, therefore, an ideal source of information about all crowd behavior.

The introductory analysis shows that the social subsystem of an electronic and virtual stock exchange reveals at least four characteristics of a nonlinear, complex adaptive system. Turniansky and Hare (1998, p. 106), analyzing the issue of self-organization, identify the main characteristics of a complex adaptive system. Such a system:

- Consists of a network of agents acting in a self-managed way without centralized control.
- The environment in which the agents find themselves is constantly changing and evolving since it is produced by the interactions with other agents.
- Organized patterns of behavior arise from competition and cooperation among agents producing structures arising from interactions and interdependencies.

The processes in a complex adaptive system are those of mutual adjustment and self-regulation. Each self-organizing structure is responsive to disequilibrium, is open to the environment for the exchange of information and energy, and is able to process information and energy. They are decentralized systems having a bottom-up direction from combining actions rather that top-down centralized control. The structure that emerges is not simply an aggregation of individual actions, but rather has unique properties not possessed by individuals alone.

Self-organization cannot be imposed from outside, but operates from within the system itself. Organization is not designed into the parts, but is generated by the interaction of those parts as a whole. The self-organizing form has implications for organizational learning. Self-organizing or self-renewing systems are characterized by system resiliency, rather than stability. When the systems have to deal with new information they recognize themselves in the ways needed to do so. Its form and function engage in a fluid process where the system may maintain itself in its present form or evolve to a new order. The system possesses the capacity for spontaneously emerging structures, depending on what is required. It is not locked into any one best form but, instead, is capable of organizing information in the structure that suits the present need. In other words, instead of making information fit the existing structure, structure is made to fit the information.

In a seemingly paradoxical way, openness to the environment, to information from outside, leads to higher levels of system autonomy and identification. Some fluctuations will always break through, but what comes to dominate the system over time is not environmental influences, but rather the self-organizing dynamics of the system itself. In response to environmental disturbances that signal the need for change, the system changes in a way that remains consistent with itself in that environment. The system is autopoietic, focusing its activities on what is required to maintain its own integrity and self-renewal (Cooper, 2006). As it changes, it does so by referring to itself; whatever future form it takes will be consistent with its already established identity.

Each element in the system influences other elements directly, indirectly, or both. The relationships are mutually determining and determined. As each agent (here: investor) tries to adapt to the others, it changes the environment of the others as well. Freedom and order coexist and support each other in autonomous systems. Wheatley (2005, p. 95) argues that "self-organization succeeds when the system supports the independent activity of its members by giving them a strong frame of reference. When it does this, the global system achieves even greater levels of autonomy and integrity."

Effective self-organization is supported by two critical elements: a clear sense of identity, and freedom. In organizations, if people are free to make their own decisions, guided by a clear organizational identity for them to reference, the whole system develops greater coherence and strength. The organization is less controlling, but more orderly. Jantsh (1980, p. 40) argues that "the natural dynamics of simple dissipative structures teach the optimistic principle of which we tend to despair in the human world: the more freedom in self-organization, the more order." This is precisely the case with the electronic stock exchange. The social subsystem of a modern stock exchange:

1. Consists of a network of investors (agents) acting in a self-managed way without centralized control.
2. The environment in which the investors operate changes and evolves constantly, which is the result of continuous fluctuations in the economy and market situation, but also is produced by the interactions among the investors.
3. Competition among the investors leads to a consensus, reflected by a current market trend.
4. This trend suggests the hidden existence of organized patterns of collective behavior, which is the result of the emergence of a natural dynamic structure of this social system.

The classification of the analyzed social system as a complex adaptive systems allows for the application of the most recent findings of many disciplines, considered to have no relations with the science of management and organization. For example, complexity theory can offer a range of new insights into the behavior of social and economic systems. The idea of self-organization and emergence can be used to identify and explain the dynamics of individual and collective behavior on the stock market. Thousands of independent and difficult to observe transactions, carried out by individual participants of the market, generate the emergence of specific and *predictable* patterns of collective behavior. These phenomena can only be identified on the higher, collective, not individual, level of social organization. Kauffman's (1996) famous phrase "order for free" describes that the process of "crystallization," also known as the emergence of complexity in complex adaptive systems. The fundamental challenge of such defined research would be to find a quantitative measure of that emergence.

Chaos theory, a sub-discipline of complexity theory, identifies, and analyzes the dynamics of nonlinear systems. In nonlinear systems, iteration helps small differences grow into powerful effects. In complex ways, the systems feeds back on itself, magnifying slight variances, communicating throughout its networks, becoming disturbed and unstable. Iteration launches a system on a journey that visits both chaos and order. The most visible consequence of iteration is found in the creation of *fractals*. The process of fractal creation suggests some ways organizations can work with the paradox that greater openness is the path to greater order. A fractal reveals its complex shape through continuous self-reference to a simple initial pattern.

To see how chaotic processes reveal the order inherent in a system requires that we shift our vision from the parts to the whole. Wholeness is what rushes in under the guise of chaos whenever we try to separate and measure dynamical systems as if they were composed of parts. For example, *strange attractors* are not the shape of chaos, but the shape of wholeness. When we concentrate on individual actions of individual investors, we see only chaos, emotions, and lack of rationality. But when we stand back and look at what is taking shape on the market, we see order. Order always displays itself as *patterns* that develop over time. Thus, the shape of the entire system is predictable or predetermined, which will be showed later on in this chapter.

There is a difference between *fractals* and *strange attractors*. Strange attractors are self-portraits drawn by a chaotic system. They are always fractal in nature, being deeply patterned, but they are a special category of mathematical object. Estimates are that there are only about two dozen different strange attractors (Posamantier & Lehman, 2007). In contrast, fractals describe any object or form created from repeating patterns evident at many levels of scale. There are infinite number of fractals, both natural and human-made. Fractals are everywhere around us, in the patterns by which nature organizes clouds, rivers, mountains, plants, our bodies. We live in a universe of fractal forms. Everywhere in this fractal landscape, there is self-similarity. There is pattern within pattern within pattern. There is no end to them, no scale small enough that these shapes cease to form.

Many disciplines have seized upon fractals, testing whether self-similar phenomena occur at different levels of scale in both natural and human-made systems. From architects who explain the beauty of building and towns as the repetition of harmonious patterns, to business forecasters who have observed a fractal quality in market behaviors. Fractals also have direct application for how we should understand organizations. All organizations are, in fact, fractal in nature. Each organization is deeply patterned with self-similar behaviors evident everywhere. These recurring patterns of behavior are what many call the culture of the organization. The organizational culture, as was noted before, is often identified directly with collective mind. Hence, if we could identify a specific fractal in the market behavior, we would be allowed to affirm that there is a sort of *collective mind* on the market. This, in turn, would indicate that there is a certain form of *collective*, or *social*, rationality, most likely quite different from the individual one.

Research Method

Three-Element Ecological Model

The idea of self-organization bears the notion of an "open system," contrary to the Newtonian "closed system." It also allows for the full utilization of the concept of "entropy" in social sciences. More than two decades ago Capra (1984, p. 32) argued that the new paradigm of rationality should take into account the fact that "an economy is a living system, and one of many aspects of a large ecological and social structure." And so, to model and structure the behavior of our complex adaptive system, we can use the elements of environmental economics—one of the most trendy areas in economics (e.g., Callan & Thomas, 2006). The general methodological concept proposed in this chapter is based on a three-element system, *society-economy-nature*, and it replaces the two-element system, *economy-nature*, which has been applied in economics since the 1960s. This will allow for the identification of the dependencies in its two-element subsystem, *society-nature*. This, in turn, will help identify and describe phenomena, which are observed in the surrounding world of nature and, to the same extent, are expected to regulate behavior of the crowd. This should be the actual, as opposed to only formal and declared, introduction of the ideas of open system and entropy to economic and social sciences.

Generally, the research method consists of the following stages:

identification-analysis-synthesis-exemplification-verification-interpretation-discussion

More accurately these stages are:

- Identification of the research area.
- Identification of the mechanism of collective behavior.
- Analysis of the identified mechanism.
- Synthesis, a mathematical description of the mechanism.
- Exemplification and verification of the mechanism.
- Interpretation and discussion: a new approach to rationality.

Next is a brief description of the main stages of the research method applied in this chapter.

Identification of the Research Area

The collectivity of investors composes a non-linear complex adaptive system. Each crowd can be defined in terms of its processes rather than its physical characteristics. The basic catalyst for the formation of a crowd is a condition of non-equilibrium. The presence of two crowds in a financial market (*bulls* and *bears*), ensures that a state of conflict of interest exists within the rules of the investment game. Such a condition creates stress and competition, and provides the purpose for the creation of a crowd. In order to achieve its objectives, a crowd must be open to the environment for the exchange of both energy and information. Crowd members of the financial market are in a constant state of expectant attention and are, therefore, vulnerable to suggestion. Moods, feelings, and ideas in such an environment are very contagious and they spread rapidly. Modern Internet communications ensure that the same effects can be quickly achieved even if the crowd is not assembled in one place. Crowd behavior ensures that a price movement triggers an emotional response among members of opposing crowds, and, thereby, ensures that the most recent movement in prices is continued into the future.

In this sense, change and progress within the analyzed system come about as a result of a dynamic interplay, both between individuals and the crowd to which they belong, and between a crowd and its environment. Independent fluctuations in the environment itself can lead to a number of different responses by a crowd. Ultimately, however, the crowd will always adapt to permanent changes in the environment. And all price movements are part of a very simple pattern, which is the response to information shocks, and prices oscillate rhythmically in response to the metabolic fluctuations of the crowd.

Identification of the Mechanism of Collective Behavior

The important feature of any self-organizing system, whether it be a crowd or a living organism, is that it *oscillates* during the transfer of energy and information. In fact, the presence of continuous fluctuations can be taken as a *prima facie* evidence of the presence of "mental activity." Once a crowd with common values and a common objective has been established, it will then respond positively to the input of new items of information from the environment. There is a great partnering that exists between the system and its environment. The theory of co-evolution relies on the fact that the relevant feedback loops generate stable fluctuations between a particular system and a higher-order system (Brand, 2006). Mathematicians call these stable fluctuations *limit cycles.* A limit cycle is defined as the isolated periodic oscillation between two variables, and is represented graphically by an isolated closed non-linear path (King et al., 2006). If the limit cycle is stable, the oscillations will spiral on to the solution path from a wide range of initial states. If, on the other hand, the cycle is unstable, a disturbance will cause the oscillations to spiral away from that solution path. It follows that co-evolving systems utilize stable limit cycles.

Figure 1 represents an idealized stable limit cycle. Within the context of this analysis, the *x*-axis on this figure represents an index of crowd behavior and the *y*-axis represents an index of environmental change. In reality, the two-dimensional limit cycle relating *x* and *y* (or the crowd and the environment) actually unfolds through *time*. For this part of the analysis, however, this factor can be omitted.

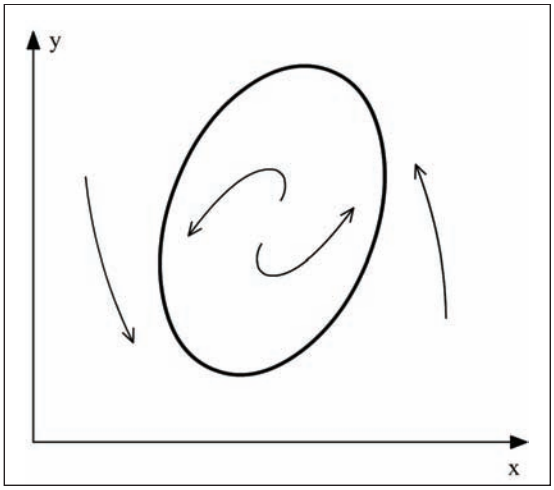
According to chaos theory, a limit cycle is one of the three possible forms of an attractor (Feudel et al., 2006). This observation is critical for further analysis and discussion.

Analysis of the Identified Mechanism

The viability and resiliency of a self-organizing system comes from its great capacity to adapt as needed, to create structures that fit the moment. Neither form nor function alone dictates how the system is organized. Instead, they are *process structures*, reorganizing into different forms in order to maintain their identity. The system may maintain itself in its present form or evolve to a new order, depending on what is required. It is not locked into any one structure; it is capable of organizing into whatever form it determines best suits the present situation.

Whenever a self-organizing system experiences any amplification process, change is at hand. If the amplifications increase to the level where they destabilize the system, the system can no longer remain as it is. At this moment, the system is at a crossroads, standing posed between death and transformation. In chaos theory, it is known technically as a bifurcation point. For the investors, it is either a moment of great fear (at the very bottom of a bear market) or great euphoria (at the end of a bull market). Abandoning its present form, the system is free to seek out a new form in response to the changed environment.

Figure 1. Idealized stable limit cycle



According to this analysis, the price-sentiment limit cycle operating in a financial market is also integrated with limit cycles relating that market to the wider economic, social, and political environment. Although limit cycles are the main mechanism whereby a self-organizing system copes with fluctuations in its environment, they do not fully represent the adjustment processes that are involved. In reality, bits of information become available only in discontinuous or discrete time intervals. The adjustment process depends on whether or not the recipient system is prepared for the information. If the information is unexpected, then the information impacts as a *shock*, and the system may have to change its dynamic structure in order to cope (Plummer, 2006, p. 50). Shocks occur because of a sudden divergence between current price movements and expected price movements, and may derive from two sources: first, they may be triggered by an unexpected movement in prices themselves; second, they may be precipitated by unexpected changes in the social, political, or economic development.

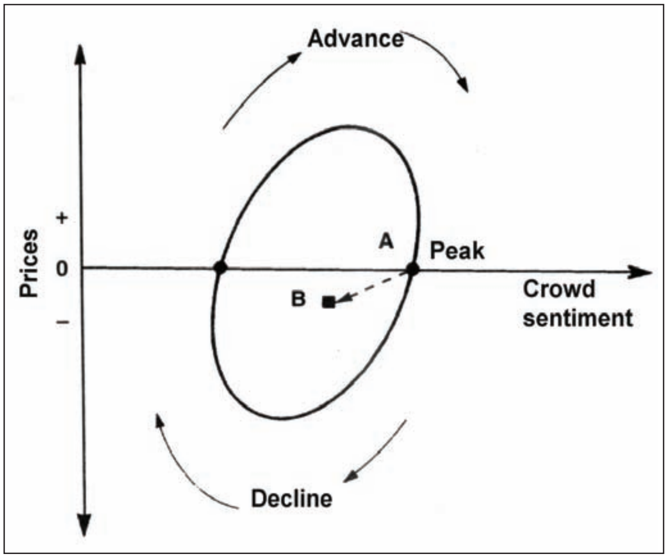
In practice, shocks are delivered to systems that already are oscillating in a limit cycle pattern with their niche in the environment. Divergences between lower-level cycles and higher-level cycles are rectified by those shocks, and the fluctuations will continue at least until the limit cycle of the next higher degree is able to reassert control. When an information shock appears, the process of adjustment begins (see Figure 2).

In this analysis, the limit cycle is biased to the right. This reflects a fact that sentiment usually turns prior to price reversals. Hence, prior to market peaks, sentiment will begin to deteriorate as the percentage increase in prices falls. On the other hand, just prior to market troughs, sentiment begins to improve and the percentage fall in prices decreases.

Whatever the source of the shock, the response of the market is essentially the same. The shock is represented here by a "jump" inward from the path of the limit cycle as the change in prices moves across the zero percent change line. Hence, in the case where a market is moving from bullish to bearish, the position on the phase plane will jump from point A to point B as the price moves into negative territory. There will be both a fall in prices and a drop in crowd sentiment (see Figure 2).

Since the limit cycle is essentially stable, it follows that behavior will try to return to the solution path. Technically it means that the fall in

Figure 2. Information shock and "jump" from the cycle path (Source: Based on Plummer, 2006)



prices begins to slow and lower prices encourage a return of "bulls." This, in turn, causes prices to rise and stimulates a reversal in sentiment. Eventually, however, higher prices encourage some profit taking or reducing the previous losses, and prices begin to slip again. The subsequent price collapse is very deep and painful, but it brings prices back to the solution path of the limit cycle, and this phenomenon is expressed by a spiral of the adaptation process of collectivity (see Figure 3).

The key question is: Since there are several different spiral movements what kind of a spiral represents these phenomena? The answer is found in the world, or even the Universe, surrounding us, because a *collectivity is also a natural system* (Frost & Prechter, 2001). And this is the stage when we can utilize the three-element system, *society-economy-nature*, and look for analogies between its two natural subsystems, *society* and *nature*.

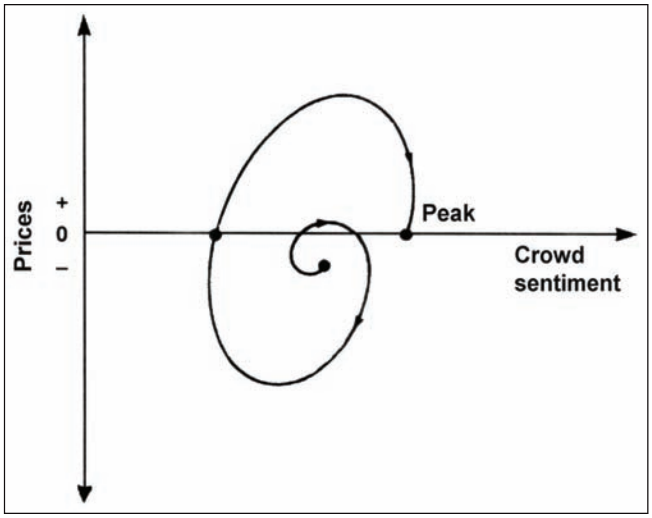
Synthesis: A Mathematical Description of the Mechanism

Contemplating the beauty and form of all the wonders of nature and giving further thought to the achievements of man in many fields, we learn that all of these have one thing in common—the *Fibonacci Summation Series* (Posamentier & Lehman, 2007). Long ago, Thomas of Aquinas described one of the basic rules of aesthetics—man's senses enjoy objects that are properly proportioned. He referred to the direct relationship between beauty and mathematics, which is often measurable and can be found in nature. Man instinctively reacts positively to clear geometrical forms, in both his natural environment and in objects created by him. Thomas of Aquinas was referring to the same principle that was a little earlier described by the 13th century mathematician, Fibonacci. He developed the summation series:

1,1,2,3,5,8,13,21,34,55,89,144, . . .

This mathematical series develops when, beginning with 1,1, the next number is formed from the sum of the previous two numbers. If each number in the series is divided by its preceding value (e.g., 21:13), the result is a ratio that oscillates around the irrational 1.618033988. . ., being higher one time and lower the next. But never in eternity can the precise ratio be known to the last digit,

Figure 3. Formation mechanism of a spiral of the adaptation process of collectivity (Source: Author's research based on Plummer, 2006)



therefore, for the sake of brevity, it is referred to as 1.618. Algebraically it generally is designated by the Greek letter phi (ϕ=1.618).

This ratio is known as the Divine Proportion, the Golden Section, or the Golden Mean. Kepler called the ratio, one of the jewels in geometry." Many people have tried to penetrate the secrets of the Pyramid of Gizeh, which is different from the other Egyptian pyramids. More detailed observations give a clue that the pyramid was designed to incorporate the phi proportion of 1.618. The same phenomenon is found in the Mexican pyramids. A different representation of Fibonacci numbers is found in the number of axils on the stem of a plant as it develops (Fisher, 2001).

The Greek mathematician Euclid related the Golden Section to a straight line (see Figure 4).

The line AB of length L is divided into two segments by point C. If C is such a point that L:AC equals AC:BC, then C is the Golden Section AB. In other words, the point C divides the line AB into two parts in such a way that the ratios of those parts is 1.618 and 0.618 (1:1.618).

The Golden Section occurs throughout nature. In fact, the human body is a tapestry of Golden Sections in everything from outer dimensions to facial arrangement.

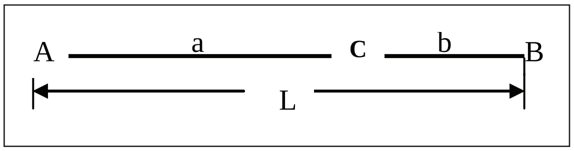
Another common occurrence of the Divine Proportion can be observed in the Golden Rectangle, which sides are in the proportion of 1.618 to 1 (see Figure 5).

According to Pythagorean theorem:

$CG = \sqrt{5} + 1$; $FG = 2$;
$CG : FG = (\sqrt{5} + 1) : 2 = (2{,}236 + 1) : 2 = 3{,}236 : 2 = 1{,}618$.

$DG = - 1$; $FG = 2$;
$DG : FG = (\sqrt{5} - 1) : 2 = (2{,}236 - 1) : 2 = 1{,}236 : 2 = 1{,}618$.

Figure 4. Golden section of a line



Works of arts have been greatly enhanced with the knowledge of the Golden Rectangle. Fascination with its value and use was particularly strong in ancient Egypt and Greece and during the Renaissance, all high points of civilization. But the value of it is hardly limited to its beauty, it serves function as well. Among numerous examples, the most striking is that the double helix of DNA itself creates precise Golden Sections at regular intervals of its twists.

While the Golden Section and the Golden Rectangle represent static pieces of natural and man-made aesthetic beauty and function, the representation of an aesthetically pleasing dynamism, an orderly progression of growth or progress, can be made only by one of the most remarkable forms in the Universe, the Golden Spiral.

To construct a Golden Spiral a Golden Rectangle can be used. Any Golden Rectangle can be divided into a square and a smaller Golden Rectangle. This process then, theoretically, can be continued to infinity. The resulting squares, which have been drawn, appear to be whirling inward. A spiral can be drawn by connecting the points of intersection for each whirling square, in order of increasing size. As the squares whirl inward or outward, their connecting points trace out a Golden Spiral (see Figure 6).

Figure 5. Construction of the Golden Rectangle

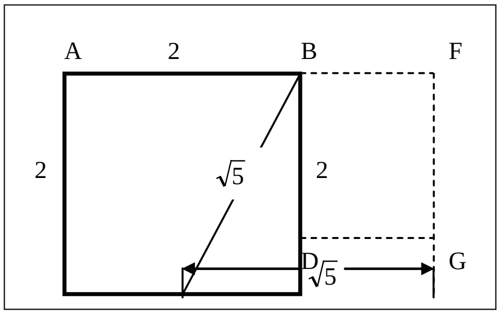
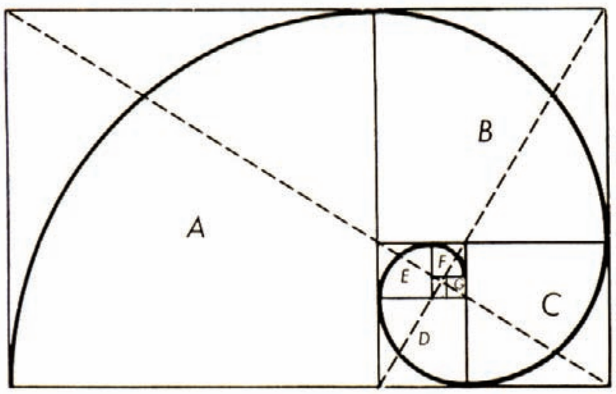


Figure 6. Geometry of the Golden Spiral (Source: Author's research based on Frost and Prechter, 2001)



At any point in the evolution of the Golden Spiral, the ratio of the length of the arc to its diameter is 1.618 and the diameter is related to the larger radius just as the larger radius is to the smaller radius, by 1.618, as illustrated in Figure 7.

The Golden Spiral, which is a type of logarithmic or equiangular spiral, has no boundaries and is a constant shape. From any point on it, one can travel infinitely in either the outward or inward direction. The center is never met and the outward reach is unlimited.

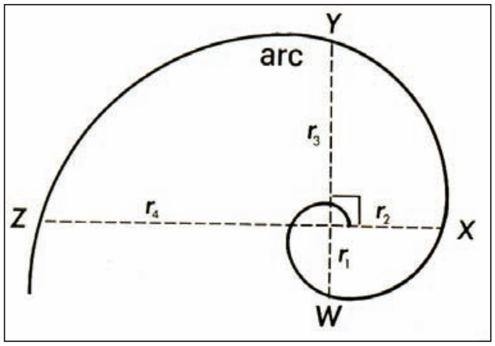
Now, the tail of a comet curves away from the sun in a logarithmic spiral. A spider spins its web into a logarithmic spiral. Bacteria grow at an accelerating rate that can be plotted along a logarithmic spiral. Meteorites, when they rupture the surface of the Earth, cause depressions that correspond to a logarithmic spiral. Pine cones, sea horses, snail shells, ocean waves, ferns, animal horns, and the arrangement of seed curves on sunflowers and daises all form logarithmic spirals. Hurricane clouds and the galaxies of outer space swirl in logarithmic spirals. Even the human finger, which is composed of three bones in Golden Section to one another, takes the spiral shape (Fisher, 2001). Everywhere, the design is the same: a 1.618 ratio, perhaps the primary law governing dynamic natural phenomena.

PRACTICAL VERIFICATION

Application of the Logarithmic Spiral on the Index Chart

According to the three-element model, this natural law, permeating the universe and described by the Fibonacci ratio $\phi = 1.618$, should refer to the dynamics of collective behavior as well. Since adaptations to the exchange of information spiral and financial markets reflect psychology and the dynamics of the crowd, the spiral identified in price formations also should be logarithmic.

Figure 7. Constant proportions in the Golden Spiral (Source: Author's research based on Frost & Prechter, 2001)



$r_2:r_1=r_3:r_2=r_4:r_3=...=r_n:r_{n-1}$
$d_2:d_1=d_3:d_2=...=d_n:d_{n-1}$
$(d_1=r_1+r_3,\ d_2=r_2+r_4,\ etc.)$

All technical approaches to understanding the stock market depend on the basic principle of order and form. No matter how minute or how large the form, the basic design remains constant. And the stock market has the very same mathematical base as do all those natural phenomena. It appears that the top of each successive wave of higher degree is the touch point of the logarithmic expansion. The spiral form of market action is repeatedly shown to be governed by the Golden Ratio, and even the Fibonacci numbers themselves appear in market statistics more often than mere chance would allow. Any point on the spiral represents the optimum price-time relationship.

The most challenging part of the spiral is to see it work in extreme market situations, when behavioral patterns are strongest. With the correct center and starting point chosen, the spiral can identify turning points in the markets with accuracy never seen before.

Examples from an Emerging Market

One of the examples of how to use the concept of the spiral to predict the basic market moves is shown in Figure 8. It represents a chart of the Warsaw Stock Exchange index.

The stock market in Poland was reopened in 1991 after more than half a century. The x-axis on the chart represents the dates of consecutive trading days, and the y-axis represents the value of the index in a logarithmic scale (albeit the scale can also be arithmetic).

A logarithmic spiral has been applied, with the center and starting point in the middle of an almost two-year base, preceding the sharp move upward. On the second ring of the curve, we can locate a point that approximately ends the long period of basing, on the third ring there is the end of the first wave of enormous gains, and a sharp and painful correction takes place (first days of June 1993). The fourth ring is the ultimate target of the bull market, and the beginning of a long and devastating bear market in March 1994.

The center of the spiral can be placed either in the middle of the market or at one of the extreme points (highs or lows). The spiral itself can be turned either clockwise or counterclockwise. The next important factor is the swing size, that is, the distance between the center and the starting point (Fisher, 2001). Once those parameters have been set, we can begin working with the curve. And the most important factor is the meaning of consecutive spiral rings. At this time no rules have been offered for investing when the first spiral ring is penetrated. Usually we may wait some important moments, when ring number two is reached. It is not often that the third ring of the spiral is penetrated in the same direction as the major trend. But when it happens a significant trend change should follow, as it took place in Warsaw in June 1993. A penetration of the fourth ring in the continuing trend direction must occur even less than any other ring penetration. But, it does happen, and it should indicate a dramatic trend change. These are moves such as the stock market collapse of October 1987 in New York, or March 1994 in Warsaw (see Figures 8 and 9). The fourth ring is the ultimate price target. When it is penetrated, the point of penetration can be used as an entry signal. There is no need to wait for a confirmation. Another good example of

Figure 8. Four spiral rings defining the Warsaw Stock Exchange bull market

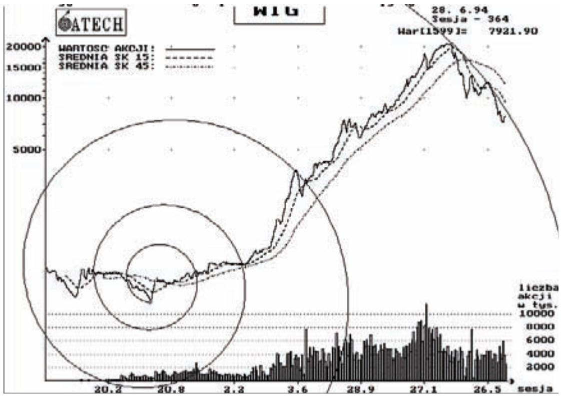
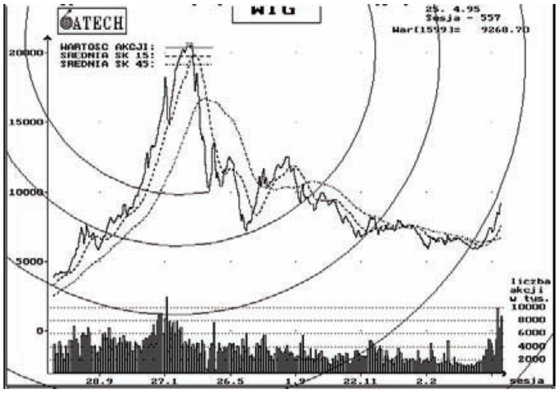


Figure 9. The fourth spiral ring as the ultimate destination of the bear market



the importance of the four rings of the spiral is presented in Figure 9 on an arithmetic scale.

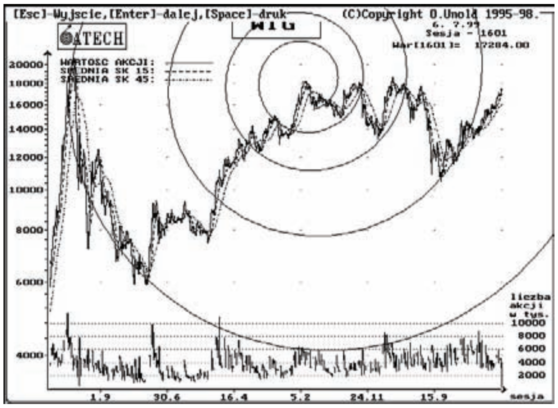
A long and painful bear market in Warsaw has its major turning points on the four rings of the spiral. On the second ring a dynamic and upward correction wave begins. The third ring points to the beginning of a consolidation phase, preceding the final shake-out. The fourth ring is the end of the bear market.

Figure 10 presents how the logarithmic spiral applies to the next stages of the development of Polish emerging stock market. The spiral embraces all the vital turning points of the index chart, starting at the peak of the first wave of the bull period in March 1994, through a year-long bear market in 1994 and 1995, the next, very extensive, bull market, to the end of the next corrective wave in July 1999.

Examples from Developed Markets

In the next step, the observations from one of the emerging markets should be confirmed at a few much more developed exchanges. And indeed, in all the following examples the development of the market trend proceeds according to the logarithmic extension.

Figure 10. Logarithmic spiral on the Warsaw Stock Exchange index chart



The next figure confirms the logarithmic extension of German DAX index, charted from January 2005 to March 2003 (see Figure 11).

Yet another one reveals a similar pattern at French CAC40, from January 1995 to March 2003 (see Figure 12).

Last but not least, the Hangseng index of the Hong Kong stock exchange, analyzed in the time frame June 1987-April 1999, follows the logarithmic expansion (see Figure 13).

The above examples, taken from a few of the world's best developed markets, confirm the universality of the analyzed mechanisms of collective behavior in complex adaptive systems.

Figure 11. Logarithmic spiral on German DAX

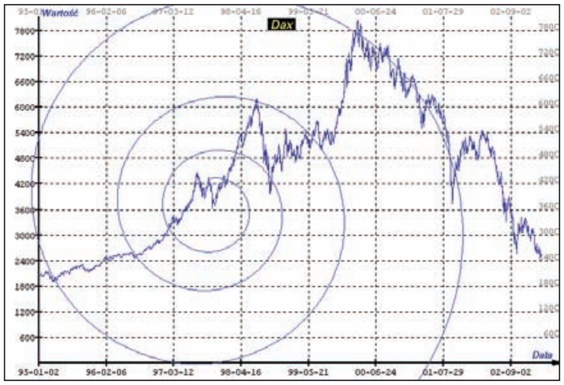
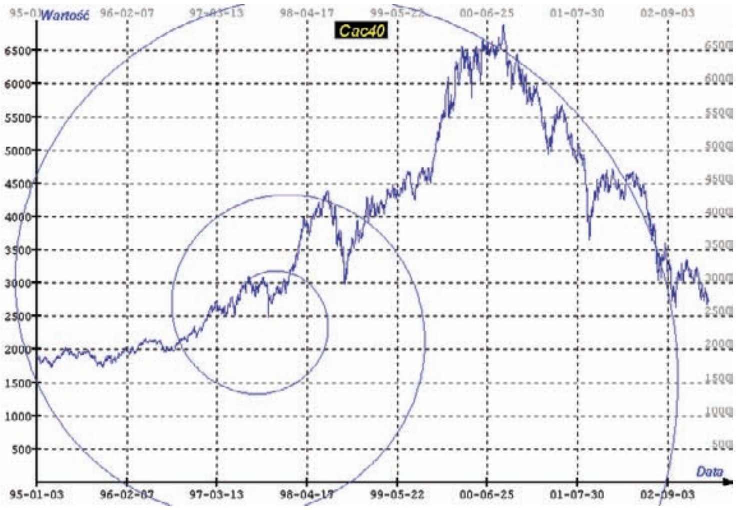


Figure 12. Logarithmic spiral on French CAC40

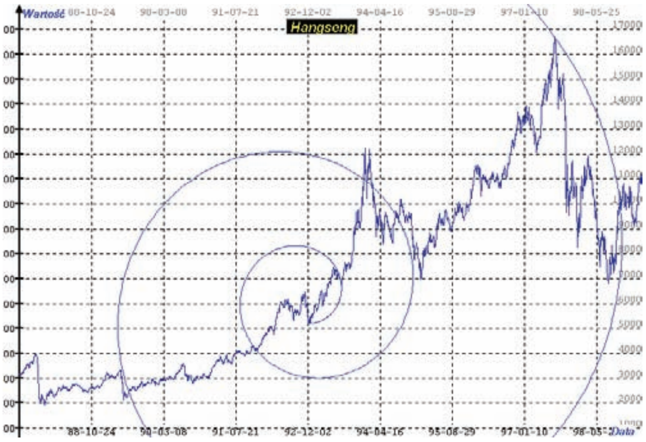


CONCLUSION: INTERPRETATION AND DISCUSSION

The most general conclusion drawn from this chapter is that the same law that shapes the spiraling galaxies mold the spirit and attitudes of men en masse. It shows up so clearly in the market because the stock market is the finest reflector of mass psychology. It is a nearly perfect recording of man's social psychological states and trends, reflecting the fluctuating valuation of his own productive enterprise and making manifest its very real patterns of progress and regress. What is more, the empirical evidence is available for study and observation. It seems that these parallels are too great to be dismissed. On the balance of probabilities, we may come to the conclusion that there is a principle, everywhere present, giving shape to social affairs. The stock market is no exception, as mass behavior is undeniably linked to a law that can be studied and defined. The briefest way to express this principle is by a simple mathematical statement: the 1.618 ratio.

The logarithmic spiral identified within the analyzed information system is self-similar and isomorphic. It follows that information processes

Figure 13. Logarithmic spiral on Hangseng index chart in Hong Kong



of collectivity also are isomorphic. The identification of isomorphism and self-similarity in the analyzed system is of great importance in the proposed research procedure. The spiral in Figure 3 represents a new, modified form of the attractor presented in Figure 1. This spiral is a metaphorical equivalent of a fractal attractor (strange attractor). This metaphor has deep theoretical grounds, as a logarithmic spiral actually is a fractal.

The identification of a fractal attractor (strange attractor) in a social subsystem of a model global information system carries far-reaching theoretical and methodological consequences. It implies self-similarity and recurrence of system behavior. Recurring patterns of behavior in an organization are called organizational culture, and the notion of "organizational culture" is used interchangeably with the concept of "collective mind" (Eden & Spender, 2003). Thus, the identification of a fractal attractor in the analyzed social system suggests, on the grounds of chaos theory, the occurrence of rationality of collective behavior and defines the model representation of the adaptability of collective behavior a spiral movement.

It is worth emphasizing that the concepts of *collective mind* and *organizational intelligence* add a crucial qualitative dimension to information systems analysis. They add the missing internal social dimension to the technical or mechanistic dimension, which is, generally, the focus of the classical theory of systems and organizations.

Another research thread that can be used to theoretically explain the identified phenomena and justify the method applied in this chapter is Heisenberg's uncertainty principle, with the example of the dual nature of electrons, that is, unpredictability of behavior on the individual level versus predictability on the collective level of an "electron cloud" (Heisenberg, 2000). The decision-making process of collectivity within a model global information system is adaptive and follows specific patterns found in nature. Therefore, unlike the decision-making process of an individual, this process can be expressed mathematically and, under certain conditions, ought to be predictable. In other words, individual behavior, which is often irrational and unpredictable, is expected to compose an adaptive, spiral, and thus, predictable process of collective decision making.

The main potential scientific result of the proposed research approach could be a new formulation of the rationality paradigm. In the era of globalization and virtualization, we shift our interest from traditionally perceived *physical collectivities* to a *dispersed, virtual crowd*, which is a totally new social phenomenon. The observations included in this chapter should allow us to identify the theoretical grounds of a new paradigm, which will refer to the behavior of crowd and the notion of adaptation as a more natural reaction to information stimuli than optimization. Moreover, adaptation would not exclude traditional optimization. Optimization would remain a specific case of adaptation, applicable to strictly deterministic decision situations.

The importance of the adaptation issue has been recognized in organizational sciences for a long time. The organization theorist Barnard held that adaptation was the central problem of organization. Barnard was concerned with cooperative adaptation, hereafter referred to as adaptation (C), which was accomplished in an intentional way. Formal organization, especially hierarchy, was the instrument through which the "conscious, deliberate, purposeful" cooperation was accomplished (Barnard, 1938, p. 4). Barnard's insights have had a lasting effect on organization theory.

A different approach to adaptation was presented by the economist Hayek, who emphasized autonomous adaptation of a spontaneous kind. He maintained that adaptation was the main problem of economic organization, and argued that it was realized spontaneously through the price system. Changes in the demand or supply of a commodity give rise to price changes, whereupon "individual participants . . . [are] able to take the right action" (Hayek, 1945, p. 527). Such price-induced adaptations by individual actors are referred to as adaptations (A), where (A) denotes autonomy. The conclusions of this chapter directly refer to Hayek's notion of adaptation, providing theoretical, methodological, and empirical framework for further research in this area.

This way, the above conclusions could contribute to an increased understanding of mutual interactions between societies and individuals in the era of birth and growth of the Global Information Society. These findings might help examine and structure the unique influence that social processes exert on the decision-making processes of an individual. In this sense, we would be able to speak of *system rationality*, which should not depend on the rationality or irrationality of the system's components.

FUTURE RESEARCH DIRECTIONS

The research method proposed in this chapter is interdisciplinary and intersectorial. It combines the theoretical and methodological principles of Information Systems with the most recent achievements in such new and progressive disciplines as chaos theory and environmental economics. On the level of theory, further research should look for deeper references between the behavior of dispersed collectivities in a model global IS and the principles of chaos theory. The identification of a fractal attractor in a model of collective behavior is just an initial step in this direction. This could overlap with methodology, when a more sophisticated mathematical apparatus would be used to describe these exciting phenomena.

The next step in the practical verification procedure could include other areas of collective activity. The global IS epitomized in this chapter is a modern, electronic, stock market. However, Fonseca (1989) already proved that a logarithmic expansion regulates the natural development of the urban populations, as well. The next case could analyze, for example, the behavior of social systems in medium and large size companies. The initial challenge here would be to find the proper indicators, which, in the case of a stock market, were the historic value of the index, represented by an index chart, or the volume of trading. Other areas of collective actions could include voting groups, but taken internationally and along a model dividing lines, for example, conservatives versus liberals. This case might be easier to structure, because of the well-known political marketing methods, and a well-developed research regarding the influence of modern IT on human behavior.

A very important research thread is the influence the global IT exerts on human behavior. While individual behavior already is pretty well described in the literature, the collective behavior still is mostly unknown. This issue could be related to the one of social rationality. For years, academics have been trying to formulate a new paradigm of rationality. All of these attempts, however, are highly theoretical and lack any practical verification. The notion of adaptive rationality, introduced in this chapter, could help construct a new approach to rationality, going well beyond the overused notion of bounded rationality, and being supported by a solid practical verification.

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Chapter 8.4

Information Technology and Diversification:

How Their Relationship Affects Firm Performance

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ABSTRACT

While the importance of IT coupled with organizational changes for business performance has been widely discussed in the information systems (IS) literature, there has been little empirical research on the issue. This research examines empirically the relationship between IT and diversification by employing multiple diversification measures. It also examines empirically the relative impact on performance of IT and diversification. Results show that diversification coupled with increased IT spending improves firm performance when its strategic emphasis is on related diversification. The results also show that firms place strategic focus on related diversification when they increase IT spending, and that they require more IT when their strategic emphasis is tilted toward related diversification. The findings imply that by providing a better means of coordination, IT enables scope economies, efficient utilization of business resources and collaboration across individual business units, eventually leveraging the benefits of diversification.

INTRODUCTION

Emerging technologies can often allow firms to reexamine how they do business, stimulate creative thinking, and ultimately create new opportunities. In the e-business environment, where process automation and digitization are critical for business success, efforts to redesign processes and effectively coordinate value chain-activities with customers and suppliers are ever more important. Information technology (IT), including the Internet and related technologies, can make its fullest impact on organizations when it is deployed in conjunction with changes in business processes, structures, and strategies.

While the importance of coupling IT with organizational changes for business performance has been widely discussed in the information systems (IS) literature (Brynjolfsson & Hitt, 1996; Brynjolfsson & Yang, 1998; Clemons & Row, 1991; Dewan, Michael, & Min, 1998; Rai, Patnayakuni, & Patnayakuni, 1997; Shin, 2001, 2006), there has been little empirical research on the issue. Brynjolfsson and Yang (1998) found that an increase of one dollar in IT capital was valued by the stock market at about ten dollars, and this extra nine dollars represented the value obtained from organizational changes to complement IT investments. Brynjolfsson and Hitt (1996) also found that IT had its greatest contribution to output in firms that adopted a more decentralized and human capital-intensive work system.

This research examines empirically the relationship between IT and diversification by employing multiple diversification measures. It also examines empirically the relative impact on performance of IT and diversification. Several empirical analyses in two stages attempt to answer the following questions:

1. Do firms increase their strategic emphasis on related diversification when they increase IT spending?
2. Is business performance improved by increased IT spending when firms place their strategic emphasis on related diversification?

By answering these questions, this study attempts to shed light on why the impact of IT on firm performance may not be constant across firms. It concludes that IT spending complements the strategic choices of firms, such as a strategic decision to focus on related diversification. The empirical aspects of this complementarity have received little attention from previous IS and economics research.

THEORETICAL BACKGROUND: PRIOR RESEARCH ON DIVERSIFICATION AND IT

Economics research posits that a firm is a collection of physical, human and intangible resources capable of undertaking a number of separate economic activities. Some resources may be relatively product specific, and thus utilized to produce a particular good or service through one business line. Other resources, however, may have the potential to increase production of goods or services in multiple business lines. When a firm has excess capacities that are insufficiently utilized in its current operations and cannot be sold in external markets, it will expand their use by diversifying its operations into multiple markets (Caves, Porter, Spence, & Scott, 1980; Clarke, 1985; Penrose, 1959; Rumelt, 1974).

A firm can diversify its operations into either related or unrelated markets. Related diversification means that a firm diversifies into business areas close to the one in which it originated (for example, computer and communications product manufacturing), while unrelated diversification refers to a firm diversifying into more distant areas unrelated to its current business (for example, computer product manufacturing and banking). When a firm pursues related diversification, its ability to achieve tangible economic benefits depends on increased coordination, communication, and collaboration among its different business lines (Hill, 1994; Hill & Hoskisson, 1987). Individual divisions share market information, managerial expertise, technical knowledge, and physical resources such as supply chains and distribution channels. Thus, when a firm pursues related diversification, it should consider the costs of coordinating resources, including the costs of information sharing, across related markets (Williamson, 1975). On the other hand, unrelated diversification is pursued with the goal of realizing economic benefits from the exploitation of an internal capital market in which capital can be more efficiently allocated than in external markets (Hill, 1988). Because there are no interrelationships among divisions, that is, no sharing of business resources, unrelated diversification does not require as much coordination and collaboration as related diversification (Hill, 1994; Hill & Hoskisson, 1987).

IT is widely used to share information and coordinate business resources across multiple markets (Clemons, Reddi, & Row, 1993; Gurbaxani & Whang, 1991; Malone, Yates, & Benjamin, 1987). Because IT provides a better means of coordination and collaboration across multiple markets, firms pursuing related diversification may require increased IT investment. Similarly, increased IT investment may facilitate diversification, particularly related diversification. A firm's IT investment, therefore, can be the cause or the effect of its diversification. In other words, IT can complement a firm's diversification strategy or vice versa.

The relationship between IT and diversification has been examined by previous IS research (Dewan et al., 1998; Hitt, 1999). Dewan et al. (1998) found that diversification, especially related diversification, was likely to increase a firm's demand for IT. They argue that their findings might reflect a greater need for coordination of assets and information processing within diversified firms. Working from similar findings, Hitt (1999) argues not only that diversified firms have a higher demand for IT capital, but that increased use of IT is associated with a slight increase in diversification. While Dewan et al. (1998) and Hitt (1999) have provided the implications of the complementarity of IT and diversification for firm performance, they did not empirically analyze the issue in their studies. The issue of how the complementarity of IT and diversification affects firm performance has been examined by several recent papers. Shin (2006) finds a positive interaction effect between IT and strategic direction, defined as the difference between related and unrelated diversification. Liu, Ravichandran, Han, and Hasan (2006) also find that the interaction effect between IT and diversification is positive only for related diversification.

This study is similar to the prior work done by Shin (2006) and Liu et al. (2006), but while the prior work focused on the interaction effect of IT and diversification, this study shows the directional effect of IT and diversification by performing empirical analyses in two stages. This study also examines lagged effects of IT, which was not done in Shin's study (2006).

DIVERSIFICATION AND PERFORMANCE IMPACTS OF IT

Diversification can increase the demand for IT because of the need for coordination and collaboration across multiple markets. In today's global economy in which firms can diversify across national borders, the use of IT for diversification has become ever more important since IT lowers the additional costs of coordination and collaboration, thereby augmenting the benefits of diversification. Thus, increased use of IT can improve the performance of highly diversified firms. However, the contribution of IT to firm performance may depend on the direction of the firm's diversification strategy (Shin, 2006). If a firm's strategic direction is oriented more toward related diversification, in which coordination and collaboration are critical for success, increased use of IT may improve the firm's performance by providing a better means of coordination and collaboration. However, if a firm's strategic direction is oriented more toward unrelated diversification, which does not require as much coordination and collaboration as related diversification, increased use of IT may have less impact on the firm's performance.

The strategic direction of diversification (strategic direction, in short) is defined here as the relative emphasis a firm places on related diversification relative to unrelated diversification.

A measure of strategic direction is constructed as follows:

Strategic Direction (SD) = Related Diversification – Unrelated Diversification

Positive scores indicate a firm's relative emphasis on related diversification; negative scores indicate its relative emphasis on unrelated diversification. It is expected that IT will improve the performance of firms when they place emphasis on related rather than unrelated diversification. On the other hand, IT is not likely to leverage the performance of firms when they place emphasis on unrelated rather than related diversification. This result does not negate the importance of unrelated diversification for firm performance, but rather highlights the importance of IT for leveraging the benefits of related diversification.

METHODOLOGY AND ANALYSIS: DATA SOURCES AND VARIABLE CONSTRUCTIONS

The study employs two data sources: *Information Week*'s annual data set of IS budgets for the three years from 1995 to 1997 and the Compustat database for the five years from 1995 to 1999.

IT intensity is calculated by dividing the IS budgets by the number of employees. As measures of diversification, we employ the Entropy indexes of total diversification, related diversification and unrelated diversification (Jacquemin & Berry, 1979). A measure of strategic direction is constructed by taking the difference between the Entropy index of related and unrelated diversification (i.e., related diversification – unrelated diversification). Two other diversification indexes—the Concentric index (Caves, et al., 1980; Montgomery & Wernerfelt, 1988; Wernerfelt & Montgomery, 1988) and the Herfindahl index—are also employed as measures of diversification.[1]

Data items such as sales, total assets, capital investment, the number of employees, and return on assets (ROA) are obtained from the Compustat database for the same firms included in the Information Week 500 data set. Tobin's q, ROA, gross margin, and revenue per employee are employed as measures of firm performance. To construct the measure of Tobin's q, we employ the same method used by Bharadwaj, Bharadwaj, and Konsynski (1999):

Tobin's q = (MVE + PS + DEBT)/TA
Where
MVE = (Closing price per share at the end of the fiscal year) * (Number of common shares outstanding)
PS = Liquidation value of the firm's outstanding preferred stock
DEBT = (Current liabilities – Current assets) + (Book value of inventories) + (Long-term debt)
TA = Book value of total assets

Tobin's q is defined as the ratio of the capital market value of a firm to the replacement value of its physical assets. This incorporates a market measure of firm value (Bharadwaj et al., 1999; Montgomery & Wernerfelt, 1988). According to Bharadwaj et al. (1999), Tobin's q is forward-looking, risk-adjusted, and less susceptible to changes in accounting practices, compared to accounting-based performance measures such as ROA. In other words, it reflects the ex-ante financial market valuation of the level and risk of future profitability. Tobin's q has been widely used in economics research to measure the intangible values of factors such as R&D and brand equity (Cockburn & Griliches, 1988; Simon & Sullivan, 1993). Some recent IS studies have also used Tobin's q to examine the intangible value created by IT (Anderson, Banker, & Nan, 2002; Bharadwaj, et al., 1999; Brynjolfsson & Yang, 1998; Tam, 1998; Tanriverdi, 2006). The use of Tobin's q for measuring intangible value is based on the assumption that the long-run equilibrium market value of a firm must be equal to the replacement value of its physical assets, giving a q value close to unity (Bharadwaj et al., 1999). Any upward deviation from this unity, where q is significantly greater than one, indicates that there is an unmeasured source of value, which is generally attributed to the intangible value created by the firm. Since IT creates significant intangible benefits such as improved market orientation, better coordination and collaboration, higher product quality, and more effective business strategies and processes, the use of Tobin's q as a measure of firm performance can provide a means of capturing IT's true value to a firm.

The sample includes 535 observations (267 different firms) for the three years from 1995 to 1997. The sample statistics are shown in Table 1.

METHODOLOGY

The basic methodology is to analyze the combined data set for five years (1995-1999) using an ordinary least squares (OLS) regression with lag variables: one-year and two-year lags. To analyze the relationship between IT and diversification, an analysis with IT and multiple diversification indexes is conducted. Then we analyze the performance impacts of IT and diversification. For the analysis with the one-year lag, IT intensity from 1995 to 1997 and diversification and firm performance from 1996 to 1998 are employed. For the analysis with the two-year lag, IT intensity from 1995 to 1997 and diversification and firm performance from 1997 to 1999 are employed.[2]

ANALYSIS OF IT AND DIVERSIFICATION

The Model

The model measures the relationship between IT and diversification, while controlling for industry- and year-specific effects.

$$DIV_{i,t} = \beta_0 + \beta_1 IT_{i,t-1} + \beta_2 DIV_{i,t-1} + \beta_3 CAP_{i,t} + \beta_4 Industry_{i,t} + \beta_5 Year_{i,t} + \varepsilon \quad (1)$$

DIV stands for the Entropy index of total diversification. It is replaced in turn by two other diversification variables: the Concentric and Herfindahl indexes. The model includes a one-year lagged variable of total diversification

Table 1. Sample statistics (1995 to 1999)

Variables and other data	Mean	St. Deviation	No. of Obs.
IT intensity (IS budgets/employee)	5,091.8	6,033.3	535
Related diversification (Entropy)	.1794	.2843	535
Unrelated diversification (Entropy)	.3713	.4146	535
Strategic direction	-.1919	.4993	535
Total diversification. (Entropy)	.5507	.5060	535
Concentric	.5214	.4932	542
Herfindahl	.3140	.2753	542
Capital intensity	.5579	.1570	535
Tobin's q	1.790	1.401	321
Return on assets (ROA)	.0911	.0951	366
Gross margin	.3409	.1722	394
Revenue per employee	268,713.4	218,208.5	393
Total sales (in million)	11,855.8	20,890.3	535
Total assets (in million)	15,852.5	35,926.9	535

($DIV_{i,t-1}$) because the analysis conducted without controlling for this variable may overestimate the significance of IT (Santhanam & Hartono, 2003; Tanriverdi, 2006; Zhu, 2004). It also helps reduce the adverse impact of serial correlation in the regression (Zhu, 2004). For the analysis of the two-year lags, the one-year lagged IT ($IT_{i,t-1}$) is replaced by the two-year lagged IT ($IT_{i,t-2}$). Capital intensity (capital investment/total assets) is included as a control variable for firm-specific effects. Because the model employs ratio variables for both dependent and independent variables, we do not include firm size as a control variable. Dummy variables for each industry categorized by the SIC code and for each year are also included in order to account for industry differences and macroeconomic (or market) trends. ε is the residual term with zero mean, which captures the net effect of all unspecified factors.

The differing impact of IT on related and unrelated diversification is estimated separately using the following two models:

$$RD_{i,t} = \beta_0 + \beta_1 IT_{i,t-1} + \beta_2 RD_{i,t-1} + \beta_3 CAP_{i,t} + \beta_4 DIV_{i,t} + \beta_5 Industry_{i,t} + \beta_6 Year_{i,t} + \varepsilon \qquad (2)$$

$$URD_{i,t} = \beta_0 + \beta_1 IT_{i,t-1} + \beta_2 URD_{i,t-1} + \beta_3 CAP_{i,t} + \beta_4 DIV_{i,t} + \beta_5 Industry_{i,t} + \beta_6 Year_{i,t} + \varepsilon \qquad (3)$$

RD and URD stand for the entropy indexes of related and unrelated diversification respectively. As in the model of diversification, each model includes one-year lagged variables of related ($RD_{i,t-1}$) and unrelated diversification ($URD_{i,t-1}$) respectively. Capital intensity and total diversification (entropy index) are included as control variables for firm specific effects. Industry and year dummies are also included as control variables.

We also estimate a model with strategic direction (the entropy index of related diversification—the entropy index of unrelated diversification) in order to directly examine if a firm places emphasis on related rather than unrelated diversification when it increases IT spending. A firm can direct its operations into both related and unrelated diversification. However, the important strategic decision is not whether to choose one or the other, but how much emphasis to place on one relative to the other. A firm can pursue both related and unrelated diversification for different reasons, but what really matters is the firm's strategic focus (Shin, 2006). Unlike models (2) and (3) shown earlier, which examine the impact of IT on related and unrelated diversification separately, the model of strategic direction captures both components at the same time. The model includes related diversification (one-year lagged), capital intensity, total diversification (entropy index), industry and year dummies as control variables.

$$SD_{i,t} = \beta_0 + \beta_1 IT_{i,t-1} + \beta_2 RD_{i,t-1} + \beta_3 CAP_{i,t} + \beta_4 DIV_{i,t} + \beta_5 Industry_{i,t} + \beta_6 Year_{i,t} + \varepsilon \qquad (4)$$

As discussed earlier, a firm's increased IT spending can be the result of its diversification: Namely, a firm that places emphasis on related diversification relative to unrelated diversification may require increased IT spending. In order to examine this reverse causality, we use a simultaneous regression model by taking IT as a dependent variable and strategic direction as an independent variable.

$$IT_{i,t} = \beta_0 + \beta_1 SD_{i,t} + \beta_2 IT_{i,t-1} + \beta_3 CAP_{i,t} + \beta_4 RDIV_{i,t} + \beta_5 Industry_{i,t} + \beta_6 Year_{i,t} + \varepsilon \qquad (5)$$

Unlike the other models, this one does not include a lagged variable of strategic direction, since a firm can adjust the level of IT spending relatively easily compared to strategic direction. A one-year lagged IT variable, capital intensity, related diversification (Entropy index), industry and year dummies are included as control variables.

Models 1 to 5 test the following hypotheses respectively:

H1: There is a positive relationship between IT and total diversification.
H2: There is a positive relationship between IT and related diversification.
H3: There is a positive relationship between IT and unrelated diversification.
H4: IT has a positive relationship with strategic direction.
H5: Strategic direction has a positive relationship with IT.

ANALYSIS FOR FIRM PERFORMANCE

The Model

The model measures the relationship between IT and firm performance as measured by Tobin's q, gross margin, revenue per employee, and ROA while controlling for diversification and capital intensity, as well as industry- and year-specific effects. The model also includes a one-year lagged variable of ROA to control for past performance since the performance impact of IT can be overestimated if there is no control for past performance (Santhanam and Hartono, 2003; Tanriverdi, 2006; Zhu, 2004).

$$\text{Performance}_{i,t} = \beta_0 + \beta_1 \text{IT}_{i,t-1} + \beta_2 \text{RD}_{i,t} + \beta_3 \text{DIV}_{i,t} + \beta_4 \text{CAP}_{i,t} + \beta_5 \text{ROA}_{i,t-1} + \beta_6 \text{Industry}_{i,t} + \beta_7 \text{Year}_{i,t} + \varepsilon \quad (6)$$

For the analysis of the two-year lags, the one-year lagged IT is replaced by the two-year lagged IT. When ROA is employed as a dependent variable, the one-year lagged variable of Tobin's q is employed as a past performance variable. The model is also estimated separately using the strategic direction variable instead of the diversification variables (RD and DIV).

$$\text{Performance}_{i,t} = \beta_0 + \beta_1 \text{IT}_{i,t-1} + \beta_2 \text{SD}_{i,t} + \beta_3 \text{CAP}_{i,t} + \beta_4 \text{ROA}_{i,t-1} + \beta_5 \text{Industry}_{i,t} + \beta_6 \text{Year}_{i,t} + \varepsilon \quad (7)$$

Models 6 and 7 test the following hypothesis:

H6: There is a positive relationship between IT and firm performance.

RESULTS: IT AND DIVERSIFICATION

As shown in Table 2, the current level of IT spending is strongly associated with an increase in diversification after two years. The coefficient of IT (two-year lagged) indicates that the null hypothesis of zero effect of IT can be rejected at a confidence level of .01 when the entropy index is employed as a measure of diversification. The F values suggest that the overall model is statistically significant at a level of .01. The results are the same for the Concentric and Herfindahl measures of diversification (Table 3). IT is also associated with an increase in related diversification, and the impact is stronger for IT spending that has been lagged for two years, with a coefficient of .065 ($p < .01$). As expected, IT is associated with a slight increase in unrelated diversification after two years. The coefficient of IT is .035 and significant at a .10 confidence level.

The model also explores the impact of IT on diversification by using the variable of strategic direction (Table 4). As expected, IT is strongly correlated with an increase in strategic direction, and its impact is stronger after two years, with a coefficient of .075 ($p <.01$). The results indicate that firms place their strategic emphasis (or focus) on related diversification when they increase IT spending.

Table 5 shows the results of a direct test of reverse causality with the simultaneous regres-

Table 2. Results for IT and total/related/unrelated diversification (entropy index)

Independent Variables	Dependent Variables					
	DIV_t		$RDIV_t$		$URDIV_t$	
	Model with One-YR Lag	Model with Two-YR Lag	Model with One-YR Lag	Model with Two-YR Lag	Model with One-YR Lag	Model with Two-YR Lag
$(IT/EMP)_{t-1}$	-.002[1] (-.090)[2]		.038* (1.848)		-.002 (-.145)	
$(IT/EMP)_{t-2}$		.076*** (3.045)		.065*** (2.713)		.035* (1.700)
$(CAP/ASSET)_t$	.028 (1.391)	.017 (.650)	.007 (.315)	-.001 (-.052)	.031 (1.720)	.023 (1.032)
DIV_{t-1}	.908*** (50.38)	.879*** (36.07)				
$RDIV_{t-1}$			.803*** (34.59)	.761*** (27.98)		
$URDIV_{t-1}$					.654*** (26.38)	.594*** (21.18)
DIV_t			.157*** (6.68)	.193*** (7.09)	.332*** (13.19)	.386*** (13.81)
Other Controls	Industry & Year	Industry & Year	Industry & Year	Industry & Year	Industry & Year	Industry & Year
Adjusted R^2	84.6 %	77.0 %	80.5 %	77.7 %	87.1 %	83.7 %
F Statistic	291.13***	145.66***	201.41***	140.51***	327.77***	207.45***
N	529	436	535	442	535	442

**** (p<.01), * (p<.10)*

[1] Standardized coefficients are reported.

[2] The values in parentheses are t-statistics.

Table 3. Results for IT and diversification (concentric and Herfindahl indexes)

Independent Variables	Dependent Variable			
	$CONC_t$		$HERF_t$	
	Model with One- Year Lag	Model with Two-Year Lag	Model with One-Year Lag	Model with Two-Year Lag
$(IT/EMP)_{t-1}$	-.015[1] (-.826)[2]		-.006 (-.345)	
$(IT/EMP)_{t-2}$		.058** (2.325)		.077*** (3.066)
$(CAP/ASSET)_t$	.027 (1.356)	.016 (.601)	.024 (1.201)	.018 (.676)
$CONC_{t-1}$	.904*** (49.75)	.876*** (36.24)		
$HERF_{t-1}$			.903*** (49.44)	.877*** (35.54)
Other Controls	Industry & Year	Industry & Year	Industry & Year	Industry & Year
Adjusted R^2	84.0 %	76.8 %	84.1 %	76.1 %
F Statistic	285.91***	149.28***	287.90***	143.76***
N	542	449	542	449

**** (p<.01), ** (p<.05)*

[1] Standardized coefficients are reported.

[2] The values in parentheses are t-statistics.

sion model. The results show that strategic direction is strongly associated with an increase in IT spending, with a coefficient of .139 ($p < .05$). The results in Tables 4 and 5 suggest that there is some causality in both directions between IT and strategic direction, which reflects a mutual reinforcement of IT and strategic direction.

Our results are consistent with the findings of previous studies done by Dewan et al. (1998) and Hitt (1999). However, this study is different from them since it examines lagged effects of IT and employs a measure of strategic direction, in addition to other diversification measures, which captures and quantifies the components of both related and unrelated diversification at the same time. It also employs a more recent data set (1995-1999), compared to the previous studies.[3] This study is also distinct from the two studies in that Dewan et al. (1998) analyzed the IT demand side only, and Hitt (1999) did not distinguish related and unrelated diversification in his analysis.

FIRM PERFORMANCE

As shown in Table 6, IT is positively associated with firm performance as measured by Tobin's q. The positive relationship is significant for both one and two-year lagged IT. The results are the same for models (6) and (7). Diversification is negatively associated with firm performance, while strategic direction is positively associated

Table 4. Results for IT and strategic direction

Independent Variables	Dependent Variable: SD_t	
	Model with One-Year Lag	Model with Two-Year Lag
$(IT/EMP)_{t-1}$	.043*[1] (1.848)[2]	
$(IT/EMP)_{t-2}$		.075*** (2.713)
$RDIV_{t-1}$	.914*** (34.59)	.882*** (27.98)
$(CAP/ASSET)_t$	.008 (.315)	-.002 (-.052)
DIV_t	-.835*** (-31.27)	-.749*** (-23.72)
Other Controls	Industry & Year	Industry & Year
Adjusted R^2	74.7 %	70.0 %
F Statistic	144.47***	94.52***
N	535	442

**** (p<.01), * (p<.10)*

[1] Standardized coefficients are reported.

[2] The values in parentheses are t-statistics.

Table 5. Results for strategic direction and IT

Independent Variables	Dependent Variable: $(IT/EMP)_t$
SD_t	.139**[1] (2.189)[2]
$(IT/EMP)_{t-1}$	.480*** (8.977)
$(CAP/ASSET)_t$	-.090 (-1.532)
$RDIV_t$	-.068 (-1.053)
Other Controls	Industry & Year
Adjusted R^2	28.0 %
F Statistic	12.12***
N	287

**** (p<.01), ** (p<.05)*

[1] Standardized coefficients are reported.

[2] The values in parentheses are t-statistics.

Table 6. Results for Tobin's q

Independent Variables	Dependent Variable			
	Tobin's q_t			
	Model with One-Year Lag	Model with One-Year Lag	Model with Two-Year Lag	Model with Two-Year Lag
$(IT/EMP)_{t-1}$	.111**[1] (2.427)[2]	.132*** (2.869)		
$(IT/EMP)_{t-2}$			.120** (2.521)	.124** (2.556)
$RDIV_t$	-.040 (-.728)		-.038 (-.646)	
DIV_t	-.120** (2.120)		-.111* (-1.934)	
SD_t		.019 (.435)		.014 (.296)
$(CAP/ASSET)_t$	-.073* (-1.648)	-.064 (-1.430)	-.070 (-1.496)	-.071 (-1.503)
ROA_{t-1}	.580*** (13.09)	.571*** (12.72)	.544*** (11.58)	.540*** (11.37)
Other Controls	Industry & Year	Industry & Year	Industry & Year	Industry & Year
Adjusted R^2	43.4 %	41.7 %	37.4 %	35.9 %
F Statistic	21.44***	21.79***	16.67***	16.99***
N	321	321	315	315

***** (p<.01), ** (p<.05), * (p<.10)**

[1] *Standardized coefficients are reported.*

[2] *The values in parentheses are t-statistics.*

with firm performance. However, the relationship is significant only for total diversification.

The explained variance (R^2) of the results is relatively low (in the ranges of 30 and 40 percent), compared to the one in the analysis of IT and diversification. This indicates that there might be some missing variables in the model. Previous research suggests that organizational resources and capabilities (e.g., R&D intensity, advertising intensity, and intangibles such as flexible culture, customer and supplier relationships, and human IT skills) can influence returns from IT investments (Bharadwaj, 2000; Wade & Hulland, 2004). On the other hand, there has been limited attention on strategic factors, such as diversification, and their importance for IT returns. Because of the focus of this research is on diversification and how it is related to IT payoffs, we do not include variables identified by previous research in our model. This might result in specification error and cause biased estimates of standard errors. However, specification error is not likely to be a problem if the included and excluded variables are independent; in that case, the estimates of included variables are not affected by variables excluded (Berry & Feldman, 1985).[4] Since the present research does not consider variables of organizational resources and capabilities, it would be valuable for future research to examine IT returns holistically by considering all the factors that affect firm performance, for example, both strategic factors and organizational resources and capabilities.

As shown in Tables 7 and 8, IT is positively associated with firm performance as measured by gross margin and revenue per employee, and its impact is significant. The results are the same for models (6) and (7). The impact of diversification, including strategic direction, is not significant, except for total diversification in Table 7. Its impact is negative as in the regression with Tobin's q.

IT is negatively associated with firm performance as measured by ROA (not reported here). However, the negative relationship is not significant, and the results are the same for models (6) and (7).

Table 9 summarizes our hypothesis test results.

The results indicate that increased IT spending improves firm performance as measured by Tobin's q, gross margin, and revenue per employee, but not by ROA. In the previous section, we found

Table 7. Results for gross margin

Independent Variables	Dependent Variables			
	GM_t			
	Model with One-Year Lag	Model with One-Year Lag	Model with Two-Year Lag	Model with Two-Year Lag
$(IT/EMP)_{t-1}$	.172***[1] (3.778)[2]	.188*** (4.140)		
$(IT/EMP)_{t-2}$			.221*** (4.765)	.224*** (4.804)
$RDIV_t$	.009 (.171)		.011 (.199)	
DIV_t	-.141*** (-2.613)		-.120** (-2.219)	
SD_t		.056 (1.302)		.044 (.994)
$(CAP/ASSET)_t$	.066 (1.307)	.084* (1.658)	.070 (1.390)	.076 (1.501)
ROA_{t-1}	.387*** (8.825)	.376*** (8.526)	.389*** (8.614)	.383*** (8.446)
Other Controls	Industry & Year	Industry & Year	Industry & Year	Industry & Year
Adjusted R^2	33.2 %	32.0 %	32.4 %	31.5 %
F Statistic	17.28***	17.84***	16.14***	16.88***
N	394	394	381	381

**** (p<.01), ** (p<.05)*

[1] Standardized coefficients are reported.

[2] The values in parentheses are t-statistics.

Table 8. Results for revenue per employee

Independent Variables	Dependent Variables			
	RPE_t			
	Model with One-Year Lag	Model with One-Year Lag	Model with Two-Year Lag	Model with Two-Year Lag
$(IT/EMP)_{t-1}$	.547***[1] (12.066)[2]	.539*** (11.972)		
$(IT/EMP)_{t-2}$			.461*** (9.444)	.459*** (9.430)
$RDIV_t$	-.015 (-.292)		-.026 (-.452)	
DIV_t	.081 (1.505)		.056 (.997)	
SD_t		-.038 (-.884)		-.033 (-.713)
$(CAP/ASSET)_t$	-.034 (-.675)	-.043 (-.854)	-.037 (-.703)	-.039 (-.734)
ROA_{t-1}	-.002 (-.057)	.003 (.069)	-.034 (-.707)	-.032 (-.671)
Other Controls	Industry & Year	Industry & Year	Industry & Year	Industry & Year
Adjusted R^2	33.6 %	33.4 %	25.9 %	26.0 %
F Statistic	17.50***	18.87***	11.99***	13.05***
N	393	393	378	378

**** (p<.01)*

[1] Standardized coefficients are reported.

[2] The values in parentheses are t-statistics.

that firms place their strategic emphasis on related diversification with increased IT spending (Table 4), and that firms require more IT when they are oriented more toward related diversification (Table 5). Overall, this implies that the economic benefits of diversification are leveraged by IT when its direction is oriented toward related diversification. By providing a better means of coordination, IT facilitates the coordination of diverse production activities and the collaboration of individual business units, eventually enhancing the benefits from this diversification. The summary of the overall findings is presented in Figure 1.

Table 9. Summary of hypothesis test results

Hypothesis	Sign	Result	Tables
1	+	Supported	2,3
2	+	Supported	2
3	+	Supported (weak)	2
4	+	Supported	4
5	+	Supported	5
6	+	Supported (but not for ROA)	6, 7, 8

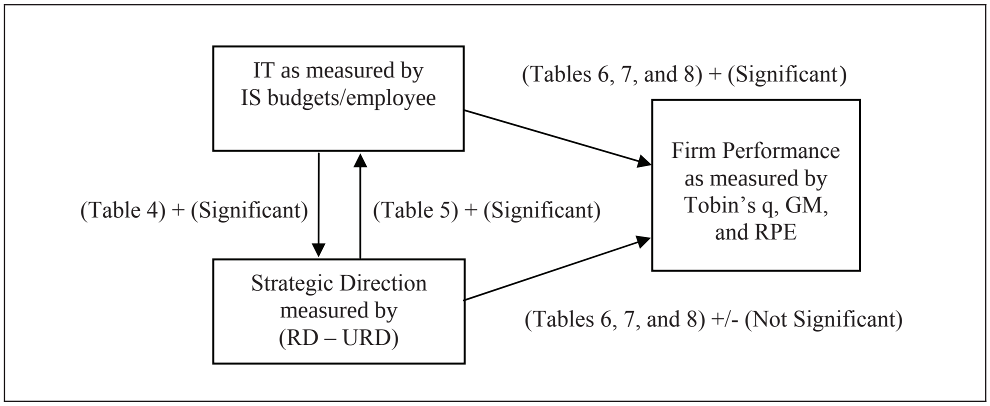
DISCUSSION AND CONCLUSION

By conducting empirical analyses in two stages,this research demonstrates that IT leverages the benefits of diversification (Figure 1). Based on the findings obtained from several two-staged empirical analyses, this research shows that IT improves firm performance when firms place emphasis on related, rather than unrelated, diversification. In other words, IT complements the strategic decision to focus on related diversification.

Replications and extensions can contribute to the accumulation of knowledge, and it is critical for the development of a discipline (Benbasat & Zmud, 1999; Berthon, Pitt, Ewing, & Carr, 2002; Santhanam & Hartono, 2003). This research contributes to the stream of IT business value research by extending previous IS studies by conducting several empirical analyses to explore: (1) the relationship between IT and diversification by employing multiple measures of diversification and (2) the impact of IT and diversification on firm performance as measured by Tobin's q, gross margin, revenue per employee, and ROA. Another contribution of this research is that it shows the mechanism of how firm performance is improved by IT and diversification by illustrating the directional effect of the two. The insignificant estimates of strategic direction in the performance analysis (Figure 1) indicate that on average technology-driven business strategy (diversification led by IT investments) has little performance impact, while business-driven technology investment has a significant performance impact. The results imply that our business strategy must guide our decisions on technology investment, not the other way around. However, the high standard errors of the estimates also indicate that some firms are obtaining a significant value from technology-driven business strategy, while others are not. This variation could be of significant interest for future research, for example, how to make technology-driven business strategy more successful.

Companies invest in IT to execute their strategies successfully, thereby creating value. In today's turbulent and fast changing global business environments, companies can create new market opportunities across national borders by developing new products or by finding new customer segments. IT is a critical strategic resource to help companies pursue these new market opportunities with low additional coordination and collaboration costs. By providing a better means of sharing information and coordinating business resources, such as supply chains, distribution channels, marketing expertise, managerial and technical expertise, market information, and other tangible and intangible resources, IT can enable scope economies and efficient utilization of business resources across multiple markets. However, when companies pursue diversification, they should be cautious not to lose their strategic focus and ensure that the new market opportunities do not impair their core strategic position.

Figure 1. Findings on IT, strategic direction, and firm performance



Note: RD (Entropy Related Diversification); URD (Entropy Unrelated Diversification); GM (Gross Margin); RPE (Revenue per Employee)

This research is not free from limitations: One limitation is that it does not consider all the factors that influence firm performance. Thus, as discussed earlier, there is considerable variance in the dependent variable (firm performance) left to be explained. However, since the focus of this research is on diversification and how it is related to IT performance, we would leave the elucidation of the unexplained variance of firm performance to future research.

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ENDNOTES

[1] The Entropy index of total diversification is a weighted average of the sales shares of the different four-digit SIC code industries, where the weight for each industry is the logarithm of the inverse of its share. The Entropy index of related diversification (RD) measures the extent of diversification arising from operations in several industries of the same two-digit SIC code industry group. The Entropy index of unrelated diversification (URD) measures the extent of diversification arising from extending operations into different two-digit SIC code industries. It follows that total diversification is equal to the sum of RD and URD. Unlike the Entropy index, the Concentric and Herfindahl indexes do not distinguish between related and unrelated diversification. The concentric index measures the degree of distance or relatedness between industries. Weights are given based on industry sales shares. This value depends on the relations between the industries. On the other hand, the Herfindahl index measures industry concentration. This index is defined as one minus the sum of squared shares of a firm's activities in different industries (Dewan et al., 1998; Shin, 2006).

[2] We take a one-year and a two-year lag structure based on previous IS research (Brynjolfsson, Malone, Gurbaxani, & Kambil, 1994), which shows that the impact of IT is not fully realized immediately and is greatest after a lag of one to two years. We analyze with a one-year and two-year lag separately because they are highly correlated.

[3] Dewan et al. (1998) used a data set from 1988 through 1992, and Hitt (1999) used a data set from 1987 through 1994.

[4] The interaction between an independent variable in the model and a variable that has been left out often causes the problem of heteroscedasticity—the error term in a regression model does not have constant variance (Berry & Feldman, 1985). Heteroscedasticity does not influence the bias of regression coefficients, but it can bias the estimation of standard errors.

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Chapter 8.5

Toward an Interdisciplinary Engineering and Management of Complex IT-Intensive Organizational Systems:

A Systems View

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ABSTRACT

An accelerated scientific, engineering, and industrial progress in information technologies has fostered the deployment of Complex Information Technology (highly dependent) Organizational Systems (CITOS). The benefits have been so strong that CITOS have proliferated in a variety of large and midsized organizations to support various generic intra-organizational processes and inter-organizational activities. But their systems engineering, management, and research complexity have been substantially raised in the last decade, and the CITOS realization is presenting new technical, organizational, management, and research challenges. In this article, we use a conceptual research method to review the engineering, management, and research complexity issues raised for CITOS, and develop the rationality of the following propositions: P1: a plausible response to cope with CITOS is an interdisciplinary engineering and management body of knowledge; and P2: such a realization is plausible through the incorporation of foundations, principles, methods, tools, and best practices from the systems approach by way of systems engineering and software engineering disciplines. Discussion of first benefits, critical barriers, and effectiveness measures to reach this academic proposal are presented.

Businesses no longer merely depend on information systems. In an increasing number of enterprises, the systems are the business. (R. Hunter & M. Blosch, Gartner Group, 2003)

INTRODUCTION

An accelerated scientific, engineering, and industrial progress in information technologies and its convergence with communications technologies (the ICT concept) has fostered the deployment of Complex Information Technology (highly dependent) Organizational Systems (CITOS) in the last decade. The CITOS concept subsumes the well-known constructs of *mission-critical systems*, *large-scale information systems, enterprise information systems*, and *inter-organizational information systems.* Generic instances of CITOS are worldwide credit card systems, brokerage financial systems, military defense systems, large ERPs, governmental tax payment systems, and worldwide e-commerce and B2B supply-chain systems in automotive and publishing industries.

Empirical evidence, such as (a) the raising of the ICT budget (measured as a percentage of sales) to 5%-9% in the 2000s (Prewitt & Cosgrove, 2006); (b) the growing of world ICT trade from 8% in 1995 to 10% in 2001 with a 4% annual growth rate (OECD, 2004); (c) the IT commoditization or democratization phenomenon being more affordable the ICT infrastructure in midsized firms in the 1990s (Carr, 2003); (d) the maturing of the myriad of ICT in the last decade (e.g., mobile computing, wireless networks, Web services, grid computing, and virtualization services); (e) the new ways for performing business-oriented operational, tactical, and strategic organizational duties through ICT (e.g., workflow systems, business process management, and service-oriented management); (f) the several tangible and intangible organizational benefits from intra-organizational processes (as in Porter's value-chain activities) and inter-organizational activities (supplier-customer value chains, B2B, and e-government initiatives) leveraged by CITOS; and (g) the thousands of US dollars lost due to availability, continuity, and capacity failures in ICT services (van Bon, Pieper, & van deer Veen, 2006) because of an hour of system downtime. These factors and others show that CITOS are relevant for business and government organizations (as well as for nonprofit organizations).

Such systems are characterized by having (1) many heterogeneous ICT (client and server hardware, operating systems, middleware, network and telecommunication equipment, and business systems applications) (2) a large variety of specialized human resources for their engineering, management, and operation; (3) a worldwide scope; (4) geographically distributed operational and managerial users; (5) core business processes supported; (6) a huge financial budget for organizational deployment; and (7) a critical interdependence on ICT. Thus, these can be correctly labeled as "complex systems" (comprised of a large variety of components and inter-relationships in multiple scales generating unexpected emergent behaviors).

According to a systemic definition, the emergent properties from a system cannot be attributed to the individual actions performed from parts. Rather the interactions among people, machines, applications, procedures, data, policies, and the organizational setting and organizational environment are responsible for their coproduction. Consequently, and because of its raised engineering and management complexity, a holistic study of human and machine component inter-relationships and of its environment is needed when the efficiency and effectiveness of CITOS are considered. It could be expected that the current IS body of knowledge (IS BoK) addresses such issues. Nevertheless, because of the ICT technological progress, combined with the extended capabilities of CITOS services demanded in large organizations (Dougmore, 2006), have raised significantly the systems engineering, management, and research complexity for users, managers, engineers, and researchers, our premise is such a current IS BoK is insufficient and an extended (interdisciplinary) IS BoK is required.

According to the international expert in complex systems Bar-Yam (2003b), to design organizational complex systems, we must recognize that "the networked information system that is being developed, serves as part of the human socio-economic-technological system. Various parts of this system that include human beings and information systems, and the system as a whole, is a functional system" (p. 17). Also "the recognition that human beings and information technology are working together as an integrated system" (p. 25) should be an imperative consideration for its design. From a service oriented management and engineering perspective (Chesbrough & Spohrer, 2006), Dermikan and Goul (2006) suggest a similar finding:

> *A transdisciplinary education program needs to be developed by utilizing organizational sociology, law, services marketing, business strategy and operations, accounting and finance, information technology, and industrial and computer engineering to provide the knowledge necessary to equip new graduates to lead this culture change.* (p. 12)

Because the current typical IS graduate curriculum lacks most systems approach foundations and contains few, if any, truly systems perspective courses (e.g., most IS development methods do not use a well-defined systems perspective (Alter, 2007; Avison, Wood-Harper, Vidgen, & Wood, 1998; Checkland & Holwell, 1995)), we hypothesize (**H1**) that a deep "system" view has been scarcely deployed in the graduate IS curriculum. We also hypothesize (**H2**) that an IS holistic view is better able than a partial view to cope with the new technical and organizational complexity that large organizations show. Feigenbaum[1] (1968) foresaw similar ideas by identifying a partial using of the systems approach in the IS discipline. His perspective, a well-defined systemic view where man-machine systems are combined (with new roles such as CSD (chief systems designer), CSMO (chief systems manager officer), CBPO (chief business process officer), and CBAO (chief business architect officer)) and their inter-relationships with their environment are considered, offers an initial effort toward a holistic view of the firm and the information systems deployed.

To test **H1** and **H2** is the long-term aim of the research stream fostered by IJITSA. In this article, we focus on a more limited but still useful purpose: to develop the rationality of two conceptual propositions relevant for the progress of the information systems discipline, and outline plausible courses of action. **Proposition P1** (**the interdisciplinary IS BoK proposition**) argues that an interdisciplinary body of knowledge is called for in information systems because of the rising systems engineering, management, and research complexity of the emergent complex information technology-intensive organizational systems (CITOS). **Proposition P2** (**the systems approach foundation proposition**) poses that **P1** is plausible through incorporating foundations, principles, methods, tools, and best practices from the systems approach by way of systems engineering and software engineering disciplines.

To support **P1** and **P2**, we use a conceptual research approach (Glass, Ramesh, & Vessey, 2004) with a descriptive and evaluative purpose. A similar scheme is used by Goul, Henderson, and Tonge (1992) in the domain of artificial intelligence (AI). The units of study are abstract elements (BoK of SE, BoK of SwE, and BoK of IS). This article is structured as follows: first, we identify the emergent engineering, managerial, and research challenges raised by CITOS. Second, we compare the underlying foundations (core definitions, disciplines of reference, teaching themes, and research methods) of information systems and of the two most emergent related disciplines (software engineering and systems engineering) that are considered essential to address such rising complexity in CITOS, and report the knowledge gaps. Third, we discuss its benefits, the hard and soft barriers to deployment, and its effectiveness measures.

THE INCREASING ENGINEERING, MANAGEMENT/BEHAVIORAL, AND RESEARCH COMPLEXITY DEMANDED BY CITOS

Conventional systems are characterized by being architecturally and functionally cohesive (they have low heterogeneity, low dispersion, low autonomy of their parts, low functional variety, and manageable functional scalability) and for being highly predictable. The classic software engineering (SE), software engineering (SwE), and IS disciplines have largely provided the adequate knowledge to design, build, and deploy conventional systems efficiently in organizations. When these systems (originally planned as conventional well-controlled physical entities with core software and hardware components), are combined with intensive human-activity systems and telecommunications components from multiples sources, as is characteristic of CITOS, the systems exhibit characteristics of complex systems: *many components, rich interactions and loose coupling among the components, the system evolves, system characteristics emerge over time, and the system pursues a mixture of component goals and system goals* (Frank, 2001; Jackson, 1991; Keating, Rogers, Unal, Dryer, Sousa-Poza, Safford, et al., 2003). Thus, an engineering complexity (manifested as many alternative designs, components, assembly procedures, equipments, tools/languages, and standards available for their realization and operation) and a behavioral and management complexity (manifested as unexpected interactions and emergent behaviors during their project management and deployment phases that might lead to critical failures and the user demand for enhanced system capabilities and functionalities) are introduced in such systems.

The Engineering Complexity of CITOS

The *complex systems* concept has long been present in the systems approach. Von Bertalanffy (1972) reports that “modern technology and society have become so complex that traditional branches of technology are no longer sufficient; approaches of a holistic or systems, or generalist and interdisciplinary, nature became necessary” (p. 420). The software engineering (Glass, 1998) and systems engineering (Bar-Yam, 2003a, 2003b) domains have also been concerned with the engineering complexity of *complex systems* (Shenhar & Bonen, 1997).

A main effect of the engineering complexity of systems is a “system failure.” In the SE domain, failures occur during the operation of the system but also those taking place during the various development stages. A system failure, as distinguished from a local component-based failure, is a failure expressed in degrading system performance. The symptom of failure is seen or measured but its source is not clear. A “system problem" refers to another scenario. An example of a system problem is a user expressing dissatisfaction with the system because of unanticipated environmental changes. System problems and failures, in a most basic systemic perspective, are not single events but a messy system of problems (Ackoff, 1981). Sources of system problems come from the conflicts raised from the interactions between the system, subsystems, and suprasystem to reach their objectives and from changes in such objectives (Ackoff, 1976).

New concepts have been developed in the SE and SwE domains to cope with engineering complexity. In the case of SE, a few of the concepts are *system of systems* (SoS) (Keating et al., 2003), *federation of systems* (FoS) (Sage & Cuppan, 2001), and *complex system* (Mage & de Weck, 2004). A SoS exists if (1) its component systems have well-substantiated purposes even if detached; (2) its component systems are managed for their own purposes; (3) its component systems, functionalities, and behaviors can be added or removed during its use; and (4) it shows emergent behavior not achievable by the component systems acting independently (at least one emergent property must be present to be considered a system). When SoS are human-activity intensive, these become a FoS (Sage & Cuppan, 2001). SoS and FoS are comprised of component systems that individually provide user-oriented functionalities and for the whole system. Each SoS and FoS are implicitly complex *systems* but not the converse. Because of the ambiguity and uncertainty in SoS, the strong interaction of the SoS and its context, and the limitations for deploying partial solutions the classic SE for single-complex systems must be updated (Keating et al., 2003). A true *systemic worldview* (our philosophy), conceptualized as "a way to thinking, deciding, acting, and interpreting what is done and how it is done" (p. 44), as well as an action-research orientation that links theory building and theory testing, are the main updates suggested. Because SoS and FoS architectures are found in CITOS, these concepts cannot be omitted in an interdisciplinary IS BoK.

Complex systems can be classified to avoid inadequate deployment of engineering and management processes. Shenhar and Bonen (1997) derived a 4x3 matrix of instances of systems based on uncertain technological and system scope dimensions. Mage and de Weck (2004) developed a more detailed classification (also based on the Theory of Systems) of a 5x4 matrix of operators (transformation/process, distribution/transport, store/house, trade/exchange, and regulate/control) and operands (matter, energy, information, and value). Natural, noncomplex artificial, and complex (artificial) engineering systems are also differentiated by the authors. Noncomplex artificial systems have either technical or social complexity. Complex engineering systems have both. Similar to other studies, a complex system is defined as a system "with numerous components and interconnections, interactions or interdependencies that are difficult to describe, understand, predict, manage, design, and/or change" (p. 2). The engineering (and management) of CITOS can be based on these classifications. Other studies have also complemented such concepts to update the classic SE view (Calvano & John, 2004; Cleary, 2005; Franke, 2001).

In the software engineering discipline, concepts such as software-intensive systems (Andriole & Freeman, 1993; Boehm, 2000), sociotechnical software-intensive systems (Sommerville, 1998), and software-intensive systems of systems (Boehm, 2006; Boehm & Lane, 2006) are examples of research efforts for addressing the engineering complexity issue associated with CITOS from an information systems perspective.

For Andriole and Freeman (1993), the best engineering strategy to address engineering complexity involves unifying the SE and SwE disciplines. These authors argue (1993) that:

> *Our working premise is simple: software-intensive systems (regardless of their application domains) are among the most important, yet hardest to create and maintain artifacts of modern society. Thirty*

> *years ago, there were few large-scale software-intensive systems. Today they pervade the public and private sectors.*(p. 165)

Thus, as "both disciplines address the same subject, the creation of complex software-intensive systems, albeit from different perspectives" (p. 165), they pose a unified software systems engineering. A similar rationality is argued by Boehm (2000): "A unified culture of systems and software engineering can tame the rapid changes in information technology" (p. 114). For Boehm, "organizations can change from slow, reactive, adversarial, separated software and systems engineering processes to unified, concurrent processes. These processes better suit rapid development of dynamically changing software-intensive systems involving COTS, agent, Web, multimedia, and Internet technology" (p. 114). A software-intensive system of systems (SISOS) concept and other core trends for the mutual interaction of SwE and SE disciplines are also proposed in a later study (Boehm, 2006). The rationale for improving the SwE acquisition process in the new scenario of SISOS is expanded in Boehm and Lane (2006). For Sommerville (1998), engineering complexity is manifested through the sociotechnical software-intensive systems. These systems can be described as:

> *Systems where some of the components are software-controlled computers and which are used by people to support some kind of business or operational process …. [Such] systems, therefore, always include computer hardware, software which may be specially designed or bought-in as off-the-shelf packages, policies and procedures and people who may be end-users and producers/consumers of information used by the system …. Socio-technical systems normally operate in a "systems-rich" environment where different systems are used to support a range of different processes.* (p. 115)

Somerville argues that SE foundations are needed in SwE programs because a computer science approach is reductionistic and isolates students from the organizational and human-based complexities in developing large-scale software development. The SE discipline contributes to improve the engineering rigor of SwE practices. This enhanced curriculum then revalues the SwE methods and tools and incorporates well-tested management engineering approaches.

In the domain of information systems, most studies have been focused on behavioral and managerial perspectives (Hevner, March, Park, & Ram, 2004), rather than engineering complexity issues. A seminal study (Nunamaker, Chen, & Purdin, 1991) introduced the system development process, from the engineering and software engineering disciplines, as a research method for IS to be used jointly with theoretical, observational, and experimental research. But the proposal is focused in the study of the final artifacts rather than in the study of the engineering and design methods to cope with CITOS. Consequently, behavioral-oriented research is ultimately stressed, and the development engineering process is offered as a mediator rather than a primary research goal.

Other authors (Hevner & March, 2003; Hevner et al., 2004; March & Smith, 1995), using the core foundations for a design science established by Herbert A. Simon (1969), have formulated a design research paradigm in information systems, one different from a routine design paradigm based in the application of the existent knowledge for building an artifact. A theoretical framework that justifies behavioral (called *natural*) and design dimensions to study IT in organizations is reported by March and Smith (1995). The behavior (*natural*) dimension accounts for the formulation and testing (justifying) of theories about how and why IT works or does not work in an organizational setting. In the design dimension, the building and evaluation of IT artifacts are conducted. These authors classify IT artifacts (e.g., the research products) as constructs, models, methods, and instantiations. Hevner and March (2003) and Hevner et al. (2004) extend the study proposing design principles and research validation methods for the IS domain. They assert that the design issue is a core topic in the engineering discipline, but it has been rarely explored in the IS domain (the design references used by these authors come from the computer science, software engineering, artificial intelligence, and political science domains). Complexity and wicked problem concepts (Rittel & Weber, 1973) are also described by these authors. From a systems approach, a similar construct: messes as a system of problems, has also been defined (Ackoff, 1973).

These few studies, then, contribute directly to the IS domain introducing the engineering complexity issue of CITOS. Paradoxically, despite some SE literature reports that the incremental deployment of IT is generating SoS (Carlock & Fenton, 2001; Keating et al., 2003), CITOS as SoS are still not studied in the IS domain.

The Management and Behavioral Complexity of CITOS

According to Sterman (2001), managerial complexity is of two types: combinatorial or dynamic. Relevant for the IS domain is that combinatorial managerial complexity is most perceived by organizational managers but dynamic managerial complexity affects them more. As Sterman (2001) indicates:

> *Most people think of complexity in terms of the number of components in a system or the number of possibilities one must consider in making a decision. The problem of optimally scheduling an airline's flights and crews is highly complex, but the complexity lies in finding the best solution out of an astronomical number of possibilities. Such problems have high levels of combinatorial complexity. However, most cases of policy resistance arise from dynamic complexity—the often counterintuitive behavior of complex systems that arises from the interactions of the agents over time. Dynamic complexity can arise even in simple systems with low combinatorial complexity.* (p. 11)

This resistance (often occurring as a delay by decision makers to make critical managerial choices regarding courses of action and to intervene in critical situations) happens because complex side effects are generated in messy organizational systems. These complex organizational systems, characterized by an underlying structure of mechanisms that is highly coupled, dynamic, adaptive, self-organizing, and with emergent counterintuitive behaviors (Sterman, 2001), demand at least a similar complex systemic solution as the controller system (Bar-Yam, 2003b).

In the domain of information systems, the management complexity is manifested in failed IT projects (CIO UK Web site, 2007; Standish Group, 2003). Failed IT projects are defined as projects where there are cost over-runs, large schedule delays, incomplete delivery of systems, system underutiliztion, or cancellations before completion or early system disposal (Ewusi-Mensah, 1997; Wallace & Keil, 2004). A common issue reported in such studies is the critical influence of management inadequacies during the implementation life cycle. Management complexity is important for CITOS deployment because an information system comprises technology, procedures, data, software, and people. Moreover, the technical, socio-economical, and political-cultural components of the CITOS environment are factors whose influences must be identified for reaching a successful system deployment (Gelman, Mora, Forgionne, & Cervantes, 2005; Mora, Gelman, Cervantes, Mejia, & Weitzenfeld, 2003). This view is supported by a vast literature on IS implementation research (Kwon & Zmud, 1987). A holistic view of the phenomenon, then, requires the inclusion of managerial complexity and interactions with engineering complexity. Efficiency and efficacy engineering project success metrics (on time project completion, on budget, and with a high percentage of expected requirements delivered) must be complemented with system effectiveness metrics (associated to managerial complexity) to manage CITOS projects.

In the SE domain, managerial complexity is manifested when large-scale but simple systems become a SoS and when the usual technical, operational, economical, and political (TOEP) feasibility priority order shifts to a political, economical, operational, and technical (PEOT) order (Carlock & Fenton, 2001). Then, "seamless interoperability and acceptable performance to all users at an acceptable cost are the most important priorities" (Carlock & Fenton, 2001, p. 245). Managerial complexity can be addressed through enterprise systems engineering (a natural extension of SE) for an updated and adequate engineering management of SoS development or procurement. In a SoS, each system component is also conceptualized as a system comprised of hardware, software, facilities, procedures, and people. Such a whole SoS operating is linked to needed support systems. Facilities and support systems have usually been ignored in the IS literature. An exception is the "SERVQUAL" concept to measure IS service quality. Management complexity of SoS is then addressed through an extended management SE life cycle involving strategic, project management (midlevel), and implementation/operational levels. Recent evidence of managerial complexity issues manifested in large-scale software systems projects and solved through a SE enhancement is reported in Hole, Verma, Jain, Vitale, and Popick (2005). Critical deficiencies in the older SwE methodology are identified as follows:

> *In its existing state (pre-SE&A) this framework did not address requirements, architecture development, integration, and verification as part of a coherent Systems Engineering methodology. Existing descriptions of these SE&A practices were general and open to interpretations, and often "hidden" in broader activities and work products.* (Hole, Verma, Jain, Vitale, & Popick, 2005, p. 80)

Enhancements, such as project mission awareness over the traditional project objectives, non-negotiable mission-critical requirements, better requirements traceability activities, project manager and lead systems engineer roles, disciplined change impact analysis, and tangible scored reviews (also generated independently in the SwE domain but rarely used in the IS domain), are reported as contributions from the SE domain. IT and IS architecture views of the full enterprise, such as Zachman's Framework (Sowa & Zachman, 1992; Zachman, 1987), have received little attention in the IS domain.

The complexity behavioral dimension in the management of large-scale projects has been reported also in the SwE domain (Curtis, Krasner, & Iscoe, 1988). An implicit holistic multilayer model (business, company, project, team, and individual milieus) is used to study the behavioral interactions in the system. Findings suggest that large-scale software development demands that the learning, negotiation, communication, and customer interactions activities (that are not usually considered in SwE management projects) be accommodated explicitly in the process.

The Research Complexity of CITOS

Because CITOS is concerned with engineering and managerial/behavioral complexity, a research complexity inherently appears when CITOS are investigated. Comprehensive IS research frameworks that recognize behavioral and engineering perspectives are recent (Hevner & March, 2003; Hevner et al., 2004; March & Smith, 1995). As noted earlier, much research in the IS discipline dilutes IT artifacts and consequently their engineering characteristics or when focused on the computational view, this ignores the behavioral issues (Orlikowski & Iacono, 2001). CITOS' complexity demands mutual research interaction from both sides.

A comprehensive IS research framework (Mora, Gelman, Forgionne, Petkov, & Cano, 2007a) uses a critical realism stance (Bhaskar, 1975) and a multimethodology research worldview (rationalized by Mingers, 2000, 2001, 2002), to frame some core ideas of the Theory of Systems (Ackoff, 1971; Gelman & Garcia, 1989; Mora et al., 2003), as a proposal to accommodate the disparate and conflicting research stances (positivist, interpretative, and critical). Four postulates are articulated in Mora et al. (2007a) to frame such disparate philosophical stances. Postulate P4 posed as integrator and underpinned in critical realism says that:

> *The world is intelligible for human beings because of its stratified hierarchy of organized complexities—the widest container is the real domain that comprises a multi-strata of natural, man-made and social structures as well as of event-generative processes that are manifested in the actual domain that in turn contains to the empirical domain where the generated events can or cannot be detected.* (p. 3)

For Bhaskar (1975), reality is independent of human beings: "a law-governed world independently of man" (p. 26), but the social structures and their generative mechanisms are conditioned to the existence of human beings at first and then these really exist and can be studied and intervened. Bhaskar also explains that "it is not the character of science that imposes a determinate pattern or order in the world; but the order of the world that, under certain determinate conditions, makes possible the cluster of activities we call science" (p. 30). Accordingly to Mingers (2002):

> *CR (critical realism) recognizes the existence of a variety of objects of knowledge—material, conceptual, social, psychological—each of which requires different research methods to come to understand them. And, CR emphasizes the holistic interaction of these different objects. Thus it is to be expected that understanding in any particular situation will require a variety of research methods both extensive and intensive.* (p. 302)

Other IS frameworks and models based on the Theory of Systems as the most adequate models to cope with the complexities faced by IS practitioners and academicians have been reported (Alter, 2001, 2003, 2007; Bacon & Fitzergarld, 2001; Ives, Hamilton, & Davis, 1980; Nolan & Whetherbe, 1980). Such IS systemic research frameworks are usually ignored in IS research, which is still guided by a reductionistic view.

Thus, there is an extensive granularity manifested by a vast array of IS relevant topics, but the topics are disconnected as a whole. An IS body of knowledge from an accumulation research tradition is missing. A plausible reason, according to Mora, Gelman, Cano, Cervantes, and Forgionne (2006a) and Mora et al. (2007a), is that the holistic view of the IS discipline has been lost from its original conceptualization in the 1960s. Consequently, research topics appear disconnected from a general standardized research framework (as SE and SwE have through a BoK).

These large unconnected research topics, the infrequently-used underlying microtheories, the broad background of IS researchers, the lack of finding accumulation, and the engineering and managerial richness of the phenomena involved are also manifestations of research complexity in the IS domain.

Consequences and Initial Interdisciplinary Efforts for CITOS Complexity

Table 1 summarizes the new engineering, managerial, and research challenges faced by practitioners and researchers in CITOS (and from the software engineering and systems engineering disciplines oriented to CITOS).

Such challenges imply a need for human resources with the adequate competencies for the development (e.g., the engineering and research design view) and the management (e.g., the behavioral research view) of CITOS. Nevertheless, the IS curriculum literature has not addressed it enough. An OECD (2004) study, for instance, claims that most critical technical competencies in ICT must be learned directly from organizations:

> *The need for ICT skills can be satisfied in part through education and training. Full-time education does not appear to be the most important path to obtaining general and advanced skills. As schools become well equipped, however, students develop at least basic ICT skills, and ICT-related degrees can be obtained through formal education. For specialist skills, however, sector-specific training and certification schemes may be more effective, given the rapid changes in skills needs and the constant introduction of new technologies.* (p. 12)

Given such complexity, our position is that an interdisciplinary (e.g., a systemic integration of several disciplines) IS graduate curriculum is a plausible course of action that will enable practitioners and researchers to acquire a holistic view of such phenomena.

Proposals for a mutually enhanced SwE and SE curriculum (Bate, 1998; Brown & Scherer, 2000; Denno & Feeney, 2002; Hecht, 1999; Johnson & Dindo, 1998; Rhodes, 2002; Sommerville, 1998) and a new unified software systems engineering discipline (Andriole & Freeman, 1993; Boehm, 2000; Thayer, 1997, 2002) are initial efforts to cope with IT complex systems.

The SE discipline is also being fostered to extend its coverage from an enterprise level focused perspective (Farr & Buede, 2003) (taught in engineering management or industrial engineering disciplines) and to redefine its identity (Emes, Smith, & Cowper, 2001). Such expansion might enable SE to strengthen a systems view for managing the complete organization and the traditional technical processes for engineering a product or service (Arnold & Lawson, 2004; Bar-Yam, 2005; Emes et al., 2001). In particular, Bar-Yam (2005), using a trade-off design between the variety (number of different and highly-independent actions pursued by the components) and scale (number of elementary components performing the same core task) of a system, suggests an evolutionary SE to design and manage complex systems where simultaneous designs, competitive teams, and ongoing fielded and virtual tests are conducted. Other proposals argue for a new SE education focused on complex systems (Beckerman, 2000; Cleary, 2005; Franke, 2001) and the systems approach (Frank & Waks, 2001). For instance, Moti and Waks (2001) report: "technological systems grow larger, more complex, and interdisciplinary, electronics and high-technology industries face a growing demand for engineers with a capacity for systems thinking" (p. 361). These authors also suggest that the SE knowledge about domain specializations (software, computer systems, etc.) be about the (1) complexity of the system; (2) interconnections of lower and upper level systems; and (3) functional domains and constraints. In the IS domain, few similar direct or indirect arguments have been reported (Hevner et al., 2004; Mingers, 2001; Mora, Gelman, Macias, & Alvarez, 2007c). Hence, our **Proposition P1** (**the interdisciplinary IS BoK proposition**) that argues that an interdisciplinary body of knowledge is called for in information systems because of the raising of systems engineering, management, and research complexity of CITOS can be supported.

A COMPARATIVE ANALYSIS OF INFORMATION SYSTEMS, SOFTWARE ENGINEERING, AND SYSTEMS ENGINEERING DISCIPLINES

To support **Proposition P2** (**the systems approach foundation proposition**) that argues that **P1** is plausible through incorporating foundations, principles, methods, tools, and best practices from the systems approach by way of the systems engineering and software engineering disciplines, this article continues and enriches three recent reports (Mora et al., 2006a; Mora, Cervantes, Gelman, Forgionne, & Cano, 2006b; Mora, Gelman, O'Connor, Alvarez, & Macías, 2007b) and is developed under the following rationale: (1) the engineering, management, and research complexity of the issues involved with the emergent CITOS is beyond the scope of the traditional monodisciplinary and reductionistic view of IS (from proposition **P1**); (2) the IS discipline is so fragmented that it has become in disconnected islands in a knowledge sea; and (3) an interdisciplinary, systemic approach (Ackoff, 1960) provides the adequate philosophical paradigm and methodological research tool to cope with the phenomena of interest.

A historical review of the origins of the SE, IS, and SwE disciplines shows that SE is the oldest (from late 1930s) followed by IS (late 1950s), and then SwE (late 1960s). We consider SE the most mature discipline, as evidenced by the existence of large-scale projects using standardized theories, methods, and tools (Honour, 2004), followed by the IS discipline. SwE, by its separation from computer science (Denning, Comer, Gries, Mulder, Tucker, Turner, & Young, 1989) as an independent discipline, can be considered the newest and less mature area of study. Using several sources (Editorial policy statement, 2006; INCOSE, 2004; SEI, 2003) and the PQR concept (Checkland, 2000), it is possible to compare general definitions (shown in Table 2) for these disciplines. At first glance, the three disciplines study disparate systems: a well-defined physical system, a computer software system, and an IT-based organizational system.

Recent SE (Rhodes, 2002) and SwE (Boehm, 2000) literature has noted the increasing inclusion of software and IT components in current and emergent complex systems. Rhodes (2002), for instance, remarks that software is a critical component, like hardware and people, in the entire artificial organizational system developed by systems engineers. Also as mentioned earlier (Sommerville, 1998, p. 115), the SwE discipline has suggested that software systems must be considered as sociotechnical software-intensive systems. From an IS perspective, this definition of software systems corresponds to what is considered an information system (Mora et al., 2003). The SE discipline has also identified that the usual technical, operational, economical, and political (TOEP) order of priorities (Carlock & Fenton, 2001) has been changed to a political, economic, operational, and technical (PEOT) order when complex and large systems are designed. It is usually accepted that SE (Hitchins, 2003) can be deployed in different hierarchical levels: (1) the Artifact SE; (2) the Project SE; (3) the Business SE; (4) the Industry SE; and (5) the Socio-economic (environment) SE. Therefore, the increasing inclusion of software components suggests a needed interaction between SE and SwE, and between these disciplines and IS to cope with the same object of study under different systemic scales.

Table 3 updates the analysis (Mora et al., 2007c) of the relations of these disciplines with their reference disciplines. A qualitative 5-point scale from 1 (very low support) to 5 (very high support) is used to report the current support level assessed by the authors and based on the different studies reviewed (Buede, 2000; Emes et al., 2005 for SE; Glass, 2003; Sage, 2000; SWEBOK (IEEE, 2001) for SwE; and Culnan & Swason, 1986; Glass et al., 2004; Vessey, Ramesh, & Glass, 2002; for IS). A grey shading is also used in the cells to show the recommendations. Six relevant implications for an interdisciplinary IS BoK can be reported.

First, the SE and IS disciplines have been shaped by at least two basic disciplines (Industrial & Manufacturing Engineering Management Science & Operations Research for SE; Behavioral & Social Science and Business & Organizational Science for IS) while SwE has been formed from just one discipline (Computer Science). SwE has been largely considered as a research stream and body of knowledge for Computer Science (Denning et al., 1989). In the last decade, the usefulness of other reference disciplines for SE and IS (Fuggetta, 2000; Kellner, Curtis, deMarco, Kishida, Schulemberg, & Tully, 1991), has been recognized in SwE. A recommendation for the IS discipline is to lessen the variety of such interactions from a high (manifested by excessive MBA courses in the curriculum of graduate MIS programs) to a normal level of support. High-level support from multiple disciplines generates a loss of identity for the IS discipline when the IT artifacts are diluted (Orlikowski & Iacono, 2001). Given the managerial and engineering complexity shown in CITOS and their technical and sociopolitical inter-relationships with their upper and lower level systems, a holistic research approach that combines behavioral and design research approaches supported for the SE and SwE disciplines is encouraged.

Second, while systems science was a core discipline of reference for IS (Ives et al., 1980; Nolan & Wetherbe, 1980) and SE (Sage, 2000), now systems science is scarcely used in IS research. To cope with CITOS, recent proposals to re-incorporate this original foundation (Alter, 2001, 2003, 2007; Gelman et al., 2005; Lee, 2000; Mora et al., 2003, 2007a) have been reported. In the SwE discipline, there has been little evidence of such incorporation, but the recent unification efforts with SE could implicitly link SwE with systems science. Such support should be encouraged in SE and extended in IS and SwE. Third, management engineering and business process engineering, which has been typically incorporated in the SE and partly in SwE curriculum (through CMMI and ISO 15504 initiatives), has been largely ignored in IS with the exceptions of BRP, ERP process modeling, and emergent ITIL initiatives (Mora et al., 2007b). According to Farhoomand and Drury (1999, p. 16), the highest average percentage (25%) of the themes published in eight premier IS journals and the ICIS proceedings during the 1985-1996 period were from "reference disciplines" while the "information system" themes reached 14%. These authors also report that "there seems to be a shift from technical themes towards non-technical themes" (p. 17). Similarly, Orlikowski and Iacono (2001) found in 177 research articles (published in the ISR journal during the period 1990-1999) that the highest percentage (25%) of papers corresponds to a "nominal" view of IT (e.g., IT is absent). Although we accept the relevance of such domains for the IS discipline to understand the suprasystems served by CITOS, we suggest a better balance between organizational, behavioral, and social sciences and management engineering. This balance provides the IS discipline with new conceptual tools for CITOS management and engineering. Then, the server system (CITOS) and the served system (business process) are system components that are studied and designed or redesigned simultaneously.

Fourth, while the SE discipline is strengthened through the interaction of other engineering and management disciplines and permits a normal self-reference, the IS and SwE disciplines have been extensively self-referenced (Glass et al., 2004). We consider that it has had more negative than positive consequences when an imperialist and nonpluralist view of models, frameworks, and theories are encouraged. Self-reference in a domain is positive when there is an open interaction with related domains and when there is an evolutionary accumulation of knowledge rather an iterative decreasing increment of knowledge. The acceptance of qualitative and interpretative research methods was largely rejected in the IS discipline through the self-reference of repetitive specific quantitative methods. Another example is the service science engineering and management initiative (Chesbrough & Spohrer, 2006), rarely addressed in IS but incorporated in the SE and SwE domains in a seamless way.

Fifth, although IS and SwE have been outside the engineering specialties, such as electronic, electrical, and mechanical, CITOS demands at least knowledge on the foundations of such disciplines for IS researchers and practitioners to get an understanding of IT limitations. Consider, for example, developing automated vision recognition systems combined with RFID and secure mobile IT for airports, banks, or worldwide package delivering services. A CIO or research academic should be able to understand the scope, limitations, and costs of deploying such solutions and collaborating in their design (as systems engineers do). IT technical knowledge must not be diluted in IS research. Another example is the planning, design, and management of a data center where network-critical physical infrastructure (NCPI) issues include electrical power, environmental cooling, space, racks and physical infrastructure, cabling, grounding, fire protection, and other issues related to design security (Industry Report, 2005).

Sixth, while SE and SwE have mutually acknowledged the need for interaction, the IS discipline still ignores possibly beneficial interdisciplinary communications. New theoretical incorporations to the IS discipline from the design/engineering paradigm could be obtained by incorporating the systems science paradigm, including the complex systems intellectual movement.

Table 4 exhibits the BoK and general research themes derived for these disciplines. From Table 4, the first inference is that SE and SwE, by their engineering heritage, are most likely to interact in the next 25 years. The IS discipline, in contrast, seems to be unaware of the dramatic changes and challenges that world organizations are demanding due to complex sociotechnical information systems. In the cells with very low interaction (value of 1 point), more interaction is suggested to expand the body of knowledge. According to the systems approach, a system is understood only if it is studied: (1) from two perspectives (like a unitary whole and as a set of interdependent parts) and (2) within its wider system and comprising internal subsystems (Ackoff, 1971; Gelman & Garcia, 1989).

Details of the need for a systems approach in the IS discipline have already been reported (Alter, 2001, 2003, 2007; Bacon & Fitzgerald, 2001; Gelman et al., 2005; Lee, 2000; Mora et al., 2003, 2007a). A second finding from Table 4 is the lack of teaching and research of IS frameworks and standards/models of processes (e.g., CobIT, ITIL, ITSEC, and ISO 20000). The SE and SwE disciplines have developed their rigor through the development, deployment, and compliance with standards of process, but such a movement has largely been ignored in the IS discipline (Beachboard & Beard, 2005). A third finding from Table 4 is that SE has fewer missing interactions than the other two disciplines. A strong implication is that systems engineers are more holistically trained, studying and carrying out large-scale and complex systems (Frank & Waks, 2001), than software engineers and information systems practitioners (Mora et al., 2006b).

In Table 5, the research approaches used in the three disciplines are reported under the same scale. The main categories of research are adapted from Denning et al. (1999), Nunamaker et al. (1991), Hevner and March (2003), Vessey et al. (2002), and Glass et al. (2003, 2004). Theoretical, conceptual, and modeling approaches can be considered pieces of conceptual research that study concepts, constructs, frameworks, methodologies, algorithms, and systems without using data directly from real artifacts. Engineering and behavioral approaches, in contrast, are empirical research methods that take data directly for artifacts, people, or organizations. The holistic systems approach is considered a pluralist and multimethod research paradigm that uses diverse research approaches relying on the complexity of the research situation, goals, and availability of resources.

Table 5 shows that the SE research is conducted mostly through modeling, but it also uses the other research approaches in a more balanced way than the other two disciplines. According to Glass et al. (2004), theoretical/conceptual studies are more frequent than engineering studies in SwE.

For the case of IS, because of its strong historical dependence on business and organizational sciences, most studies are empirical (behavioral approach). Recent studies have argued the need for using modeling/simulation (Mora et al., 2007a) and engineering/design approaches (Hevner & March, 2003; Hevner et al., 2004; Nunamaker et al., 1991) in the IS discipline. In a similar way, other studies have suggested that SwE must conduct empirical research (Kitchenham et al., 2002) and expand the few modeling/simulation studies performed (Madachy, 1996).

Table 5 also shows a behavioral approach bias for the IS discipline, even though the table covers positive and interpretative stances. We believe that the understanding of, and the effective intervention in, single large scale and emergent CITOS demand an interdisciplinary and multimethodological research approach. Mingers (2001) has reported extensively the relevance and need of such an approach for the IS research stream through a critical realism philosophical stance (Mingers, 2002). Previous analysis for management science and operations research (highly linked to SE) has also been reported (Mingers, 2000, 2003). In this article, we support this proposal and believe that the systems approach can glue the disparate, conflicting, and still monodisciplinary views of our discipline (Mora et al., 2007a). In concordance with some SE and SwE studies, we also believe the IS behavioral approach can enhance the SE and SwE disciplines. For the IS discipline, a more balanced use of the engineering, modeling, conceptual, and formal theoretical and behavioral approaches under the holistic paradigm of the systems approach is encouraged.

DISCUSSION AND IMPLICATIONS FOR AN INTERDISCIPLINARY BoK IN INFORMATION SYSTEMS

To complete this proposal, we identify the investment resources required, the potential benefits, and the effectiveness measures for developing the aforementioned interdisciplinary IS BoK to cope with the emergent CITOS. In the investment dimension, hard and soft issues can be considered. Hard issues are the financial resources required to redesign a graduate curriculum, prepare new human resources, and deploy integrated labs for students. Under the assumption of an already existent common core engineering curriculum for SE and SwE, the challenge is the incorporation or adaptation of it to the IS domain. It is typical for academic institutions to share labs and library resources, so the new investments in better equipped and integrative labs would be a worthy investment. The virtualization and distribution of ICT resources actually can allow a large campus to share valuable ICT resources with small academic units. For instance, a small business data center lab (not a computer network lab) could be developed for training SE, SwE, and IS graduate students in different problem and solution domains. For the SE and IS disciplines, the ICT architectural planning of the data center as well as the managerial and financial operations of the ERP installed in the data center lab are adequate issues for several courses in the curriculum suggested in Table 4. For SwE students, the same lab can be useful to deploy and test service-oriented application software and middleware. An implicit benefit for SE, SwE, and IS graduate students is the interdisciplinary team interaction for solving problems under a systems approach. The investment needed will be determined by supply and demand. Regarding soft issues, the existence of such an interdisciplinary IS BoK—that should support the current IS 2006 curriculum (Gorgone, Gray, Stohr, Valacich, & Wigand, 2006)—with the SE and SwE foundations, principles, and methods also demands: (1) adjustments in the faculty power relationships; (2) the management risk of identity loss in the discipline; and (3) the compliance with national accreditation boards procedures. Soft issues, then, become the main barriers for this proposal.

The main benefits estimated from this interdisciplinary IS BoK are (1) the revaluing of the IS discipline as a core element in modern society and business organizations; (2) the update of the body of knowledge required by IS practitioners and academics to cope with the emergent CITOS; (3) the joint development under a holistic view of the rich and complex phenomenon of CITOS with the two highly related disciplines of SE and SwE; (4) the development of a shared mindset of concepts and worldviews with SE and SwE practitioners and academics; and (5) the increased supply of a new generation of IS professionals and researchers to meet growing organizational demands.

Figures of merit to evaluate the effectiveness of this proposal are the following: (1) trends of the critical failures reported in CITOS (similar to the measures reported in Standish Group (2003); (2) trends of the financial losses derived by failures in CITOS; (3) trends of the simplification and standardization of principles, foundations, and methods shared for the three disciplines used in organizations; (4) trends of the high-quality and relevant research conducted and published under the paradigm proposed in this article; and (5) trends in the enrollment of IS graduate programs under this new interdisciplinary IS BoK. Hence, we understand that this proposal is a challenge that will generate positive as well as negative reactions. However, our academic responsibility and final purpose is to strengthen the IS discipline to face the challenges of business organiztions and society. The IT artifact as an artificial symbolic processor for processing, storage, and transport data, information, and knowledge (Simon, 1999) has transformed the world. Now, the challenge for the IS discipline (Ackoff, 1967) will be to transform such IT artifacts and align them with the emergent CITOS concept.

Proposition P2 (**the systems approach foundation proposition**), that poses that **P1** is plausible through incorporating foundations, principles, methods, tools, and best practices from the systems approach by way of systems engineering and software engineering disciplines, can also be supported.

CONCLUSION

We have developed this article with the aim to improve and reposition the IS discipline to accommodate the emergence of CITOS. In this proposal, we articulate the rationale for two propositions. **P1** argues that a plausible response to cope with CITOS is an interdisciplinary IS, SE, and SwE engineering and management body of knowledge, and **P2** argues that such realization is plausible through incorporating foundations, principles, methods, tools, and best practices from the systems approach by way of the systems engineering and software engineering disciplines. We believe the evidence articulated from the comparison of the IS discipline with SE and SwE (through the structured systemic definitions, the disciplines of reference, the knowledge for research and teaching, and the main research paradigms used) supports our claim. It has also been argued that:

> *The ability of science and technology to augment human performance depends on an understanding of systems, not just components. The convergence of technologies is an essential aspect of the effort to enable functioning systems that include human beings and technology; and serve the human beings to enhance their well-being directly and indirectly through what they do, and what they do for other human beings. The recognition today that human beings function in teams, rather than as individuals, implies that technological efforts that integrate human beings across scales of tools, communication, biological and cognitive function are essential.* (Bar-Yam, 2003b, p. 1)

Thus, we believe that this position paper and the new *International Journal in Information Technology and the Systems Approach* are robust academic efforts toward this essential purpose.

The road, however, will not be an easy academic endeavor.

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ENDNOTE

[1] The title and aim of this article was inspired in Feigembaum's (1968) paper.

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Chapter 8.6

Strategic Technology Planning for the Techno-Global Economy:

Cities in the Market

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ABSTRACT

Indications are strong that globalization is an irresistible force, fomented by, or at the very least, enabled by technology. This chapter refers to the technology driven aspects of globalization as “techno-globalization” and describes the role of strategic technology planning in the marketing of cities in this global economy. It describes strategic technology planning for information and communication technologies and its intersection with marketing planning. It is intended to guide managers through the technology planning aspects of ICTs and city marketing. In addition to providing practical guidelines for preparing a technology plan that supports the organization’s strategic and marketing objectives, the chapter explains many of the nuances of the preparation and alignment of organizational strategic plans using current information systems and organizational theory concepts.

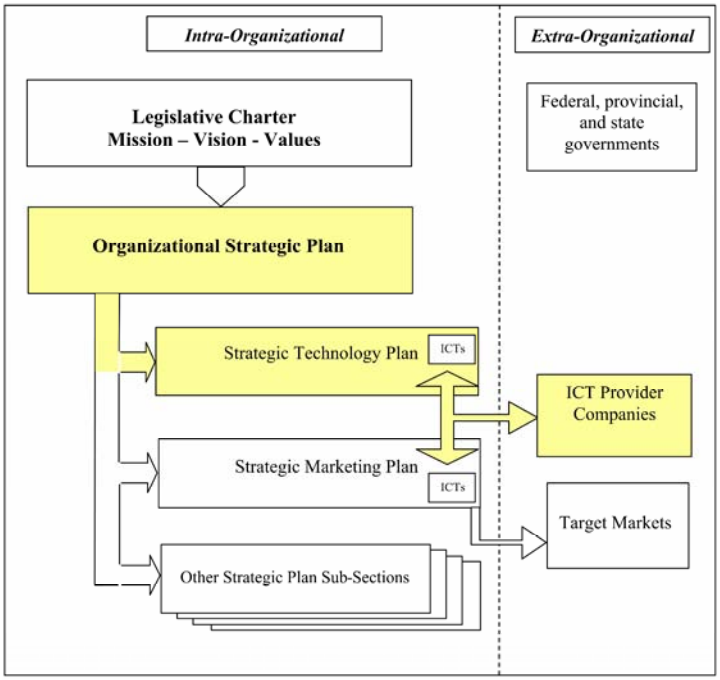
INTRODUCTION

Strategic technology planning is a specialized instance of strategic planning. Because of the particular nature of technology strategy, it embraces many elements of strategic planning, but necessarily includes technology planning considerations and technology evolution forecasting that are not normally part of standard strategic planning. Strategic technology planning can be thought of as a strategic view of the entity’s technology infrastructure and requirements that results in the identification of “best fit” technology initiatives in support of the entity’s overall strategic direction. In parallel, marketing planning takes the marketing perspective at both a strategic and tactical level. When viewed in relation to the marketing plan, the strategic technology plan moderates and supports the marketing plan at the tactical level and in its transition from a strategic perspective to a tactical focus. The chapter provides specific guidelines regarding the development and content of the strategic technology plan, but leaves the details of the actual plan preparation to each municipality's information technology governance and planning process. The chapter describes strategic technology planning, what it is, and how it properly integrates with the organizational strategic plan and peer strategic planning components.

Naturally, municipal organizations have many active plans in a multitude of areas. Some of these plans are strategic, some are financial and some are operational. The following chart, Figure 1, depicts some of the elements of the overall strategic planning process. This diagram shows the segments of the overall system of planning that are addressed by this chapter. The shaded areas are directly addressed and the areas without shading are not addressed or are mentioned only tangentially. The organizational strategic plan and the strategic technology plan are discussed. The role of strategic planning in marketing, the role of information and communication technologies (ICTs) in marketing, and the potential interactions with ICT providers are addressed.

This chapter is intended to provide useful information to people who have oversight or direct responsibility for a municipality's marketing planning and/or technology planning activities. The purpose of this chapter is to describe strategic technology planning and its intersection with ICTs, and their joint intersection with marketing planning as it relates to municipal marketing. Strategic technology planning is oriented to the specific requirements of planning technology to support the planning entity's overall strategic and tactical plans. Therefore, this chapter is a little less of a "what is" description and more of a "how to" explanation. The next sections will discuss strategic technology planning, the role of strategic technology planning in marketing planning, and, in parallel, the role of ICTs in marketing. This chapter also discusses the process of constructing the technology segment of your overall city marketing plan, and reviews certain tactical considerations related to successful implementa-

Figure 1. The overall system of planning



tion. It should be noted that, by their very nature, governmental entities are monopolies. However, when their considerations move beyond their geographic boundaries, they move from being the only one to being one of many. Planning, and specifically various types of strategic planning, is often couched in a "competitive" context. Within the monopoly, the competitive frame of reference has limited application. But outside the monopoly, in the "marketing as one of many" framework, the competitive frame of reference applies. It is from this perspective that commercial and quasi-governmental planning references are used in the following discussion.

STRATEGIC TECHNOLOGY PLANNING

The Techno-Globalization Planning Context

In many nations of the world, people are increasingly migrating into a technology laced way of being. The proliferation of Information and Communication Technology (ICT) is having an impact around the world, and the impact is not limited to the "industrialized nations" that are the usual suspects. Recent scholarly literature provides examples of the role of ICTs in many a far-flung place. Trinidad and Tobago have a national ICT plan (Warnaby & Bennison, 2006). There are examples in Mongolia (Amarsaikhan, Lkhagvasuren, Oyun, & Batchuluun, 2007; Uyanga, 2005), in Tunisia (Hulm, 2007), and the Philippines (Ramos, Nangit, Ranga, & Triñona, 2007). In his 2006 Nobel Prize acceptance speech, Muhammad Yunis (2007) describes how the success of his Grameen Bank in providing micro-credit to poor women in Bangladesh morphed into Grameen Phone. Grameen Phone, in what Yunis describes as the synergistic confluence of micro-credit and ICT, provides 300,000 women with mobile phones which they use to sell telephone services to villagers around Bangladesh.

Certainly many people in the world do not currently have access to technology. However, in many of the more industrialized nations of the world it appears to be mostly those who actively choose to avoid email and cellular phones that do not have them in their lives. For many people, the ubiquitous nature of ICTs makes them so much a part of daily life they are essentially invisible.

These contextual changes manifest themselves in international communications. The proliferation of ICTs worldwide now makes it possible to have a substantive virtually instantaneous document or data exchange with a person on the other side of the globe. This sort of instantaneous global communication is now many people's expectation. It is now of note when someone separates themselves from ICT connectedness by temporarily abandoning their technology devices or traveling to locations without connectivity. Techno-globalization is the proliferation of ICTs and the resulting information and communication exchange that has become institutionalized in much of the global society.

This institutionalization is the new personal existence paradigm for an increasing number of people. These are the digital aboriginals. There is a book (Tarlow & Tarlow, 2002) with these words in the title, but here we will use our own definition. Digital aboriginals are here defined as people who have grown up in a quasi-digital environment, and who consider solid state portable music/video players, computerized games, and handheld computing/telephone devices part of the wallpaper of their lives. These digital natives have ICT expectations that appear to exceed the capabilities of the extant ICT infrastructure and their numbers are growing throughout the world. Naturally, there really is no definitive line between digital aboriginals and those who are not. This is more of a continuum and we all exist somewhere along that scale. Furthermore, this is a multi-dimensional issue and we may be at different points on the continuum in our personal lives than in our professional lives. However, it is fair to extrapolate this line of thinking to the conclusion that increasingly, people move through their lives in a personal technological environment that might be referred to as a "techno-bubble," which is, of course, highly dependent on ICTs. A person's "techno-bubble" can be defined as that assemblage of technology that ranges from our mobile phones and mobile computing devices to automobiles with "brains" and their own mobile data connections. For many people this is the technological environment or even the techno-ecosystem in which they live, and, in many cases, move about. A question to consider is how this evolution and migration of peoples' expectations will impact geographically oriented marketing efforts.

The Planning Paradigm

Plans ranges from the very broad and high level mission statements that may be applicable over decades, down to very tactical task lists related to that day's events. There are an enormous number of documented approaches to sub-dividing and structuring every step along this planning continuum. In general, any planning that is prefaced with the word "strategic" differentiates itself by virtue of the fact that it relates more to strategy than it does to tactical or financial considerations. In different words, it relates to what are we intend to do and why are we doing it, more than it relates to exactly how we will do it or how much will it cost or how we will pay for it. The strategic planning process was explained well by Porter (1980; 1985) and has since been suitably elaborated by many other authors. When strategic planning is done in a governmental organization, public policy considerations often supplant, or at least supplement, the typical mission and purpose guidelines used in commercial strategic planning work. Naturally, this moderates the applicability of commercial sector planning approaches in governmental planning.

An interesting example of this difference is described by Davison, Wagner and Ma (2005) in their analysis of various paths that governments can take in the transition to e-government. They specifically address the somewhat pregnant pause between the adoption of web-based technologies for commercial B2B (business to business) and B2C (business to consumer) interactions and governmental adoption of the same for G2B (government to business) and G2C (government to citizen) interactions. These authors note that there usually is a significant difference between a commercial B2C website's interest in keeping the consumer on the site as long as possible and the governmental G2B or G2C website's interest in providing information or service quickly and allowing the citizen to go on their way as quickly as possible. It is a difference that is typical of the difference between commercial and governmental planning requirements. Beyond their useful explication of this differentiation, Davison, Wagner and Ma (2005) do a good job of describing the most successful paths to be taken in planning the transition from government to e-government. In a similarly insightful way Mason (2007) does a good job of using complexity theory to describe the external environment's effect on the development of strategic plans. Overall, the planning process often has multiple mediating, moderating and sometimes intervening factors that will influence the direction established by the plan. These influencing factors, in turn, are appropriately expressed in the follow-on tactical and operational plans.

Tactical plans address the implementation and operational issues, and financial plans address costs and funding issues. In order to avoid deadlocks or an excessive number of feedback cycles and iterations, many strategic plans include some high level revenue and expense projections thereby setting the direction and magnitude expected. Of course, one of the traps here is that operations oriented managers who have trouble dealing at the true strategic level will often turn a strategic planning process into a tactical or financial planning process. The balancing act of keeping the strategic planning strategic while also keeping it feasible and affordable benefits from the involvement of experienced executives whose accumulated experience helps guide the strategic with a practical and tactical perspective.

Guideline 1: *Keep the plan strategic, but include high level revenue and expense projections.*

The organization's strategic plan addresses the entire organization and properly sets the direction and overall bounds for all other organizational planning. Each significant organizational function or department could reasonably develop their own sub-strategy and prepare their own strategic plan. If a city is interested in marketing itself, for example, then a strategic marketing plan that is supportive of the direction established in the super-ordinate strategic plan is appropriate. Another area that very often warrants the development of a supporting strategic plan is information technology or information systems.

The Intersection of Strategic Planning and Strategic Technology Planning

A great deal has been written about strategic technology planning. Commercial organizations regularly prepare strategic information systems plans (SISPs) or strategic information technology plans (SITPs) as part of their strategic planning process. Information technology researchers, theoreticians and practitioners regularly write about the SISP/SITP process. From a taxonomical perspective, the scope of information systems (IS), information technology (IT), and information and communication technology (ICT) are, technically, all different, though they describe substantially overlapping domains. When these overlapping domains are raised to a strategic planning level, the differences begin to diminish. The choice between them is often driven by organizational history and the orientation of those managing the planning effort. The IS domain often includes data and processes not entirely computer systems based, where IT is usually essentially a technology oriented domain. The ICT domain is very closely aligned with the IT domain, but the term is more popular in countries other than the U.S.A. Since, at the organizational planning level, information systems, information technology, and communication technology all need to be addressed, this chapter will use the terms interchangeably in their more generic sense and abbreviate to SISP/SITP to refer to that strategic plan. The following paragraphs summarize some noteworthy thinking on these topics that is relevant to the planning process discussed in this chapter.

Malnight and Keys (2007) provide useful perspective on tuning the planning process to global change in their article entitled *Surfing the storm: Translating long-term global trends into today's decisions.* They discuss the advantages of taking a continuous and systematic approach to scanning the environment and collecting information about what it means to the organization. Applied here, their ideas indicate that there needs to be a continuous effort at gathering the relevant data, constructing shared insights, understanding the implications for the city and making appropriate decisions. This advice is particularly salient to the topic at hand given the fast paced changes in ICTs and the challenges of incorporating technology planning into the marketing planning and implementation process. It can be done. Wonglimpiyarat (2007) provides an example of how a similar process was successfully used by the country of Thailand. Wen and Shih (2006) describe how another large Asian country proactively managed strategic IT prioritization.

Guideline 2: *Make a practice of systematically and continuously scanning the environment.*

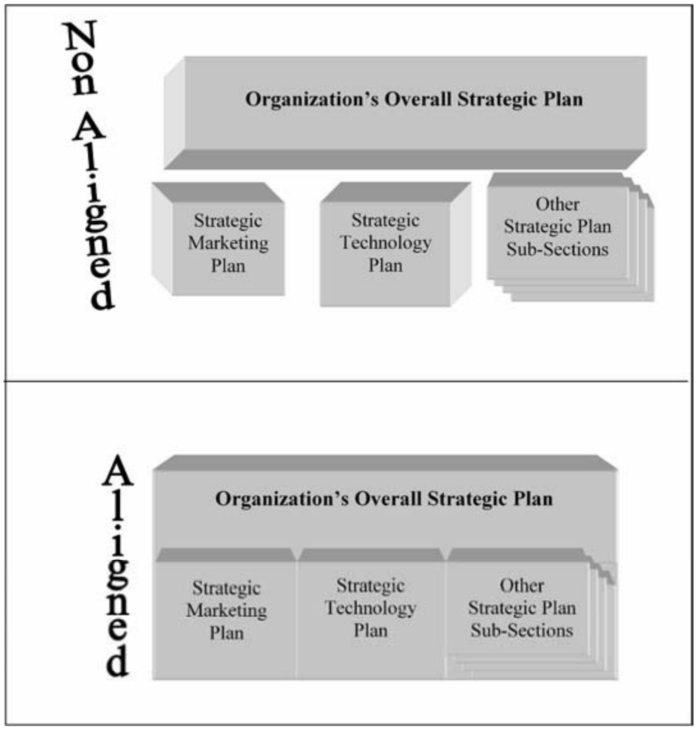
One aspect of the intersection of strategic planning and strategic systems planning is the need for alignment of technology planning with the organizational strategy. A great deal has been written about the need, and how it can be effectively accomplished. For example, in 1999 Henderson and Venkatraman wrote an excellent monograph presenting their "Strategic Alignment Model" (1999, p. 472). They parse the process into four domains, business (organizational) strategy, IT strategy, organizational infrastructure and processes, and IT infrastructure and processes. As you can see in their breakdown, organizational strategy and IT strategy are the first two essential components. They also take their alignment model to the next step and insightfully incorporate the organizational dynamics and the technology infrastructure. These second two are an important insight and are highly recommended for inclusion in the city marketing planning process.

Guideline 3: *Beyond alignment, also incorporate organizational and infrastructure considerations.*

The question of alignment is not always intuitively obvious. Even when the overall plan and various sub-parts are in place, they can have substantially different orientations. This can occur in various degrees and in some, or all, components. Figure 2 represents this concept diagrammatically. The plans need to be aligned under a single overall strategy. They need to be directionally aligned meaning that the route to achieve the organizational goals is coordinate. They need to be aligned in terms of scope; a narrow scope sub-section plan may not be out of alignment in any way other than the fact that it simply doesn't cover enough ground, or perhaps is overly ambitious. They also need to be aligned horizontally, meaning the peer-to-peer sub-sections are aligned.

Many other authors, researchers, and theoreticians have written about IT alignment. Peak and Guynes (2003) describe a successful IT alignment implementation at the Omaha Public Power District. Chan, Sabherwal and Thatcher (2006)

Figure 2. Alignment of plans



report on their research into factors affecting the IT alignment process at both business and non-profit organizations. Huang and Hu (2007) describe how to use the balanced scorecard system to achieve IT alignment. Kearns and Sabherwal (2007) present a knowledge based view of achieving IT alignment. These research articles and reports are a sampling of the broad range of available literature on IT alignment. Two observations are immediately evident. First, the need for, and benefits of, strategic technology planning alignment with the organizational plans are widely discussed and accepted as a necessary part of successful planning. Second, if your own organization has a unique need or a preferred approach, it is very likely you will be able to find specifically applicable literature to study.

It may also be helpful to note how other governmental organizations view the SISP/SITP question, and here are some examples. Thorogood, Yetton, Vlasic and Spiller (2004) describe an instance at a Southern Australian governmental organization where a public policy decision was successfully implemented through an SITP incorporating IT alignment. Another interesting example is the work by Holley, Dufner and Reed (2002; 2004) who have written two research articles. One addresses SISPs in U.S. state governments and the other addresses SISPs in county governments. Morton (2006) takes a social sciences perspective and uses critical realism to analyze IT alignment in a multi-department governmental organization.

And finally, Roge and Chakrabarty (2003) have written about their research into IT's integration with marketing strategy and operations. These authors indicate that their research shows the evolution and development of the integration or alignment of IT with marketing operations has progressed to the point that IT is now regularly integrated with marketing strategy. Taking the concept of alignment to the next logical step, we can now look at not only the vertical alignment of IT strategy with organizational strategy, but also the horizontal or peer-to-peer alignment of IT strategy with marketing strategy.

Guideline 4: *Be sure the SISP/SITP is fully aligned with the organization's strategy and the marketing strategy.*

How Strategic Technology Planning Integrates with Other Types of Planning

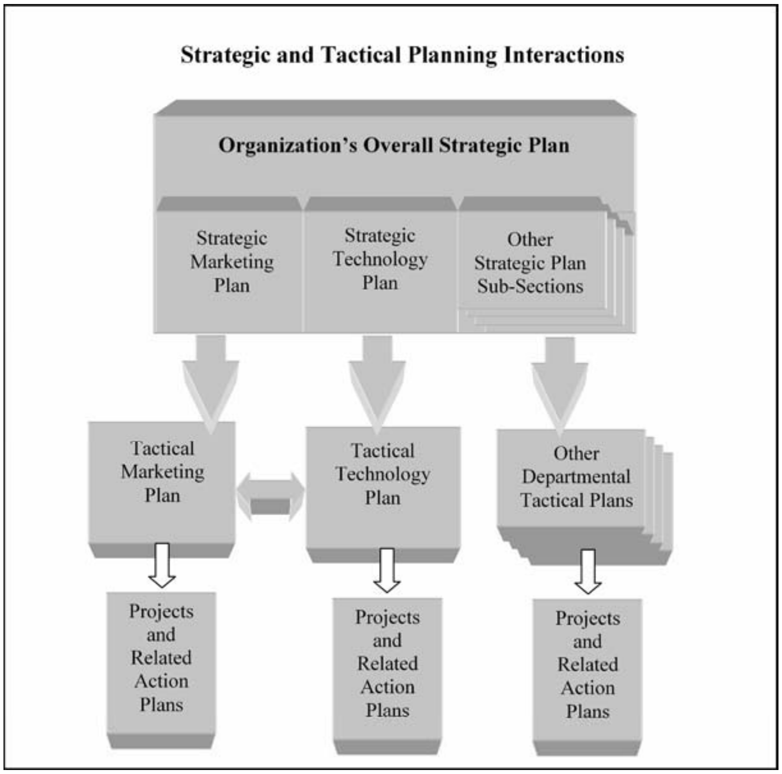
As was mentioned above, strategic technology planning is oriented to the specific requirements of planning technology in support of the overall strategic plan. One of the more challenging aspects of this process is lack of clarity, and sometimes the out-right absence (non-existence), of the overall strategic plan. The organizational strategic plan is often an emergent design, and even when brought to a firm conclusion, the best of them are immediately open to revision and improvement.

Consequently, a successful approach to strategic technology planning requires an element of simultaneous development with the overall plan and any concurrent peer-to-peer sub-section development. This process requires the technology planners to be ready to facilitate and enable the development of the grand plan. The questions asked, the ideas developed, and the documented progress can all help move forward a deficient or incomplete overall plan.

Guideline 5: *These plans are best done in a cooperative, simultaneous co-development mode.*

In addition, the technology planners must actively interact with any concurrent planning efforts, including the marketing plan development. As is depicted in Figure 3, below, there is a top level strategic planning component that defines organizational mission, purpose and overall direction. The supporting strategic plan sub-sections address strategic planning for the various major sub-sections or departments, such as the strategic marketing plan and the strategic technology plan.

Figure 3. Planning components and relationships



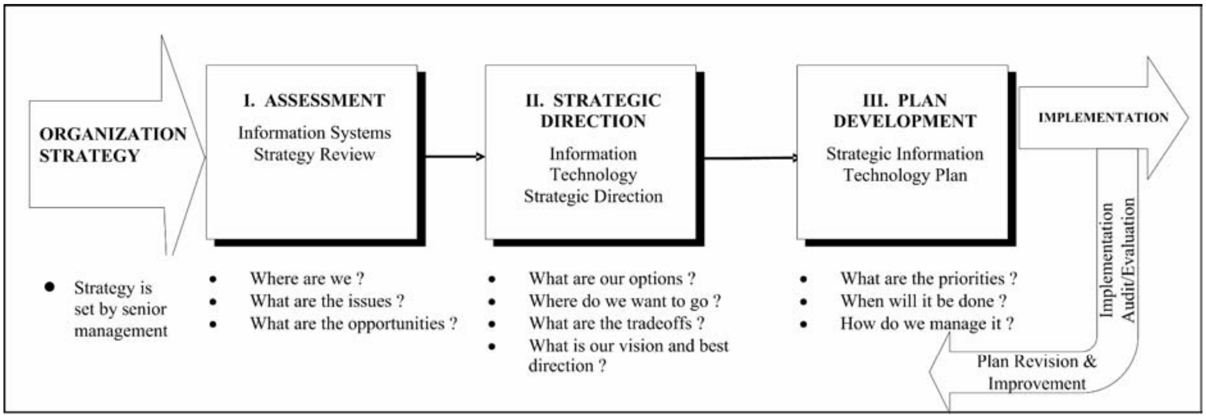
Key Elements of Strategic Technology Planning

Strategic technology plans usually incorporate the conceptual development of enterprise software, hardware, networking, and personnel plans. The plan typically includes identification of the preferred technologies, and a staged program for the acquisition, implementation, and support of various technological solutions. Technology planning also frequently incorporates consideration of external entities and their technological direction and potential for success. The reasons for this can range from a simple reliance on an external provider up to a tight lockup with a true technology partner. Unlike strategic technology planning for an enterprise with a more limited scope of activities, the strategic technology planning in support of a city, including its marketing planning can have a rather broad perspective and naturally it should address internal and external considerations of all major ICTs.

Guideline 6: *Setting the scope of the plan is very important and should receive careful consideration.*

The strategic information technology/systems planning process. Although there are many acceptable variations, the SISP/SITP processes generally have broad elements of similarity. It usually starts with an assessment that answers the question "where are we right now?" One aspect of this current assessment is the evaluation of both the state of the implemented technology and the organizational environment, including the status of the organization's strategic plan. The next phase of the planning process answers the question "where do we want to go?" This phase is typically the development of one or several systems and technology strategic initiatives that

Figure 4. The SISP/SITP planning process (© 2007 McCready Manigold Ray & Co., Inc.)



maintain alignment with the organizational strategy. The third phase, the "how will we get there?" phase is the plan development that structures the specifics and establishes priorities within the strategic direction and approach established in the second phase. The Figure 5 depicts the flow of the process.

The written plan combines the products of all three phases of the planning process. Naturally there are many variations on this planning process, but processes that do not incorporate all of these elements should be used with caution. Once the implementation process has been initiated, the quality of future planning efforts can be improved by a plan evaluation process. This process is based on the plan evaluation criteria established at the outset plus a practical ex post facto perspective. Following the principle of commensurate complexity (Thorngate, 1976; Weick, 1979), larger organizations require more detailed and complex plans, and typically will have multiple large subsections in each phase that deal with individual organizational subdivisions and major initiatives.

Guideline 7: *Establish the audit and evaluation criteria for the plan during Phase One and Two.*

The components of the plan document. Typically most SITPs or SISPs will have an outline that is reasonably similar. Once again, the size, complexity, and level of technology dependence of the organization will influence the number of sections and the complexity of the plan. An internet search for "SITP" or "SISP" or "ICT plan" will usually generate links to a few copies of governmental or quasi-governmental organizations' strategic plans. Acquiring some of these plans will provide some live examples to review and compare. Because many users of the SISP/SITP are not interested in reading all of the detail, the documents usually contain a fairly comprehensive executive or management summary.

Other key planning elements. A strategic technology plan in support of city marketing includes elements such as the technology infrastructure and governmental facilitations such as tax incentives and regulatory concessions. More specifically, a complete strategic technology planning process will address the target technological environment, the specific ICTs incorporated, the facilitating regulatory and taxation environment, the budgetary/funding strategy—including the revenue strategy, if any.

One significant point that should be brought up early in this discussion is a very real risk raised by Grenny, Maxfield and Shimberg (2007). Their research reports a problem noted by 85% of their participants in technology planning projects. It is referred to as "fact-free planning" by these researchers. In summary, it is the phenomenon of the people responsible for developing the plan acceding to the pressures and expectations of various managers and organizational stakeholders and thereby ignoring contravening facts. Based on the authors' explanations, the key to managing this risk is the ability of those conducting the planning functions to "confront, discuss and manage the phenomenon effectively" (p. 47). This point is further supported by Holley, Dufner and Reed. They make the following point: "When elected officials negotiate to set objectives, feasibility issues may not be considered fully. Setting an organizational objective without consideration of its information systems (IS) feasibility precludes SISP" (2002, p. 399).

Guideline 8: *Be alert to and attentively manage the "fact-free" planning phenomenon.*

The Connection Between Technology Planning and Marketing

The strategic technology plan and the strategic marketing plan can intersect in several ways. The marketing plan may anticipate the organization having a particular technological capability, like an internet website or an on-line system for employees to use in servicing customer/citizen requirements. If the marketing plan calls for advertising or marketing a particular technological capability to potential short term or permanent arrivals, the technology plan will need to assess the capacity and readiness of that capability if it exists, or how to put it in place if it does not.

For city marketing, where the marketing plan addresses a target market segment that is known to, or is likely to, desire or require a specific technological environment or capacity, inevitably that should become part of the technology plan. If the marketing plans target teenagers with iPod devices that play videos, then planning the capability to deliver iPod video broadcasts is important. Similarly, if the marketing plan calls for attracting a certain size or type of business that requires ICTs, planning the appropriate type and level of ICT infrastructure support is required. In a municipality, IT is a service provided to the organization. The SITP will need to be aligned with the organizational strategy in a vertical sense, and will also need to be aligned with the marketing plan from a horizontal or peer-to-peer perspective. The following section addresses that concept.

THE ROLE OF STRATEGIC TECHNOLOGY PLANNING IN MARKETING

Although Kavaratzis and Ashworth suggest that it is time to "transition from city marketing to city branding" (2006, p. 184), others appear to be looking even farther ahead. In an interesting article about technology marketing in this new era, Singer (2006) notes that "the paradigm of brand is worn out. Marketing and strategy must now be about shaping the competitive ecosystem" (p. 96). This raises a new standard that applies to the issue at hand. Through skilful representations of a city's advantages, interests, and facilities that substantially exceeds that of "competing" cities, the city marketing competitive ecosystem can evolve and be shaped to the advantage of the market leaders. The question to be addressed is that of an appropriate method to shape this particular competitive ecosystem.

Defining the Marketing Objective

The marketing objective explains the target and intentions of the marketing plan. It is a risky venture to undertake the development of a technology strategy to support an unknown or poorly defined objective. That applies to the objective and strategic direction provided by the superordinate organizational plan and the objective and strategic direction provided by peer plans like the marketing plan. This risk assessment is based on the obvious logic, recognized strategic planning theory, and the practical experience of having seen unsuccessful attempts to circumvent the inevitability of this requirement.

Guideline 9: *Be sure that the objectives of related plans have been developed and clearly set forward.*

In parallel with the strategic planning misfires mentioned above, there are times when those whose role properly includes the responsibility for planning the marketing objective don't fully understand or know what is required. When the strategic technology planner runs into that circumstance and it is exhibited as a lack of the recognition of the need for a clear marketing objective, the strategic technology planner can work to facilitate the development of enough of a marketing objective to support the strategic technology planning process. This can be done in several ways, and one successful approach is to lead others to the objective through a process of asking questions as Marquardt (2005) so effectively explains in his book *Leading with Questions*. Without a clearly defined marketing objective that has been properly vetted within the organization, the strategic technology planner is substantially constrained in producing a successful technology plan to support the marketing effort. In short, the marketing objective is a necessary, but not sufficient, condition for a successful technology plan.

Guideline 10: *The technology planners should support other organizational strategic planning teams in developing actionable objective statements.*

Assessing Strengths and Weaknesses

With an understanding of the marketing objective in hand, the strategic technology planner can move through a traditional strategic planning strengths and weaknesses analysis of the organization and the region's technological position relative to the marketing objective. If these concepts are a little rusty or perhaps somewhat new to the reader, a good place to start are the well-known books on the topic written by Porter (1980; 1985). In a subsequent section we'll describe the more tactical process of creating the ICT inventory and the related evaluation and planning. This assessment process is a review of the entity's general ICT strengths and weaknesses. Naturally it is important that this strength and weakness assessment be honest, without any boosterism. The extant weaknesses are not necessarily a liability, simply a fact that should be acknowledged and dealt with in the strategic technology planning process. As is often the case, properly identifying a problem here is some substantial part of the solution.

Technological Market Positioning

An important issue is how to position your organization from a technological perspective. For example, a city trying to attract technology businesses could promote both the availability of ICT infrastructure and the potential employees being trained by the city's educational system. If a marketing objective is to attract conventions and trade shows, having a convention center with a high capacity wireless network installed and ready for use can be a significant support. In instances like these the role of strategic technology planning is, obviously, to map out the ICT strategy to support the strategic marketing objective.

Another part of the marketing research the technology strategist will need to undertake is to develop an understanding of the technologies being offered or marketed by the likely municipal competitors. It is rare for a city to have such a unique offering to market that no competition exists. In this era of techno-globalization, the competition may be much more geographically distant than was historically the case. Outsourcing has crystallized many people's understanding of how a city a great distance away can be a viable competitor.

The strategic technologist's contribution to the development of the city marketing plan can be substantial. In the ideal situation, the overall strategic plan is completed first and then the marketing plan and the strategic technology plan are completed concomitantly and in concert. Most likely this will be done in an iterative fashion, as the two plans are taken to increasing levels of detail. In the implementation of this cooperative, iterative approach, the relevant sections of the draft marketing plan are provided to the IT planners who do the necessary data collection and evaluation. The IT planners, in turn, provide the marketing planners with their assessments that provide an initial reading on technical feasibility and perhaps order-of-magnitude costs. It certainly is possible to have a completed marketing plan, and then to undertake the supporting strategic technology planning process. However, experience indicates that the marketing plan will be richer as a result of an interactive process, and it is more likely to avoid revision detours generated by technology roadblocks. These occur when the technology required to support a marketing concept turns out to be unavailable, impossibly expensive, or otherwise untenable.

Guideline 11: *Ideally, the SISP/SITP and the marketing plan are developed cooperatively and iteratively.*

In this collaborative, iterative process, the technology planner will benefit from the creative and expansive thinking of a good marketing planning person or group. The inspiration generated can lead the technology planner to new insights into the marketing/branding process and perhaps contribute to "shaping the competitive ecosystem" as Singer suggests (2006, p. 96). Of course the same benefits can apply in the reverse direction when the channels of dialog are open and flowing. An exceptional job of market positioning can create new competitive dynamics in a world where strong and early market position can translate into competitive advantage. As was noted earlier, this is not necessarily based on unique capabilities, simply on unique marketing. However, when the marketing program lays claim to a capability, the capacity to deliver on that promise is essential in order to maintain both organizational credibility and any advantage gained. This next section discusses the role of strategic technology planning in setting forward the implementation framework.

Framing the Structure for Implementation

There is a reasonable possibility that the marketing objective and/or marketing plan will not explicitly call out specific technologies. It is entirely possible it will be a generic requirement. The strategic technology planners serve best when they apply their knowledge of the technological environment and offer up the leading alternatives with their advantages and disadvantages.

For example, if, as in our earlier hypothetical, the concept of a wireless network in a convention center is in play for attracting convention business, it would be the technology planner's role to provide the advantages and disadvantages of an quasi-open network with limits on internet browsing and email attachments, versus a fully open network free to everyone within range of its signal. The technology planner might contrast these to other options such as an array of "hotspots" or even a "walled garden" solution. Hotspots are small area open networks of the type common in the technological market positioning of some coffee shops. Walled garden networks are those that apply strict limits to the websites and content permitted on the network. These are common at kiosks and at public terminals in some hotels and airports. The user may be accessing the sponsor's selected website(s) via the internet, but is not able to get over the wall to the rest of the internet world.

All of these are viable options for our hypothetical convention center wireless network market positioning example. All of these options can reasonably be implemented, and the decision most properly is not left to the technology planner. When the marketing function eschews this sort of evaluation and interaction as "too technical" or not essential, the organization misses an opportunity to obtain significant advantage. Without input, the technology planner makes the decisions based on technology factors and/or their intuition about what the marketing planning group intends or can use to the city's advantage. The interaction described is an example of an effective healthy organizational interaction. The strategic technology planner, the marketing planner, and the senior municipal executives who oversee them are jointly responsible for enabling and ensuring this process.

After the alternatives are presented and discussed, and the choices or preferential rankings are done, the implementation framework can be completed. Naturally, even though we only discussed one example, that of the convention center wireless network, there will very likely be three to five, or occasionally as many as seven, technology elements included. If there are more than seven, it is likely that this stage of the planning is being done at too low or detailed a level. Larger more complex organizations may have more total elements in their planning, but their *strategic* technology planning and marketing planning will initially be done at a more general level, and subsequent efforts will take the plans to a more detailed level. A smaller municipality may have a complete plan with only three technology elements.

The strategic technology framework should lay out the elements required to achieve the technological market positioning described in the previous section, the ways that these elements interact and support each other, and should clearly state how they will integrate (or not) with the enterprise technology architecture in the final implementation. In addition, if any acquisition, development, or construction (hard or software) is required, the timing, sequence, and responsible agency should be set forward as part of the strategy. At this level of planning, the timeframes are broad estimates that are often stated in calendar quarters, and occasionally in months for smaller, short term, efforts. The strategic technology plan is a high level direction-setting plan and the particular technology being planned is one of its most tactical elements. In this current era, it is almost certain that every complete strategic technology plan will include consideration of communication and networking technologies. The next section reviews ICTs and their role in marketing and consequently strategic marketing plans.

THE ROLE OF INFORMATION AND COMMUNICATION TECHNOLOGIES IN MARKETING

As was mentioned in the previous section, writers and thought leaders in the field of "place marketing" or geography oriented marketing propose moving forward from marketing, to branding (Kavaratzis & Ashworth, 2006), to "shaping the competitive ecosystem" (Singer, 2006, p. 96). Many aspects of marketing and branding revolve around differentiation, and a city's ICT infrastructure certainly can be a differentiator. Furthermore, since perception is the most salient aspect of many of these efforts, promoting an ICT that competitors have, but do not present well, can result in a perceptual differentiation that provides a distinct advantage. This can be accomplished in part by removing an element of uncertainty in the marketing target's evaluation and assessment. If they have explicit assurance that a capability exists in one location, but no explicit assurance that it exists in another, the location that successfully marketed the capability will have the advantage. This can be as simple as making specific note of the geographic coverage of mobile telephone service, or as complex as promoting the existence of high capacity "backbone" data transmission capability.

When this concept is combined with the "techno-bubble" discussed earlier, the intersection is the opportunity to assure, or remove some uncertainty, regarding the ability to maintain connectivity when they come to the geographical area being marketed. So, one of the roles of ICTs in marketing is connectivity assurance for this increasingly technology dependent way of being.

Recognizing the Ubiquitous Nature of ICTs

Regarding the ubiquity of ICTs, think for a moment of a street corner in a moderately affluent larger city. Some percentage of the cars going by have a mobile phone based computer data connection. The people in the cars are likely to be carrying at least one mobile communication device on their person. A phone installed in the car may serve a dual purpose of allowing either the passenger or the vehicle to make a call. Some cars are programmed to automatically call for assistance when the crash-safety air-bags are triggered. The municipal bus passing by may have one or more communication devices installed, including a global positioning system and an emergency communication system. The police car passing by may have multiple instances of active ICT devices including a computer with an intranet and/or internet online research capability. The teenager passing on the sidewalk may be armed with multiple devices, but likely has a mobile phone at a minimum, and that phone provides voice, text messaging and probably internet access. In the apartment above, a grandmother may have her high-speed internet connection open on her computer while talking on her land-line telephone with her mobile phone in her purse. The utility meter at the rear may have a passive or active data connection. In the retail store across the street there may be corporate data connections via either satellite, fiber-optic cable, land lines (cable or telephone), and in a few cases, mobile phone technology.

This snapshot inventory of the pervasive presence of ICTs in many people's lives simply serves to remind that this connectivity is both fixed and mobile, transient and persistent, and personal and employment related. When a person or business is considering coming to your city, what role will the availability of these ICTs play in their decision-making process? Naturally that translates into the role of ICTs in city marketing. The following four sub-sections offer some practical suggestions for the next step is thinking through this aspect of information and communication technology planning.

A Framework for Analyzing the Role of ICTs in Marketing

When considering the role of ICTs in marketing planning and the related technology planning process, it may be helpful to parse the concepts to achieve greater specificity. Some ICT capabilities are simply basic infrastructure, like paved roads, traffic lights, water, and sewer. The data network at city hall is an example of basic ICT infrastructure. If it's not in place and functioning it gets attention, but otherwise is simply expected to be maintained in an adequate manner. On the other hand, a new initiative to put free public wireless internet service, like that in place in St. Cloud, Florida or downtown Hermosa Beach, California rises above the level of basic infrastructure. It is likely that residents of St. Cloud and Hermosa Beach will someday see the free wireless internet the same way the rest of us see our basic infrastructure, but until it is in place in a significant percentage of municipalities, it will be viewed as a special initiative. The continuum described here is one that ranges from very basic essential infrastructure to special technology initiatives that differentiate the municipality.

A second continuum to consider is the ownership and control of the infrastructure, in this case the ICTs. This range extends from municipally owned telephone equipment in city hall, through joint ventures with technology partners, to commercial ICT companies resident in or providing services to the community.

In the first continuum, concept of basic ICT infrastructure to special ICT initiative can be somewhat artificially divided into two halves, basic and special initiatives. In parallel, the second continuum can be divided into municipal ownership, partnership ownership, and commercial ownership. If these two continua are arrayed against each other in a matrix as in Figure 5, we get a view of some of the aspects of this topic that need to be assessed in planning the role of ICTs in city marketing. The St. Cloud, Florida and Hermosa Beach, California examples of free public internet access running on the municipal high speed internet access is a special initiative municipally owned ICT infrastructure from the top left box on the matrix. Commercial telephone company or cable fee-based internet access is basic commercially owned ICT infrastructure. This classification is very much context dependent. For example, the Grameen Phone project in Bangladesh that was described earlier is a special initiative in Bangladesh, but basic ICT infrastructure in other places. This extreme comparison is drawn to make the point that each city's environmental circumstances will be a little different and placement on this matrix is relative.

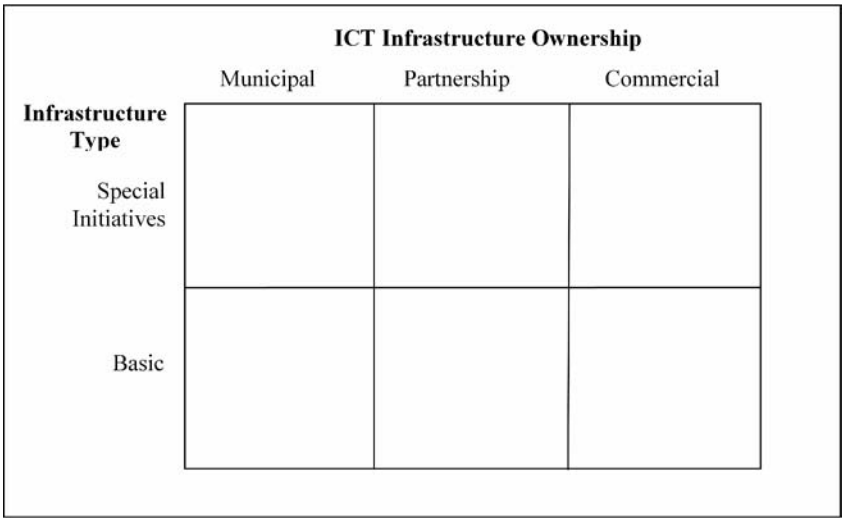
The value of the matrix is that it can be an aid to help parse your city's ICT infrastructure so you can assess, inventory, plan, and partner using an appropriate referential framework. Your city marketing plans may include elements from all six divisions in this framework. If your marketing plan includes partnership and commercially owned ICT infrastructure, you may find that you will need to move beyond the standard introspective model for municipal planning. This is not, in and of itself, problematic. It is simply a different requirement that enters into the equation as a result of the role of ICTs in city marketing.

Guideline 12: *An infrastructure ownership/type matrix helps analyze ICT's relationships to marketing.*

Assessing Your ICT Infrastructure

In an earlier section, we noted the importance of conducting an assessment of installed or current technological capabilities. The pace of change is too rapid to here provide an authoritative list of the ICT technologies to be included in your municipality's ICT infrastructure assessment

Figure 5. ICT infrastructure analysis matrix



	ICT Infrastructure Ownership		
Infrastructure Type	Municipal	Partnership	Commercial
Special Initiatives			
Basic			

and inventory. Therefore, the recommendations here regard the process more than they provide a sample inventory. As an example, the elements of the communications technology infrastructure assessment can be broken into three broad segments: high speed backbone, commercial grade, and consumer level.

High speed backbone capacity is the fiber optic, satellite, micro-wave, radio frequency, or other high-speed/high-capacity wholesale transmission capacity. Inevitably, this process requires some level of partnership information exchange with private enterprise organizations that own or manage this level of "backbone" transmission capacity. If marketing to businesses that have significant ICT demands is part of your marketing strategy, a thorough review of the availability of commercial grade service is essential. A marketing plan that can describe the area's overall high speed backbone capacity and also list multiple commercial grade service providers is a stronger presentation to today's technology savvy commercial decision-makers. The provision of consumer level service generally falls to private enterprise organizations, and thinking of the purpose here, city marketing at the consumer level might fall into three categories. Cities that are trying to attract new residents. Cities that trying to attract individual tourists. Cities that are trying to attract conference/convention/trade show business.

The assessment work product. Applying the results of the assessment of your ICT infrastructure in the framework suggested in Figure 5 should result in a reasonably complete inventory of the matrix of ICT capabilities and their capacity. As was described above, the first phase of the IT planning process is the assessment of the current environment. In order to develop the portion of that strategic plan which relates to ICTs and marketing, you will need to have an inventory the addresses both quality and quantity (or capacity) of your ICT infrastructure. This assessment should produce that inventory for both the governmental infrastructure and the relevant commercial capabilities.

Mapping Out Your Position

Once you have assessed the ICT infrastructure you will be able to engage in a strategic review of your city's ICT strengths and weaknesses. If the organization's strategic plan clearly sets an ICT direction or the marketing plan is sufficiently developed to indicate a planned marketing direction, you can use the inventory to analyze your strengths and weaknesses in light of those intended directions. This is often done using a "gap analysis." The gap analysis is exactly what the name implies. A list of requirements is compared to the existing capabilities and the magnitude of the "gap" between existing and required is documented. The obvious benefit of the gap analysis is that it results in the identification of the areas where current (and perhaps planned) capabilities don't meet expectations.

Guideline 13: *Conduct an assessment using gap analysis as a tool.*

When a municipality is planning to use ICTs as part of its marketing strategy, the ICTs fall into two categories. Those which the city owns or controls, and all others. Since the marketing plan may include the promotion of ICTs controlled by others, this process of assessment, inventory and analysis may require coordination or a partnership with private enterprise. The next section describes some elements of the tactical approach related to the role of ICTs in city marketing.

Planning Your Tactical Approach

When the cooperative or iterative process of reconciling and aligning the strategic technology plan and strategic marketing plan within the bounds and direction of the organizational strategic plan have been completed, the tactical action plan will be prepared. When you have completed the assessment, the inventory and the gap analysis described above, you may want to quickly assess whether there is any "low hanging fruit" in the results. These can be taken as an immediate tactical win.

CONSTRUCTING A TECHNOLOGY PLAN TO SUPPORT THE CITY MARKETING PLAN

This section addresses the amalgamation of these planning and strategy elements. The strategic technology plan and its coordination with the organizational strategic plan, support the city marketing plan. Knowing what the current and planned technology capabilities are, and the organization's strategic intentions as described in the city's overall strategic plan provides part of the framework for the city marketing plan. With these perspectives clearly in hand, the marketing plan can market to these strengths and intentions.

Multiple Audiences

As the reader can clearly see, the segmentation and construction of each city's plan will, of necessity, be different. In any event, there is a need to address multiple audiences. The choices made in this regard will depend on the city's planning orientation and the prioritization of the various audiences. To facilitate that process, some of the various audiences and typical reasons for interest are described here.

The first, and most obvious, audience is that of the elected officials. Generally the agenda here is fairly well known, and consequently a little easier to address and accommodate. It is an error to ignore this reality since many of these politicians are acutely conscious of the public positions they have taken during and after the election cycle and will apply that litmus test to their evaluation of the technology and marketing plans.

A second audience is that of the professional/career municipal managers. Support from the strongest and/or most influential members of this group is virtually a necessary condition for successful implementation of the plan, consequently the planning process and its interim results need to be fully vetted within this group.

Cities usually have business oriented groups, like a Chamber of Commerce or downtown business group that combines boosterism and perhaps some quasi-governmental role. Since some amount of boosterism is a natural part of their role, they have great potential to support the city marketing plan, but need to be included in the plan development.

Another audience that needs to be considered when ICTs are part of the city marketing plan is the ICT companies. Using a current example, if free internet service is to be provided through the city's broadband connection, the contractual provider may see this as an advantage in marketing to other municipalities, or may have concerns about the plan. This audience should be included in the plan development in an appropriate manner.

Of course a significant audience for the plan is the citizenry and their common proxy, the local mass media. It is unlikely that citizens will want to read the entire plan, and this leads to a specific requirement for dealing with this audience. The plan will need a clear, complete and succinct summary that both sells and informs. Individual communities will have different numbers and types of media that can be offered access to the plan summary (and the detailed plan). Local television stations may be receptive to a well prepared position piece. This quickly becomes an opportunity to demonstrate your city has examined the "competition" and is ready to move forward.

Guideline 14: *Be sure that your plan successfully addresses the many important audiences.*

Formulating Multiple Orientations of the Plan

In the discussion of the multiple audiences for the strategic technology plan, we reviewed various groups inside the municipal community who are mostly potential users of the plan, a somewhat introspective view. This section addresses a parallel, more outward looking perspective that may appropriately be implemented in summaries or abstracts of the plan for those who are more *readers* of the plan than they are *users* of the plan. In a sense, this is about marketing the strategic technology marketing plan.

Local stakeholders. The local stakeholders are primarily those addressed in the multiple audiences section above. However, local stakeholders also include the individual businesses in the hospitality or services businesses that may benefit from increased business driven by some aspect of the city marketing program. In some cases, these companies may have a marketing plan that could be adjusted to coincide with, or be supportive of the city's plan. Attention to these opportunities can strengthen both public support for the plan and a successful implementation. In addition, you should include in your considerations any local stakeholders that may see the plan as disadvantageous. As is usually the case, foresight and a specific plan of action is more likely to result in a better conclusion.

National targets. When a city's marketing plan includes an international orientation, there is a possibility that there will be an audience for the plan at the national level. When a municipal marketing plan is coordinate with national marketing plans, there is an opportunity for synergy and national level support. Whether the aim of the city marketing plan is tourist, conference/trade show, or commercial business, there may be potential support at the national level. This should be considered and where the opportunity exists, an appropriate nationally oriented summary of the plan should be prepared.

Consumer targets. At the consumer level, the city marketing plan can address tourists, transitory, or permanent visitors. Generally targets of this type will be offered some specific set of benefits in the marketing plan. As was discussed in the techno-globalization section at the beginning of this chapter, in this day and age, assurance of the opportunity to stay "connected" while visiting the city is an attractive feature and should be included in your ICT planning considerations. Overall, the consumer orientation of the plan, if any, may have the broadest range of potential messages. Once again, careful consideration of how and what message will be delivered is better than acceptance of a random or default choice in this matter.

Industry and commercial targets. This segment can be targeted with considerable precision. If the orientation of the city marketing plan includes commercial or industrial targets, writing an appropriate summary or applicable section of the plan can be a benefit. As was mentioned earlier, removing an element of uncertainty for a decision-maker can be advantageous. For example, if the plan is able to say that your city is interested in attracting businesses of a certain type and is willing to offer certain advantages or specific concessions, these give the corporate decision-maker both an assurance of a welcoming municipal climate and a referential authority to include in her/his explanation and justification of a decision to come to your city. This may be simply to hold a conference or trade show, or it may be to locate an office or other facility. If it is a trade association or travel/hospitality industry company, they may be interested in both the business climate and the tourist orientation and, as described above, the marketing plan should address both of these aspects.

Supporting Research

Because the field of technology is perennially fast moving and evolutionary, current research is inevitably required. As you might expect, the internet is an excellent place to get both current information and investigate what your city's "competitors" are doing and the state of the art. As an example, an internet search of the words "municipal wireless" will generate a significant list of results. It isn't possible to provide a comprehensive list of useful sites here, however, one example is a site named www.muniwireless.com founded by an attorney named Esme Vos. This is a commercial site with abundant advertising. However the advertising supports useful research. You can find lists of municipal wireless implementations, articles on current requests for proposals for municipal wireless networks, and articles on specific orientations like tourism and wireless municipal networks. In short, this website and other similar ones are a valuable source of information and research data. Naturally you will want to tailor your own searches to your specific needs, but your planning process will be richer and more complete with this important and useful internet based scan of the environment.

Once the strategic plan is complete, begin the tactical and operational planning process. One of the keys to the transition from a strategic plan to a tactical plan is having a skilled tactical planner working with the approved strategic plans and working in conjunction with the financial planners. The reality in governmental entities is often that the financial plan is produced through a combination of administrative recommendations/requests and a legislative/political process. The more closely the tactical, financial and implementation plans are aligned with a properly vetted organizational strategy, the more likely it is that they will be approved and successful.

CONCLUSION

The intersection of strategic technology planning and marketing is, inevitably, different for each municipality. This chapter surveyed the strategic planning paradigm, the role of strategic technology planning in marketing, and the role of ICTs in marketing. In addition, the chapter described the process of constructing and organizing both the strategic technology plan and the ICT marketing sub-plan.

What Can We Conclude?

A successful strategic plan depends on the existence of a clear organizational strategy, which is best captured in a written strategic plan document. If a written plan document doesn't exist, the strategic technology planner needs to invest the time and effort required to get a statement of strategic direction approved by top management. As we address the topic of the interaction of marketing and technology, the same thing applies to a strategic marketing plan. If one doesn't exist, then the technology planner needs to help guide those responsible for marketing the city to the development of a definitive statement of the marketing strategy. The strategic technology plan needs to be aligned with both the organizational strategic plan and the strategic marketing plan (and any other appropriate peer plans). Successful strategic technology planning generally involves a process of simultaneous development with peer strategic plans like the strategic marketing plan. The iterative co-development method is usually the shortest path to successful completion of both planning processes.

Lee and Bai (2003) captured these concepts well in their article discussing organizational mechanisms necessary for successful SISP/SITP plan preparation in the digital era. They trace the evolution of the SISP/SITP planning process over several decades. They explain the progression from "technology mode" to the "align mode" to the "impact mode" to the most developed, the current "fit mode" (p. 33). These four phases were driven by technology, business issues, competition, and organizational issues respectively. The approach described in this chapter intends to reflect the full range described by Lee and Bai (2003). Successful participation in the techno-global economy virtually requires this level of sophistication.

Organizational strategic technology plans incorporate conceptual development of enterprise wide software, hardware, networking, and personnel plans. They often incorporate consideration of external entities and their technology direction. This is especially true when marketing plans will include non-owned ICT capabilities. The objective of the intra-organizational aspect of the plan is to set the strategy and direction of the information and communications technology for the municipality and its delivery of service and support to its constituencies. The objective of the extra-organizational aspects of the plan will include identifying and assessing the technology and capabilities that are required to support the objectives of the strategic marketing plan.

The three phases of the strategic technology planning process are the assessment (Where are we right now?), setting the strategic direction (Where do we want to go?), and developing the plan (How will we get there?). In the discussion of this process, we noted the need to manage the fact-free planning phenomenon. In conclusion, with the organizational strategic direction clearly understood and the marketing objective documented and agreed upon, the scope and requirements for the intra-organizational and extra-organizational assessment should be very clear. The gap analysis technique is recommended as a useful tool to collect and present the differences between what is in place, and what will be needed. This level of sophistication is also essential to success.

What can we conclude the attributes of a successful final product are? The well-done strategic technology plan will address the multiple targets and audiences discussed in the previous sections. It will be aligned with both the organizational strategy and the marketing strategy. It will lay out the elements required to achieve the technological market positioning set forward in the marketing plan. It will clearly set forward the organization's technology strategy and plans for both internal and outward looking initiatives. It will exhibit a broad organizational perspective, result from good group interaction, capture the required organizational knowledge and incorporate organizational change management requirements.

Planning of this sort is almost always an iterative organizational learning process. The review, revision, and renewal of the plan in subsequent years is a natural part of the process and should, as was noted in Figure 4 and Guideline 7, be anticipated at the beginning of the effort. Wherever possible, the initial planning process should include measurement and evaluation metrics that can be used to assess how well your plan has succeeded in meeting your objectives.

With or without specific measurements, a frank assessment of the previous plan should be done before the next iteration of the planning process is undertaken. This can be done very successfully by convening a group of appropriately knowledgeable people. The charge given to this group should be to bring to the meeting their own list of the successes and failures of the prior plan. When these are discussed in the group setting, the individual perspectives get incorporated into the group understanding of the plan. When this group learning is recorded, it becomes a valuable organizational knowledge tool to guide those responsible for the development of the next planning iteration.

Guideline 15: *Consider using a peer-review group to help assess the success of the prior plan and recommend future improvements.*

FUTURE TRENDS

From 2000 through 2007 there was much discussion about municipalities providing free internet access to citizens. In spite of the existence of some free municipal networks, the current trend appears to be moving away from broad, free access networks. There are several factors which militate against free municipal networks. Free wireless service is not currently an essential municipal service, but more of a luxury. In the final analysis, it may be provided free to the users, but there are costs to building and maintaining the network. Some service providers who agreed to partner with cities and provide free access to citizens have found that advertising and other anticipated sources of revenue are really not sufficient to make it worthwhile at this current time. Some rather localized free municipal networks, like those at some airports seem more likely to survive and be replicated.

There is clear potential to capitalize on technology in addressing the city marketing challenge. The techno-global economy fosters an increasing reliance on and demand for technology infrastructure. In the future, technology infrastructure may come to hold the same position as an essential utility that water supply, sewer, land-line telephone, and electric utilities currently hold. As people come to see various aspects of technology infrastructure, especially communications capabilities, as increasingly essential and assumed, the future city marketing potential grows. Farsighted city marketing and technology plans can anticipate this future state and market toward it.

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Chapter 8.7

Mission-Critical Group Decision-Making:

Solving the Problem of Decision Preference Change in Group Decision-Making Using Markov Chain Model

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ABSTRACT

Review on group decision support systems (GDSS) indicates that traditional GDSS are not specifically designed to support mission-critical group decision-making tasks that require group decision-making to be made effectively within short time. In addition, prior studies in the research literature have not considered group decision preference adjustment as a continuous process and neglected its impact on group decision-making. In reality, group members may dynamically change their decision preferences during group decision-making process. This dynamic adjustment of decision preferences may continue until a group reaches consensus on final decision. This article intends to address this neglected group decision-making research issue in the literature by proposing a new approach based on the Markov chain model. Furthermore, a new group decision weight allocation approach is also suggested. A real case example of New Orleans Hurricane Katrina is used to illustrate the usefulness and effectiveness of the proposed approaches. Finally,

the article concludes with the discussion on the proposed approaches and presents directions for future research.

INTRODUCTION

Mission-critical events such as hurricanes, terrorist attacks, fires, and earthquakes require different governmental departments to work together to respond to those emerging crises and reach consensus quickly to make effective decisions within a short time period. Traditional group decision support systems (GDSS) have not specifically addressed this important issue in the research literature (Fjermestad & Hiltz 1999; Huang, 2003; Huang & Wei, 2000; Huang, Wei, & Lim, 2003; Tan, Wei, Huang, & Ng, 2000; Zigurs, DeSanctis, & Billingsley, 1991; Vogel, Martz, Nunamaker, Grohowski, & McGoff, 1990). A special type of GDSS, mission-critical GDSS (MC-GDSS), can be designed to support this group decision-making process.

Mission-critical group decision-making has some important characteristics that are different from conventional group decision-makings (Belardo & Wallace, 1989; Beroggi, Mendonça, & Wallace, 2003; Huang & Li, 2007; Limayem, Banerjee, & Ma, 2006; Mendonca, Beroggi, Gent, & Wallace, 2006; Wallace & DeBalogh, 1985): (1) decision-makers have to make nearly real-time decision. Decision-making on emergency response has to be made within a short time because of the nature of critical mission, (2) mission-critical decision-making problem is unstructured, fuzzy and unexpected in nature, and (3) information available to decision-makers is insufficient and not always accurate because complete information may not be collected in a short time, thus the decision makers can only rely on such incomplete information to making decisions. Therefore, conventional decision support approaches may not well solve decision problems of mission-critical events.

Prior research studies mission-critical decision-making from different perspectives. LaPorte and Consilini identify two emergency response patterns based on frequency and scene information respectively (LaPorte & Consilini, 1991). Ody thinks that crisis decision-making task, one type of mission-critical decision-making tasks, consists of three segments, pre-incident identification of hazards, the use of agreed communications, and the introduction of a third party to promote the coordination of decision makers (Ody, 1995). Wilkenfeld, Kraus, Holley, and Harris design a decision support system, GENIE, and demonstrate the usefulness of GENIE to help decision makers maximize their objectives in a crisis negotiation. Experimental results show that GENIE users, as compared to non-users, are more likely to identify utility maximization as their primary objective and to achieve higher utility scores (Wilkenfeld, Kraus, Holley, & Harris, 1995). Papazoglou and Christou propose a method on optimization of the short-term emergency response to nuclear accidents, which seeks an optimum combination of protective actions in the presence of a multitude of conflicting objectives and under uncertainty (Papazoglou & Christou, 1997). Bar-Eli and Tractinsky explore psychological performance crises under time pressure towards the end of basketball games (Bar-Eli & Tractinsky, 2000). Zografos, Vasilakis, and Giannouli present a methodological and unified framework for developing a decision support system (DSS) for hazardous materials emergency response operations (Zografos, Vasilakis, & Giannouli, 2000). Weisaeth, Knudsen, and Tonnessen discuss how psychological stress disturbs decision making during technological crisis and disaster, at an operative level of emergency response and at the strategic and political level respectively (Weisaeth, Knudsen, & Tonnessen, 2002). Chen, Sharman, and Rao et al. develop a set of supporting design concepts and strategic principles for an architecture for a coordinated multi-incident emergency response system based upon emergency response system requirement analysis (Chen, Sharman, & Rao et al., 2005).

As Arrow points out, based on the construction of group preference, group decision-making is a procedure of synthesizing the preferences of each decision-maker in a group and sorting decision alternatives or choosing the best decision alternative from a decision alternative set (Arrow, 1963). Group decision preference relation of a group should satisfy five rational terms: preference axiom, impossible axiom, completeness, Pareto optimization, and non-autarchy (Arrow, 1963). Prior studies by Arrow (1963), Dyer (1979), Keeney (1975), and French (1986), and so forth, provide a theoretical foundation on group decision preference relation analysis in group decision-making research literature. Group decision preference is a function of individual preferences on group decision-making issues. Preference is a term originally coming from economics. In group decision-making research literature, it is used to represent decision-makers' partiality on value (Dyer & Sarin, 1979). The procedure of forming individual preference is a decision-maker's meta-synthetic thinking procedure of perceiving all the information relating to expectation, information, sensibility, creativity, and so on, which is a extremely complex procedure (Bordly & Wolff, 1981). Some prior studies try to explore these complicated issues from different angles, including Weighted Average Method, Bordly Multiplication (Bordly & Wolff, 1981), Bayesian Integration Method (Keeney & Kirkwood, 1975), Entropy Method (French, 1986), and Fuzzy Cluster Analysis (Dyer & Sarin, 1979). Generally speaking, a decision-making group's decision preference on decision alternative sets will change as decision-makers adjust their decision preferences after communicating with other group decision-makers through group interactions, which could lead to group decision-marking preference convergence.

In this article, how a group reaches decision consensus quickly and effectively in group decision-making on emergency response is focused on. Emergency response, as one type of mission-critical group decision scenario, requires an MC-GDSS to collect group members' decision-making choice preferences automatically and quickly determine a group's overall decision choice preference. Further, group members may also dynamically change their decision preferences after seeing other group members' decision choice preferences during group decision-making process. This dynamic adjustment of decision preferences will continue until all the group members do not rectify their preferences. After a few rounds of group interactions with decision preference adjustment, group consensus may be reached on the group's final decision choice. Prior studies in the research literature have not considered the preference adjustment as a continuous procedure and neglected its impact on group decision-making. This article intends to address this important group decision-making research issue and proposes a new approach based on the Markov chain model.

In addition, one central element of group decision-making is decision weight. Prior main solutions to decision weight allocation in the research literature can be summarized. The first solution is the authority allocation method (Mallach, 2000). An authoritative decision maker allocates decision weight for each decision-maker, which may be biased. Another solution is the Nominal Group Technique (Potter & Balthazard, 2004; Shyur & Shih, 2006). Nominal Group Technique is a kind of anonymous survey which should be done for some rounds. Each member of a group endows weight to other decision members according to his/her own experience, value system, and personal judgment. The anonymous survey process will continue until all decision-making members' opinions converge. These two methods largely involve subjective judgment on decision weight allocation (Chen & Fu, 2005; Williams & Cookson, 2006), which is likely to lead to subjective biases as well. Other methods are based on forecasting each decision-maker's weight according to historical experience and data, such as entropy method and fuzzy cluster analysis (French, 1986), where two disadvantages exist. First, those require a lot of historical data, which is not easy to collect in reality. Second, the external environment of decision-making is changing fast. Therefore, historical successful experience may not provide a good indication for successful current and future decision-makings. This article proposes a new decision weight allocation approach, which can help address the problems of prior methods in terms of subjective biases and requiring substantial quantity of historical data.

The remainder of this article is organized as follows: The next section proposes a new decision weight allocation method. The third section presents a new approach to construct a Markov state transition matrix in group decision-making, addressing the neglected research issue of dynamically changed decision preference in the group decision-making process. A real case example of New Orleans Hurricane Katrina is used to illustrate the usefulness and effectiveness of the proposed approach. Finally, the article concludes with the discussion on the research results and presents directions for future research.

PROPOSING A NEW DECISION WEIGHT ALLOCATION APPROACH FOR MISSION-CRITICAL GROUP DECISION-MAKING

This section proposes a new decision weight allocation approach for mission-critical group decision-making. First, a group decision preference judgment matrix is defined, followed by a quantitative consistence indicator to measure decision-maker's decision consistence. Second, a clustering method to analyze the distances among decision preferences in a decision-making group is put forward. Finally, a decision weight is determined by both decision preference consistence indicator and decision preference distance indicator.

Group Decision Preference Judgment Matrix

In this article, the concept of preference utility value from economics literature to quantitatively represent preference, which describes preference direction or priority of a decision-maker is used. It would be difficult for a group member to accurately judge which decision choice is certainly the best among those alternative decision choices, especially for mission-critical problems. In reality, group decision-makers do pair wise comparisons *on each pair of two decision alternatives (or decision choices)* and give their decision preferences using fuzzy terms like "equal, a little better, better, much better, absolutely better." *Based upon this line of logic thinking, each decision-maker's preference utility value can be generated.* The definition of preference utility value $\theta_r(x^i, x^j)$ *and its quantificational values are given in Appendix A.1.*

Thus, according to the r^{th} decision maker of a group, DM_r's pair wise comparison between each two alternatives on the set, we get a preference judgment matrix P_r. Apparently, it is a positive symmetrical matrix. Decision-makers only need to judge $s(s-1)/2$ times, which is equal to the amount of the elements of the upper or lower triangular matrix.

$$P_r = \begin{pmatrix} \theta_r(x^1,x^1) & \theta_r(x^1,x^2) & \cdots & \theta_r(x^1,x^s) \\ \theta_r(x^2,x^1) & \theta_r(x^2,x^2) & \cdots & \theta_r(x^2,x^s) \\ \cdots & \cdots & \cdots & \cdots \\ \theta_r(x^s,x^1) & \theta_r(x^s,x^2) & \cdots & \theta_r(x^s,x^s) \end{pmatrix} \quad (1)$$

Suppose there are l decision-makers, then there are l preference judging matrices altogether.

Decision Preference Consistence Indicator for a Preference Judgment Matrix

Although it is relatively easy for decision-makers to do pair wise comparisons and give the preference utility value, it may not be easy to derive sequential order of the decision alternatives from a preference judgment matrix. What is more, the derived order may often be self-contradictory. For example, analysis of a given preference judgment matrix may lead to a contradictory conclusion that A is more preferred than B, B is more preferred than C, and C is more preferred than A. This kind of contradiction indicates that a decision-maker may not always be consistent enough to make decision. As a result, a quantitative consistence indicator from AHP (Satty, 1988) is introduced to measure decision-maker's decision consistence. Let CI_r denote the r^{th} decision maker DM_r's consistence indicator. The larger the indicator is, the worse the consistency of the preference judgment matrix becomes. Based on the theory of matrix, the preference utility value of DM_r on x^i, denoted by $\pi_r(x^i)$ can be derived and the consistence indicator from a matrix' characteristic vector and characteristic value, as illustrated in the Appendix A.2.

Clustering Analysis and Decision Preference Difference

Besides the individual carefulness measured by the consistence indicator, the differences among the individual preference and other's preferences (preference distance d_r) also play an important role in reaching consensus in group decision-making. As to an individual decision-maker, the larger the difference is, the extremer she is, and the less contribution she makes to the group consensus, and vice versa. In this section, firstly, a clustering method to classify the group decision-makers' preferences is introduced. Secondly, each decision-maker's preference distance to measure the extremenesses among the group members is computed. The clustering method and the definition of preference distance (d_r) are illustrated in Appendix B. The Euclidean preference distance (d_r) between the preference utility value vector of DM_r on X and the specified cluster center shows the preference distance of the decision-maker under the average criteria. The smaller d_r is, the lower the decision-maker's preference distance is, and the more contributions the decision-maker makes to group consensus.

As to those clusters that only contain one element, the distances between the element and the cluster centers of all the other clusters are calculated and the minimum distance is chosen to represent the corresponding decision-maker's preference distance.

The Optimization of Decision Weight Allocation

The decision weight allocation for group decision-makers can be described as the following optimization problem.

$$\min F(w) = \sum_{r=1}^{l} [CI_r + d_r] w_r^2 \qquad (2)$$

Subject to:

$$w_r \geq 0 \ (r = 1, 2, \cdots, l)$$

$$\sum_{r=1}^{l} w_r = 1$$

where $CI_r = (\frac{\lambda_{\max}^{(r)}}{s-1} - \frac{s}{s-1})$ denotes the consistency degree of decision-maker DM_r and $\sqrt{\sum_{k=1}^{s} \left|\pi_r(x^k) - \pi(x^k)\right|^2} = d_r$ denotes that person's preference distance. Equation (2) shows that the higher an expert's consistency is, the lower her/his extremeness is and the larger weight she/he should be assigned. A solution of the decision weight vector assigned to a group of decision-makers, $W = (w_1, w_2, \cdots, w_s)$ is given in the appendix C. Thus we have:

$$w_r = 1 \Big/ \left[(CI_r + d_r) \bullet \sum_{r=1}^{l} 1 \Big/ (CI_r + d_r)\right].$$

This approach of allocating decision weighs has at least two advantages over traditional approaches. First, it is less subjectively biased because as the decision weight allocation is based on individuals' current objective decision information with less subjective factors. Second, the allocation approach may be more accurate because it considers both individuals' decision preferences and the differences between individual decision preferences and others' decision preferences of a group.

PROPOSING A MISSION-CRITICAL GROUP DECISION-MAKING SUPPORT APPROACH USING MARKOV CHAIN MODEL

This section proposes a mission-critical group decision-making approach to address the issue of the impact of dynamic decision-making preference change on group decision-making. More specifically, the Markov state transition matrix is used to determine the dynamic nature of group decision-making preference changes, decision-making convergence, and decision preference distance. The section on group decision-making and Markov chains presents how to construct this Markov state transition matrix. Based upon that, an optimal group decision-making choice can be generated.

Group Decision-Making and Markov Chains

After the t rounds adjustment, the preference utility values in all the rounds for decision-maker DM_r are:

$$\pi_r = \begin{Bmatrix} \pi_r^1(x^1) & \pi_r^1(x^2) & \cdots & \pi_r^1(x^s) \\ \pi_r^2(x^1) & \pi_r^2(x^2) & \cdots & \pi_r^2(x^s) \\ \cdots & \cdots & \cdots & \cdots \\ \pi_r^t(x^1) & \pi_r^t(x^2) & \cdots & \pi_r^t(x^s) \end{Bmatrix}.$$

In this matrix, each row stands for the preference utility value vector in each round. Comparing the k^{th} row with the $(k+1)^{th}$ row ($\{k = 1, 2, \cdots, t\}$), if there exists $\pi_r^{k+1}(x^i)\downarrow \Leftrightarrow \pi_r^{k+1}(x^j)\uparrow$, the state variable $E_{ij} = E_{ij} + 1$ is set, which shows that the decision-maker has ever changed her/his preference from the alternative x^i to x^j. For each decision-maker, there are at most $t-1$ times of adjustment. Packing all the adjustment for the group together, we have:

$$T_r = \begin{bmatrix} 1-\sum_{j\neq 1}\frac{E_{1j}}{E_r} & \frac{E_{12}}{E_r} & \cdots\cdots & \frac{E_{1s}}{E_r} \\ \frac{E_{21}}{E_r} & 1-\sum_{j\neq 2}\frac{E_{2j}}{E_r} & \cdots\cdots & \frac{E_{2s}}{E_r} \\ \cdots\quad\cdots & \cdots\quad\cdots & \cdots\quad\cdots & \cdots\quad\cdots \\ \frac{E_{s1}}{E_r} & \frac{E_{s2}}{E_r} & \cdots\cdots & 1-\sum_{j\neq s}\frac{E_{sj}}{E_r} \end{bmatrix} \tag{3}$$

where T_r is the preference state transition matrix for decision-maker DM_r, E_{ij} denotes the preference transition times from x^i to x^j and $E_r = t-1$ is the sample space for the state transition times.

For example, the preference utility value matrix for decision-maker DM_r is:

$$\Lambda_r = \begin{bmatrix} 0.1 & 0.3 & 0.2 & 0.4 \\ 0.2 & 0.2 & 0.3 & 0.3 \\ 0.2 & 0.3 & 0.2 & 0.3 \\ 0.2 & 0.4 & 0.2 & 0.2 \\ 0.3 & 0.3 & 0.2 & 0.2 \end{bmatrix}.$$

The first row of the matrix is the initial value and the sample space is $t-1 = 5-1 = 4$.

Comparing the second row with the first row, we have $x^2 \to x^1, x^4 \to x^3$.

Comparing the third row with the second, we have $x^3 \to x^2$.

Comparing the fourth row with the third, we have $x^4 \to x^2$.

And, comparing the fifth row with the fourth, we have $x^2 \to x^1$.

According to Equation (9), we have the preference state transition matrix T_r for decision-maker DM_r is:

$$T_r = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0.5 & 0.5 & 0 & 0 \\ 0 & 0.25 & 0.75 & 0 \\ 0 & 0.25 & 0.25 & 0.5 \end{bmatrix}.$$

In this matrix, $\frac{E_{11}}{E_r} = 1$ shows that the decision-maker never changes her preference on x^1.

Define the overall state transition matrix of the decision-making group in the t rounds adjustment procedure as:

$$T = \frac{1}{l}\sum_{r=1}^{l} T_r. \qquad (4)$$

In Appendix D, a review on discrete time Markov chains is given. It is also shown that the group decision-making procedure satisfies a Markov chain. Therefore, the Markov property can be used to predict adjustments of the decision-makers' preference.

Nine Implementation Steps of the Proposed Group Decision-Making Support Approach

The proposed approach for supporting mission-critical group decision-making works in following nine steps:

1. State a group decision-making problem and background information to each group member, including the mission-critical event, available information, constraints, decision alternatives, decision-making rules, the user handbook of a MC-GDSS that is being used, and so forth.
2. Each decision-maker gives her/his preference judgments between each two alternatives on the set of alternatives using the quantificational values given in Appendix A. The preference judgment values for decision-maker DM_r are presented in the matrix P_r. All the decision-makers can share their opinions, evidences, and explanations on the screen of the MC-GDSS system to support their view points.
3. Substituting the corresponding values into the approximate calculation algorithm presented in Appendix A yields the preference utility values for a decision-maker DM_r in the t^{th} round, $\{\pi_r^t(x^1), \pi_r^t(x^2), \cdots, \pi_r^t(x^s)\}$. As stated, the individual preference adjustment in group decision-making is a continuous procedure in which the decision-makers adjust their preference in each round respectively based on the communications among the group members. The continuous adjustments make group decisions converge gradually. The preference utility values vector $\{\pi_r^t(x^1), \pi_r^t(x^2), \cdots, \pi_r^t(x^s)\}$ for the decision-maker is used for constructing the Markov state transition matrix in step (8).
4. With the preference values worked out in step (3), the preference utility values matrix Λ^t for the t^{th} round are had. Using the Equation (-16), the preference distance d_{ij} between decision-maker DM_i and DM_j on X are had. Substituting these preference distances into Equation (17), the preference difference matrix D can be constucted. Furthermore, given $\varepsilon = \frac{\max d_{ij} - \min d_{ij}}{2}$, clustering analysis on the preference difference matrix D based on the definitions 3 and 4 can be done.
5. The MC-GDSS system displays the preference utility values and the clustering results on screen, which is a public communication space for group decision-makers to see and then maybe adjust their preferences. After that, members can go back to step (2) and begin another round of decision discussion with further preference judgment as well.
6. Repeat the above procedure from step (2) to step (5) for $t = 7 \pm 2$ times. The choice of $t = 7 \pm 2$ is based on two reasons. First, conventional Delphi method usually repeats more than four times (Giunipero, Handfield, & Eltantawy, 2006; Lao, Dovrolis, & Sanadidi, 2006). Second, empirical research in psychology shows that 7 ± 2 is a common experienced value for human being's thinking-span (My-

ers, 2005; Murphy, Roodenrys, & Fox, 2006; Over, Hooge, & Erkelens, 2006). In addition, the value for t can also be determined by a group decision meeting organizer according to the meeting time limit and other factors.

7. Calculating the weight assigned to each decision-maker with the solution given in the appendix C yields the weight vector $W = (w_1, w_2, \cdots, w_s)$ for the group.
8. Constructing the Markov state transition matrix T using Equation (3) and (4) with the saved preference values $\{\pi_r^t(x^1), \pi_r^t(x^2), \cdots, \pi_r^t(x^s)\}$.
9. Multiplying decision weight vector $W = (w_1, w_2, \cdots, w_s)$ by the preference matrix Λ in the last round, and then by the Markov state transition matrix T, we have Equation 5, seen in Box 1. Where $[x^1, x^2, \cdots, x^s]$ is the preference utility values vector on the decision alternative set X and $\max\{x^i\}$ $(i = 1, 2, \cdots, s)$ is the final decision made by the group.

Here some points on this group decision-making support approach are clarified:

1. The nine steps of group decision-making only need some interactions between group decision-makers and a MC-GDSS system, without additional interactions of group decision meeting's organizer as in traditional group decision-making setting. In this way, decision-making process may be sped up, which is important to mission-critical decision-making tasks.
2. Each decision maker can share her/his opinion, present her/his explanation, and browse other's opinions anonymously or with her/his identity.
3. The clustering analysis result of individual decision preference values in each decision round is displayed in public screen and used as a reference for decision preference adjustment for the next decision round.
4. Every decision-maker is encouraged to adjust her/his preference based upon the clustering analysis result of the previous decision round. If each decision-maker sticks to her/his initial decision position and does not adjust her/his decision preference at all in following decision rounds, the group will never reach consensus and such group decision-making makes no sense, which should be stopped. Otherwise, after a few rounds of group interactions, it could be possible for a group to reach consensus and final group decision can be achieved.

A Real Case Illustrating the Usefulness and Effectiveness of the Proposed Approach

Background Information

1. New Orleans is the largest city of the state of Louisiana in the USA and the second largest American port next to New York City. It is located at the southeast part of the state of Louisiana and at the lower part of Mississippi River near the sea. The city is next to Pontchartrain Lake in its north. The city is around 950 square kilometers with a population of 500,000. Moreover, the Great New Orleans District has a population of 1180,000.

In August 2005, Katrina, a category 5 hurricane called a "Perfect Hurricane" by meteorologists with its 280 kilometer-per-hour winds, lashed the city of New Orleans. New Orleans Mayor Ray Nagin of the city of New Orleans called for voluntary evacuation of the city's residents on August 27, 2005.

On August 28, New Orleans Mayor Ray Nagin sent down a compelling order of all-out evacuation of the city's residents and provided 10 refuges for the city's remaining residents. The Louisiana Superdome is assigned as an island refuge.

On August 29, Katrina made a landfall as a category 5 hurricane over the Gulf of Mexico and lashed Southern America. New Orleans's flood embankments could not withstand the ferocity of the hurricane and were breached at two sites. As a result, 80% of the city was flooded. In some parts of the city, the water continued to rise at a speed of one foot per hour.

Constraints

The New Orleans government assigned a 7000-people rescue army. For 700,000 refugees scattered in an area of 950 square kilometers, the rescuers were only one percent of the refugees.

The city was out of communication. Except the 10 refuges, the rescuers were not aware of the location or quantity of the refugees. The city was out of traffic transportation. The vehicles such as buses were not usable any more. Helicopters were the main transporters. Moreover, the city was out of clean water, power, and cooking. There have already appeared hostile looting and murders.

Decision Alternatives

x^1 (the first decision alternative for this mission-critical event): Search for the separated refugees. If the rescue is just in time, the death rate of the refugees can be reduced. Although people in refuges were besieged, they could be kept away from death.

x^2 (the second decision alternative for this mission-critical event): Evacuate those serious patients. Without clean water and power, they might die immediately.

x^3 (the third decision alternative for this mission-critical event): Evacuate people in refuges as there is no clean water, power, and cooking. Give up the search for separated refugees temporarily because they may not die in a reasonable time period.

x^4 (the fourth decision alternative for this mission-critical event): Arrest the looters in order to make the city safe, which can also help with the rescue work to be done in a safe context.

2. Assume that there are six decision-makers in the governmental rescue committee. Every decision-maker does pair wise judgments and gives her/his preference judgment according to the quantitative values given in Table 1 of the first section. The initial preference judgment matrix is illustrated in Table 1.
3. Substituting the corresponding values into the approximate calculation algorithm presented in the appendix A, we have the preference utility values for a decision-maker DM_r in the t^{th} round, $\{\pi_r^t(x^1), \pi_r^t(x^2), \cdots, \pi_r^t(x^s)\}$. The preference utility values for the six decision-makers in the first round are shown in Table 2.
4. With the preference utility values worked out in step (3), we have the preference utility values matrix Λ^t for the t^{th} round. Using Equation (16), we have the preference distance d_{ij} between decision-maker DM_i and DM_j on X. Substituting these preference distances into Equation (17), the preference difference matrix D can be constructed. The preference distances and the preference difference matrix are shown in Table 3.

Given $\varepsilon = \frac{\max d_{ij} - \min d_{ij}}{2}$, we have $\varepsilon^1 = 0.239$, as shown in Table 3 in bold font. Thus, we get $d_{31} \leq \varepsilon^1$, $d_{62} \leq \varepsilon^1$. According to the definitions 3 and 4, there are 4 clusters in this round, DM_1 and DM_3 belong to the same cluster in $\varepsilon^1 = 0.239$, so do the DM_2 and DM_6. DM_4 and DM_5 are independent clusters respectively. The cluster analysis result is shown in Figure 1. In Figure 1, the numbered black dots denote the current preference states of the decision-makers. The diameter of the circle is the clustering distance in this round, $\varepsilon^1 = 0.239$. All the dots that can be enclosed in a circle belong to a specific cluster, which shows that the decision-makers in the same cluster come to partial consensus in ε.

Table 1. Pair wise preference judgments and preference utility values on a set of alternatives

DM_1	x^1	x^2	x^3	x^4	π	CI	DM_2	x^1	x^2	x^3	x^4	π	CI
x^1	1.00	0.33	3.00	0.33	0.17		x^1	1.00	5.00	2.00	1.00	0.38	
x^2	3.00	1.00	2.00	1.00	0.36		x^2	0.20	1.00	1.00	0.50	0.12	
x^3	0.33	0.50	1.00	0.50	0.12		x^3	0.50	1.00	1.00	0.17	0.11	
x^4	3.00	1.00	2.00	1.00	0.35	0.097	x^4	1.00	2.00	6.00	1.00	0.39	0.087
DM_3	x^1	x^2	x^3	x^4	π	CI	DM_4	x^1	x^2	x^3	x^4	π	CI
x^1	1.00	0.33	2.00	0.20	0.13		x^1	1.00	5.00	3.00	2.00	0.50	
x^2	3.00	1.00	3.00	1.00	0.37		x^2	0.20	1.00	2.00	2.00	0.20	
x^3	0.50	0.33	1.00	0.50	0.12		x^3	0.33	0.50	1.00	0.33	0.10	
x^4	5.00	1.00	2.00	1.00	0.38	0.075	x^4	0.50	0.50	3.00	1.00	0.20	0.123
DM_5	x^1	x^2	x^3	x^4	π	CI	DM_6	x^1	x^2	x^3	x^4	π	CI
x^1	1.00	0.33	6.00	5.00	0.34		x^1	1.00	5.00	4.00	0.33	0.33	
x^2	3.00	1.00	5.00	3.00	0.48		x^2	0.20	1.00	0.50	0.33	0.09	
x^3	0.17	0.20	1.00	2.00	0.10		x^3	0.25	2.00	1.00	0.50	0.15	
x^4	0.20	0.33	0.50	1.00	0.08	0.139	x^4	3.00	3.00	2.00	1.00	0.43	0.132

5. The preference judgment results can then feedback to all the decision-makers based upon the results as shown in Table 3 and Figure 1. Decision-makers can make adjustments after seeing the first round of deliberation. The group then begins another round of decision-making (i.e., repeating the decision-making process starting from step 2).
6. Repeat step (2) through step (5) for five times, t = 5.

Table 2. The preference value for every decision-maker in the first round

0.17	0.36	0.12	0.35
0.38	0.12	0.11	0.39
0.13	0.37	0.12	0.38
0.50	0.20	0.10	0.20
0.34	0.48	0.10	0.08
0.33	0.09	0.15	0.43

7. Different preference difference matrices in each round are gotten. Here the difference matrix in the last round are only presented, as shown in Figure 2 and Table 4. The scales in Figure 1 and Figure 2 are the same.

DM_1 and DM_3 belong to the same cluster in $\varepsilon^1 = 0.239$, so do the DM_2 and DM_6. DM_4 and DM_5.

As shown in Figure 2, the clustering distance in the fifth round is $\varepsilon^5 = 0.143$. It can be seen that the individual preferences are clustered into three

Table 3. Preference difference matrix in the first round

0					
0.313	0				
0.054	0.353	0			
0.393	0.245	0.446	0		
0.347	0.486	0.383	0.350	0	
0.321	**0.071**	0.354	0.307	0.532	0

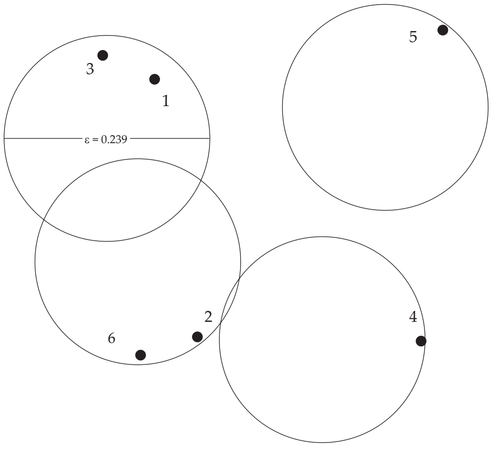
Box 1.

$$\left[w_1, w_2, \cdots, w_s\right] \begin{bmatrix} \pi_1(x^1) & \pi_1(x^2) & \cdots & \pi_1(x^s) \\ \pi_2(x^1) & \pi_2(x^2) & \cdots & \pi_2(x^s) \\ \cdots & \cdots & \cdots & \cdots \\ \pi_l(x^1) & \pi_l(x^2) & \cdots & \pi_l(x^s) \end{bmatrix} \begin{bmatrix} T_{11} & T_{12} & \cdots & T_{1s} \\ T_{21} & T_{22} & \cdots & T_{2s} \\ \cdots & \cdots & & \cdots \\ T_{s1} & T_{s2} & \cdots & T_{ss} \end{bmatrix} = [x^1 \quad x^2 \quad \cdots \quad x^s] \tag{5}$$

clusters. DM_1, DM_3 and DM_4 belong to the same cluster, DM_3 and DM_5 belong to the same cluster, and DM_2 and DM_6 belong to the same cluster. In Figure 2, the diameter of the larger circle is the clustering distance in the first round ($\varepsilon^1 = 0.239$). From this figure, it is easy to see that if we use this distance to cluster the individual preferences, five decision-makers have come to consensus in $\varepsilon^1 = 0.239$, that is, DM_1, DM_2, DM_3, DM_4, and DM_6. Thus the clustering distance is reduced gradually in each round and shows the convergence of the group preference and the procedure of reaching consensus.

Substituting the values into the solution given in the appendix C yields the weight vector for the decision-making group $W = (0.131 \quad 0.264 \quad 0.163 \quad 0.165 \quad 0.113 \quad 0.162)$.

Figure 1. Clustering result of the individual preference utility values in the first round

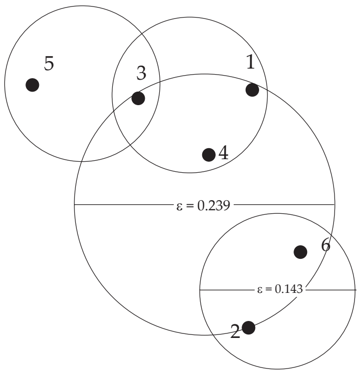


8. Construct the Markov state transition matrix T using Equation (3) and (4) with the saved preference utility values$\{\pi_r^t(x^1), \pi_r^t(x^2), \cdots, \pi_r^t(x^s)\}$. In this example, if $\pi_r^k(x^i) - \pi_r^{k+1}(x^i) > 0.01$ and $\pi_r^{k+1}(x^j) - \pi_r^k(x^j) > 0.01$ occurs, it is considered as an one time transition $\pi_r^{k+1}(x^i)\downarrow \Leftrightarrow \pi_r^{k+1}(x^j)\uparrow$, let the state variable $E_{ij} = E_{ij} + 1$, thus it indicates that the decision-maker DM_r transits from alternative x^i to alternative

Table 4. Preference difference matrix in the fifth round

0					
0.155	0				
0.098	0.215	0			
0.079	0.145	**0.091**	0		
0.211	0.318	**0.115**	0.186	0	
0.155	**0.060**	0.236	0.168	0.346	0

Figure 2. Clustering result in the fifth round



x^j for one time. The final preference state transition matrix is

$$T = \begin{bmatrix} 0.333 & 0.417 & 0.0417 & 0.208 \\ 0.125 & 0.875 & 0 & 0 \\ 0.083 & 0 & 0.917 & 0 \\ 0.292 & 0.333 & 0.083 & 0.292 \end{bmatrix}.$$

9. Multiply the weight vector $W = (w_1, w_2, \cdots, w_s)$ by the preference matrix Λ in the last round, and then by the Markov state transition matrix T, we have

$$\begin{bmatrix} 0.131 & 0.264 & 0.163 \\ 0.165 & 0.113 & 0.162 \end{bmatrix} \begin{bmatrix} 0.23 & 0.32 & 0.19 & 0.26 \\ 0.33 & 0.23 & 0.13 & 0.31 \\ 0.22 & 0.40 & 0.15 & 0.23 \\ 0.28 & 0.35 & 0.15 & 0.22 \\ 0.21 & 0.50 & 0.11 & 0.18 \\ 0.31 & 0.20 & 0.17 & 0.32 \end{bmatrix}$$

$$= [0.273 \quad 0.314 \quad 0.148 \quad 0.262] \qquad (6)$$

$$\begin{bmatrix} 0.273 & 0.314 \\ 0.148 & 0.262 \end{bmatrix} \begin{bmatrix} 0.333 & 0.417 & 0.0417 & 0.208 \\ 0.125 & 0.875 & 0 & 0 \\ 0.083 & 0 & 0.917 & 0 \\ 0.292 & 0.333 & 0.083 & 0.292 \end{bmatrix}$$

$$= [0.219 \quad 0.476 \quad 0.169 \quad 0.133]. \qquad (7)$$

[0.219 0.476 0.169 0.133] is the preference utility values vector on the set of alternatives X and the alternative x^2, corresponding to $\max\{x^i\}$ ($i = 1, 2, \cdots, s$) = 0.476, is the final alternative chosen by the decision-making group.

Comparing the result of Equation (6) with the result of (7), it can be seen that if the possible decision preference changes are not taken into account (the dynamic nature of group decision-making process), it will come to the static conclusion $x^2Rx^1Rx^4Rx^3$ as shown in Equation (6) (i.e., the preferred decision alternatives are determined in following sequential order: the most preferred decision alternative x^2, followed by the decision alternatives x^1, x^4, and x^3). This conclusion is drawn by traditional meta-synthetic approaches on group decision-making, that is, after decision weights for every decision-maker are assigned and fixed, the group preference value on each decision alternative is determined by the sum of each decision-maker's decision weight multiplied by her/his *current preference value* of the alternative. Finally, all alternatives are sorted in the order of their preference values to derive the final group decision.

On the other hand, if the possible decision preference changes are not taken into account, the conclusion comes to the result $x^2Rx^1Rx^4Rx^3$ as shown in Equation (7), different from the result of Equation (6), which would be closer to group decision-making in reality. This difference shows the importance of considering dynamic decision preference change into group decision-making model.

The decision difference between traditional methods and the currently proposed one may not always ensure a better group decision result, which will be further discussed.

Considering an ergodic Markov chaie, let T be a probability matrix. If there exists a $m(m > 1, m \in Z)$, which makes all the elements of T^m positive, T is called a normal stochastic matrix. A probability vector π must exist, which makes

$$\pi = \pi T \text{ and } \pi_j = \lim_{n\to\infty} T_{ij}^n \text{ for all } i \qquad (8)$$

The probability vector π is called the steady state vector for the state transition matrix T.

It is easy to show that the preference state transition matrix in our example is a normal stochastic matrix. Thus there must exist a probability vector π, the steady state solution to the group decision-making problem on the alternative set. Therefore the following Equations are resolved.

$$\begin{cases} \pi = \pi T \\ \sum_{i=1}^{s} \pi_i = 1 \\ \pi_i > 0 \quad i = 1, \cdots, s \end{cases} \qquad (9)$$

or see Box 2.

Box 2.

$$\begin{cases} [\pi_1 \quad \pi_2 \quad \pi_3 \quad \pi_4] = [\pi_1 \quad \pi_2 \quad \pi_3 \quad \pi_4] \begin{bmatrix} 0.333 & 0.417 & 0.0417 & 0.208 \\ 0.125 & 0.875 & 0 & 0 \\ 0.083 & 0 & 0.917 & 0 \\ 0.292 & 0.333 & 0.083 & 0.292 \end{bmatrix} \\ \pi_1 + \pi_2 + \pi_3 + \pi_4 = 1 \\ \pi_i > 0 \quad i = 1, \cdots, s \end{cases} \tag{10}$$

We have

$$\pi = [0.161014988 \quad 0.663345006 \quad 0.128267958 \quad 0.047323744] \tag{11}$$

The result shown in Equation (11) represents the decision preference order $x^2Rx^1R\,x^4R\,x^3$, the same result derived from Equation (7). Note that now this conclusion in Equation (11) has nothing to do with the decision weight vector W and decision preference value matrix Λ in the last round, and only depends on the decision preference state transition matrix T.

Comparing the Equations (6), (7), and (11), several conclusions can be drawn:

1. The traditional meta-synthetic approaches on group decision-making, neglecting the dynamic nature of decision preference adjustments/changes of group decision-makers, can lead to the loss of important decision element/information for group decision-making.
2. The dynamic nature of decision preference adjustment/change is one important part of group decision-making process, which should not be neglected.
3. The conclusion drawn on Equation (11) merely depends on the Markov state transition matrix, not on the decision weight vector W and decision preference value matrix Λ in the last round. This shows that if there would be enough time for a group to continue group decision-making process, group consensus will be reached in the form as shown in Equation (11).
4. The static conclusion $x^2Rx^1R\,x^4R\,x^3$ derived from Equation (6) can be considered as a transient result that will change as group decision-making process proceeds.
5. The dynamic decision-making conclusion $x^2Rx^1R\,x^4R\,x^3$ derived from Equation (7) can be considered as a stationary result that includes the developing trend of group decision-making process. That is that, as group decision-making rounds continue ($t > 5 \to \infty$), group decision result will come to the conclusion as shown Equation (11), the same as being derived from Equation (7).
6. As a result, it is shown that the group decision-making steps based on the Markov Chain, can help a group derive decision conclusion, as shown by Equation (11), which could otherwise be achieved by a big number of (or even infinite) group decision-making rounds. Therefore, in mission-critical group decision-making situation with short response time, the proposed approach could help a group reach consensus on final group decision within a few decision-making rounds (usually 5~9 rounds), rather than a big number of decision-making rounds (or infinite decision-making rounds), which may lead to more efficient and effective group decision-making.

DISCUSSION AND FUTURE RESEARCH

Discussion and Implications

This study contributes to the research literature in three aspects. First, prior research does not consider group decision-making preference being dynamic, which would be fixed and not be changed in group decision-making process, neglecting its existence and its impact on group decision-making. The proposed approach in this article solves this problem using the Markov Chain model. Further, the proposed approach can automatically determine and present group decision-makers' decision preference distances as well as similar decision preference clusters they belong to, which clearly shows similar and different positions of group decision-makers on a given mission-critical decision-making task in its first round and subsequent decision-making rounds, which in turn may support group decision-makers in more effectively adjusting their decision preferences/positions to help reach group final decision more efficiently and effectively. This is very important to mission-critical decision-making tasks. Future studies can use empirical research methodologies to examine this research issue.

Second, the proposed group decision weight allocation approach solves the problems of traditional methods that require substantial historical decision data and largely involve subjective judgment.

Third, the proposed approach provides a solution to Coudorcet's group decision paradox. One commonly used group decision rule is group concensus or majority rule (Nunamaker, Briggs, Mittleman, Vogel, & Balthazard, 1997; Huang & Wei, 1997; Huang, Wei, & Tan, 1999; Watson, DeSanctis, & Poole, 1988). When there are more than three decision alternatives, it may be possible to generate a group decision cyclic loop, which would be theoretically impossible to read a group consensus or majority rule (Coudorcet, 1785). For example, there are three decision-makers (DM_1, DM_2, DM_3) in a group and three alternatives (A, B, C). Table 5 shows possible decision results for each decision-maker.

It is so-called the Voting Paradox (also known as Condorcet's paradox) (Coudorcet, 1785; Deemen, 1999; Nanson, 1882), as shown in Figure 3.

Let the number of decision-makers in a group be l, P denotes the probability of generating group decision circular loop based on majority rule. Prior studies report the relationship between l and P, as shown in Table 6 (Niem & Weisberg, 1968); but when l is large, the relationship between the number of alternatives s and P is shown in Table 7 (Niem & Weisberg, 1968).

In this research, each decision-maker's decision preference judgment matrix based on pair wise comparisons are had and the characteristic vector from AHP is introduced to derive the sequential order of decision alternatives of each decision-maker. When decision-makers do pair wise comparisons on decision alternatives, which leads to a group decision preference judgment matrix, this matrix might result in group decision

Table 5. Decision result for each decisoin maker

Decision Maker	Preferences
DM_1	$A\ R_1\ B\ R_1\ C$
DM_2	$B\ R_2\ C\ R_2\ A$
DM_3	$C\ R_3\ A\ R_3\ B$

Figure 3. Voting paradox

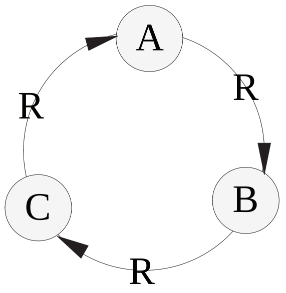


Table 6. Relationship between l and P

l	P
3	0.0556
9	0.078
15	0.082
25	0.0843
…	…
∞	0.0877

Table 7. Relationship between s and P

s	P
3	0.0877
9	0.4545
15	0.082
25	0.7297
…	…
∞	1

cyclic loops. However, this matrix is only used for determining group decision-makers' decision weights, not for determining group's final decision. So it will not lead to Condorcet's paradox. When a group comes to the final group decision, a group decision cyclic loop can be avoided because the group decision sequential order of decision alternatives from a decision-maker are gotten based upon the calculation of the characteristic vector of her preference judgment matrix, not the preference judgment matrix itself. Therefore, the group decision-making approach proposed in this research can avoid the possibility of group decision circular loop, which provides a solution to Condorcet's paradox in group decision-making.

In practice, incorporating the proposed approaches to an existing GDSS system, the system may have a potential to help a group reach group decision consensus faster and more effectively, which can be especially important to mission-critical decision-making tasks. While global terrorism currently becomes one major threat to all the countries of the world, and while more globalized world economy would possibly lead to one country's major economic problem quickly becoming an emerging mission-critical problem of other countries within days or sometimes hours, many of those cross-border mission-critical problems would require group decision-makers to respond quickly and make decisions quickly. The proposed approach provides a possible solution to those mission-critical group decision-making problems that may be faced by both developed and developing countries. Field studies can be conducted to further investigate the effectiveness of such proposed GDSS systems in the future.

Research Limitation

It should be noted that not all the Markov state transition matrices in group decision-making process, based on the Markov chain approach, would surely be normal stochastic ones, which can be shown in the example.

If decision preference adjustment only runs for a few rounds, for example, $t < 5$, the overall state transition matrix for a group can be shown in the matrix T:

$$T = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0.5 & 0.5 & 0 & 0 \\ 0 & 0.25 & 0.75 & 0 \\ 0 & 0.25 & 0.25 & 0.5 \end{bmatrix}.$$

It is clear that T is not a normal stochastic matrix, and its steady state solution can not be resolved using Equation (9). In this case, group decision-making result can be conducted derived from Equation (7) instead of Equations (8) ~ (11). As a result, the proposed approach, though being efficient and effective in most cases, may not be so in all cases. Future research can look at this limitation and provide further improvement.

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ENDNOTE

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APPENDIX A

A.1 Definition of Preference Utility Value and a Set of its Quantificational Values

Let G denote a decision-making group, DM_r be the r^{th} decision-maker of the group with l decision-makers, then $G = \{DM_r | r \in \Omega\}(\Omega = \{1, 2, \cdots, l\}, 2 \leq l < +\infty)$. Let X be a set of alternatives, x^i be the i^{th} alternative and there are s alternatives in the alternative set, then $X = \{x^i | i \in \Omega\}(\Omega = \{1, 2, \cdots, s\}, 2 \leq s < +\infty)$.

Definition 1. Preference utility value $\theta_r(x^i, x^j)$: *Let* R_r *denote the preference relation of* DM_r *on* X. *Let* $x^i R_r x^j$ *denote that comparing* x^i *with* $x^j (x^i, x^j \in X)$, DM_r *tends to choose* x^i. *According to the needs of the decision-making, let* $\theta_r(x^i, x^j)$, *a real number, denote the quantificational difference of* DM_r*'s preference degrees on the two alternatives* x^i *and* x^j.

Let's define the quantificational values of $\theta_r(x^i, x^j)$ as in Table 5.

$\theta_r(x^i, x^j)$	the signification to DM_r
1	x^i and x^j has equal preference degree
3	Compared with x^j, x^i is a little better
5	Compared with x^j, x^i is better
7	Compared with x^j, x^i is much better
9	Compared with x^j, x^i is absolutely better
2, 4, 6, 8	The middle state's corresponding utility values of the judgments
reciprocal	Compared x^j with x^i, the utility value of preference $\theta_r(x^j, x^i) = 1 / \theta_r(x^i, x^j), \theta_r(x^i, x^i) = 1$

A.2 The Solving Process of the Consistence Indicator CI_r

From the theory of matrix, the Equation $(P_r - \lambda I)\pi^T = 0$ has at least one group of solutions, where π^T is the characteristic vector, λ is the characteristic value. An approximate calculation algorithm is given to get the maximal characteristic value $\lambda_{\max}^{(r)}$ and characteristic vector $\pi_r = (\pi_r(x^1), \pi_r(x^2), \cdots, \pi_r(x^s))$ of P_r in Appendix A.

1. Calculate the geometric mean of all the elements in each row of the matrix

$$\bar{\pi}_r(x^i) = \sqrt[s]{\prod_{j=1}^{s} \theta_r(x^i, x^j)} \quad i = 1, 2, \cdots, s \tag{12}$$

We have $\bar{\pi}_r = (\bar{\pi}_r(x^1), \bar{\pi}_r(x^2), \cdots, \bar{\pi}_r(x^s))$

2. Normalize $\bar{\pi}_r(x^1)$

$$\pi_r(x^i) = \frac{\bar{\pi}_r(x^i)}{\sum_{j=1}^{s} \bar{\pi}_r(x^j)} \quad i = 1, 2, \cdots, s \tag{13}$$

Then $\pi_r = (\pi_r(x^1), \pi_r(x^2), \cdots, \pi_r(x^s))$ is the approximate solution of the characteristic vector. We call $\pi_r(x^1)$ the preference utility value of DM_r on x^1. The set $\{\pi_r(x^1), \pi_r(x^2), \cdots, \pi_r(x^s)\}$ denotes the preference utility values set of DM_r on the set of alternatives.

3. Calculate the maximal characteristic value $\lambda_{\max}^{(r)}$ of the matrix P_r

$$\lambda_{\max}^{(r)} = \sum_{i=1}^{s} \frac{(\mathrm{P}_r \pi_r)_i}{s\pi_r(x^i)} \tag{14}$$

where $(P_r \pi_r)_i$ is the i^{th} element of the vector $P_r \pi_r$.

The consistency test index CI from AHP is introduced (Saaty, 1988)

$$CI_r = \frac{\lambda_{\max}^{(r)} - s}{s-1} = \frac{\lambda_{\max}^{(r)}}{s-1} - \frac{s}{s-1} \tag{15}$$

Let CI_r denote the r^{th} decision maker DM_r's preference judgment consistency. CI_r is an indicator to measure whether the decision maker's judgment is careful. The smaller CI_r is, the better it is. Especially, when $CI_r = 0$, the preference judgment matrix P_r is a complete consistency matrix, which represents the complete consistency of DM_r's preference judgment. However, when people do pair wise comparisons they cannot ensure their judgments are completely consistent because of the complexity of the objective reality and the limitation of human thoughts. There usually exists error of estimation which makes CI_r larger than 0. The larger CI_r is, the worse the consistency of P_r becomes.

APPENDIX B: CLUSTERING METHOD AND DEFINITION OF PREFERENCE DISTANCE

Packing all the preference values $\pi_r(x^1)$ $(1 \le i \le s;\ 1 \le r \le l)$ from the l decision-makers in the group, we have the $l \times s$ preference value matrix Λ

Definition 2. *The Euclidean preference distance between decision-maker DM_i and DM_j on a set of alternatives X is*

$$d_{ij} = \sqrt{\sum_{k=1}^{s} \left| \pi_i(x^k) - \pi_j(x^k) \right|^2}. \tag{16}$$

The Euclidean preference distance d_{ij} also denotes the difference of consensus between decision-maker DM_i and DM_j on X.

Packing the preference distances of all the l decision-makers, we have the $l \times l$ preference difference matrix,

$$D = \begin{bmatrix} 0 & & & & \\ d_{21} & 0 & & & \\ d_{31} & d_{32} & 0 & & \\ \cdots & \cdots & \cdots & 0 & \\ d_{l1} & d_{l2} & d_{l3} & \cdots & 0 \end{bmatrix} \tag{17}$$

where d_{ij} is nonnegative. The closer DM_i and DM_j are to each other, the smaller d_{ij} is. As $d_{ij} = d_{ij}$ and $d_{ij} = 0$, we have the matrix as shown in Equation (17).

Definition 3. *Let* $C = \{c^{\omega}: \omega = 1, 2, \cdots, m\}$ *be the preference cluster of the group G on a set of alternatives X,* ε *be the given clustering distance. If the distance between each two elements in* c^{ω} *satisfies the constraint* $d_{ij} \leq \varepsilon \in c^{\omega}$*, we call that* c^{ω} *is a cluster, that is, the sub-group comes to consensus in* c^{ω}*.*

Definition 4. *With respect to the decision-makers* DM_i *and* DM_j*, if* $(d_{ij} \leq \varepsilon) \in c^{\omega} \subseteq C$*, we call that* DM_i *and* DM_j *come to partial consensus in* c^{ω}*. As to* $d_{rq} \leq \varepsilon^k \in c^k, (d_{ij} \leq \varepsilon^l) \in c^l$*, if and only if* $\varepsilon^k = \varepsilon^l = \varepsilon$ *and* $d_{ri} \leq \varepsilon$, $d_{rj} \leq \varepsilon$, $d_{iq} \leq \varepsilon$, $d_{jq} \leq \varepsilon$*, we call* $c^k = c^l$ *is the same cluster.*

Example 1. *Suppose there is an initial preference utility value matrix as follows,*

$$\Lambda = \begin{bmatrix} 0.1 & 0.3 & 0.2 & 0.4 \\ 0.2 & 0.4 & 0.1 & 0.3 \\ 0.3 & 0.1 & 0.4 & 0.2 \\ 0.4 & 0.2 & 0.3 & 0.1 \\ 0.3 & 0.3 & 0.3 & 0.1 \\ 0.2 & 0.2 & 0.2 & 0.4 \end{bmatrix}. \tag{18}$$

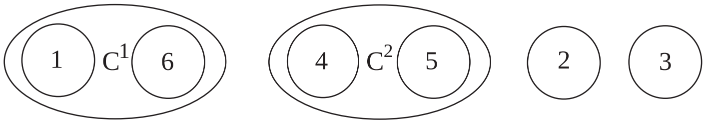
Substituting the values into Equation (16), the consensus difference matrix (the preference difference matrix) as follows is had,

$$d = \begin{bmatrix} 0 & & & & & \\ 0.2 & 0 & & & & \\ 0.4 & 0.447 & 0 & & & \\ 0.447 & 0.4 & 0.2 & 0 & & \\ 0.374 & 0.316 & 0.245 & 0.141 & 0 & \\ 0.141 & 0.245 & 0.316 & 0.374 & 0.346 & 0 \end{bmatrix}. \tag{19}$$

1. Given $\varepsilon^1 \leq 0.15$ thus $d_{61} = d_{54} = 0.141 \leq \varepsilon^1$

The results DM_1, $DM_6 \in c^1$ and DM_4, $DM_5 \in c^2$ can be had. Although $d_{61} = d_{54} \leq \varepsilon^1$, $\min\{d_{65}, d_{64}, d_{51}, d_{41}\} = 0.346 > \varepsilon^1$ thus c^1, c^2 are not the same cluster according to Definition 4 and the two clusters come to partial consensus separately. DM_2 and DM_3 have not come to consensus with others as shown in Figure 3.

Figure 3.



2. Given $\varepsilon^2 \leq 0.2$, we have $d_{21} = d_{43} = 0.2 \leq \varepsilon^2$ and $d_{61} = d_{54} = 0.141 \leq \varepsilon^1$, that is, $DM_1, DM_2 \in c^3$ and $DM_3, DM_4 \in c^4$ come to consensus respectively based on the consensus of $DM_1, DM_6 \in c^1$ and $DM_4, DM_5 \in c^2$. Here c^3 and c^4 are not the same cluster, as shown in Figure 4.
3. Given $\varepsilon^3 \leq 0.25$, we have $d_{61} = d_{54} = 0.141 \leq \varepsilon^1$, $d_{21} = d_{43} = 0.2 \leq \varepsilon^2$, and $d_{62} = d_{53} = 0.245 \leq \varepsilon^3$, that is, $DM_1, DM_2, DM_6 \in c^5$ come to consensus in c^5 and $DM_3, DM_4, DM_5 \in c^6$ come to consensus in c^6 as shown in Figure 5.

Assume k clusters are being sought after clustering with given ε and there are $\hat{l}$ elements in one of the k clusters, c^{ω}.

Definition 5. *To those clusters that have more than* 2 *elements, that is,* $2 \leq \hat{l} \leq s$*, the cluster center is defined as*

$$\hat{\pi} = \frac{1}{\hat{l}}\sum_{i=1}^{\hat{l}} \pi_i . \tag{20}$$

The Euclidean distance of preference between a decision-maker DM_r and the specified cluster center is then defined as

$$d_r = \sqrt{\sum_{k=1}^{s} \left|\pi_r(x^k) - \hat{\pi}(x^k)\right|^2} . \tag{21}$$

APPENDIX C: A SOLUTION OF THE DECISION WEIGHT VECTOR

Construct the Lagrange function for the optimization model,

$$L(w,\xi) = \sum_{r=1}^{l}[(\frac{\lambda_{\max}^{(r)}}{s-1} - \frac{s}{s-1}) + \sqrt{\sum_{k=1}^{s}(\pi_r(x^k) - \hat{\pi}(x^k))^2}\,]w_r^2 + 2\xi(\sum_{r=1}^{l} w_r - 1). \tag{22}$$

Figure 4.

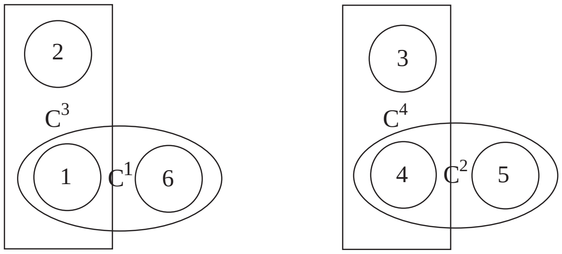
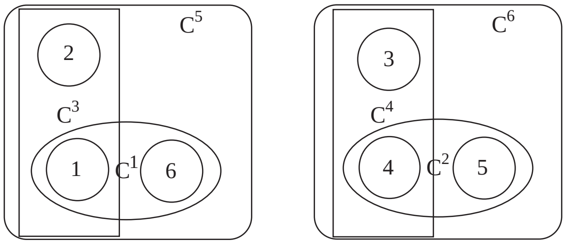


Figure 5.



From the first-order condition of Equation (24), we have

$$\begin{cases} \dfrac{\partial L}{\partial w_r} = 2[(\dfrac{\lambda_{\max}^{(r)}}{s-1} - \dfrac{s}{s-1}) + \sqrt{\sum_{k=1}^{s}(\pi_r(x^k) - \hat{\pi}(x^k))^2}\,]w_r + 2\xi = 0 \\ \dfrac{\partial L}{\partial \xi} = \sum_{r=1}^{l} w_r - 1 = 0 \end{cases}$$

which implies that

$$\begin{cases} w_r = \dfrac{-\xi}{[(\dfrac{\lambda_{\max}^{(r)}}{s-1} - \dfrac{s}{s-1}) + \sqrt{\sum_{k=1}^{s}(\pi_r(x^k) - \hat{\pi}(x^k))^2}\,]} & (23) \\ \sum_{r=1}^{l} w_r = 1 & (24) \end{cases}$$

Thus, we have

$$\begin{cases} \xi = -\dfrac{1}{\sum_{r=1}^{l} 1 \Big/ [(\dfrac{\lambda_{\max}^{(r)}}{s-1} - \dfrac{s}{s-1}) + \sqrt{\sum_{k=1}^{s}(\pi_r(x^k) - \hat{\pi}(x^k))^2}\,]} & (25) \\ w_r = \dfrac{1}{[(\dfrac{\lambda_{\max}^{(r)}}{s-1} - \dfrac{s}{s-1}) + \sqrt{\sum_{k=1}^{s}(\pi_r(x^k) - \hat{\pi}(x^k))^2}\,] \bullet \sum_{r=1}^{l} 1 \Big/ [(\dfrac{\lambda_{\max}^{(r)}}{s-1} - \dfrac{s}{s-1}) + \sqrt{\sum_{k=1}^{s}(\pi_r(x^k) - \hat{\pi}(x^k))^2}\,]} & (26) \end{cases}$$

From Equation (26), the decision weight vector assigned to a group of decision-makers, $W = (w_1, w_2, \cdots, w_s)$ can be derived.

APPENDIX D: DISCRETE TIME MARKOV CHAINS AND MARKOV PROPERTY OF THE GROUP DECISION-MAKING PROCEDURE

A sequence of random variables $\{E_n\}$ is called a Markov chain if it has the Markov property:

$$T\{E_{n+1} = j \mid E_n = i, E_{n-1} = i_{n-1}, \ldots, E_0 = i_0\} = T\{E_{n+1} = j \mid E_n = i\}$$
$$T_{ij} = T\{E_{n+1} = j \mid E_n = i\} \qquad (27)$$

Here, E_i is an event and T_{ij} is the probability to transit from state i to state j of the event. The property is called Memoryless. In other words, “Future” is independent of “Past” given “Present.” Here the transition probabilities T_{ij} satisfy

$$T_{ij} \geq 0, \quad \sum_{j=0}^{\infty} T_{ij} = 1.$$

The Chapman-Kolmogorov Equation for a discrete-time Markov chain is as follows: If the distribution at time t_n is $\pi^{(n)}$, then the distribution at time t_{n+1} is given by

$$\pi^{(n+1)} \tag{28}$$

Because each decision-maker in the group independently puts forward her/his preference judgment matrix, the preference state E^r_n of decision-maker DM_r is independent of other decision-makers and the future preference state E^r_{n+1} is independent of other states except the current state E^r_n, thus the group decision-making procedure satisfies Equation (27).

Obviously, the transition probabilities T_{ij} constructed from Equation (3) satisfy

$$T_{ij} \geq 0, \quad \sum_{j=0}^{\infty} T_{ij} = 1.$$

Equation (4) shows that the overall state transition probabilities matrix is the mean value of the matrices of transition probabilities of each decision-maker, thus the group property is implied in the individual properties.

Therefore, the Chapman-Kolmogorov Equations, Equation (28) can be used to get $\pi^{(n+1)}$ at “time”t_{n+1} from $\pi^{(n)}$ at “time” t_n.

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Chapter 8.8

Enhancing Decision Support Systems with Spatial Capabilities

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ABSTRACT

This chapter introduces spatial dimensions and measures as a means of enhancing decision support systems with spatial capabilities. By some way or other, spatial related data has been used for a long time; however, spatial dimensions have not been fully exploited. It is presented a data model that tightly integrates data warehouse and geographical information systems — so characterizing a spatial data warehouse (SDW) — ; more precisely, the focus is on a formalization of SDW concepts, on a spatial-aware data cube using object-relational technology, and on issues underlying a SDW — specially regarding spatial data aggregation operations. Finally, the MapWarehouse prototype is presented aiming to validate the ideas proposed. The authors believe that SDW allows for the efficient processing of queries that use, jointly, spatial and numerical temporal data (e.g., temporal series from summarized spatial and numerical measures).

INTRODUCTION

Decision support systems aim to identify historical and localizable tendencies, behaviors and information patterns, which help the decision support process. The technologies that underpin this process, using time and space dimensions as decisive factors, are: data warehouse (DW) — with online analytical processing (OLAP) interface — and geographical information systems (GIS). DW/OLAP systems are responsible for both data extraction from several operational sources and data organization according to a historical, thematic and consolidated multi-dimensional model (Malinowski & Zimányi, 2004), composed by facts (numerical measurements related to business processes) and dimensions (descriptive aggregated information, often hierarchically disposed, which is arranged to define the facts). Conceptually, a DW is a multi-dimensional array, or simply a data cube. OLAP queries over a DW provide data exploration and analysis operations by means of aggregate navigation through dimension hierarchies — drill-down, roll-up. Other typical OLAP operations are data cube slicing, dicing and pivoting. Materialized data cubes aim to guarantee high performance of OLAP operations. On the other side, GIS provide manipulation, storage and visualization of spatial data, so that decision-makers may enhance the quality of their analysis using the spatial dimension.

The main objective of this chapter is to present a spatial data warehouse (SDW) (Rivest, Bédard, & Marchand, 2001; Pourabbas, 2003) conceptual model which tightly integrates DW and GIS. Also, we rigorously define a logical model suitable for implementing decision-making processes using spatial data. The other two main contributions of the chapter are: (1) the proposal of a query language for the logical model with query optimization techniques, and (2) the presentation of a prototype developed in order to validate our ideas.

The advantages separately provided by GIS and DW technologies have motivated research on their integration. Existent integration approaches do not fulfill the requirements for a *stricto sensu* integration, which are: (1) to summarize spatial data (e.g., map-overlay, region merge) through spatial dimensions — spatial roll-up and its counterpart, spatial drill-down —, and (2) to synchronize spatial and numerical historical summarized data.

A case study on agricultural crops in Brazil is discussed throughout the chapter. In order to have an efficient seed distribution policy to Brazilian farmers, several issues ought to be taken into account including soil type, rainfall and type of seed. Hence, a SDW may help authorities in finding the best policy for a particular situation, based on dynamic maps, tables, graphics, reports, and so on. As it can be noticed, this application encompasses space, time and analytical dimensions. Query examples exploiting these dimensions in this particular application domain include:

- Which cultivation better adapts to each municipality, region or state following the plantation conditions of last year (semester or month, etc.)?
- What are the favorable pattern conditions to the corn (mango or coffee, etc.) cultivation for a particular geographical region?
- Where is the best place to plant a particular crop?
- When is the best season for planting a given crop?

The remainder of this chapter is organized as follows. A background with discussion of related work is presented in the following section. Then our spatial multidimensional model is addressed, followed by the proposal of an object-relational spatial data cube. Query optimization techniques and a description of a prototype which aims to validate the proposed ideas — the MapWarehouse Project — are presented. Finally, the conclusion and further research to be undertaken are highlighted.

BACKGROUND

The research on spatial data warehouse is very incipient. Many of the research proposals are based on either federated or integrated architectures. In federated architecture, numerical and spatial data are linked through some common properties without affecting their original sources. Moreover, the responsibility for information capture and translation among different sources is limited to some components. This usually originates lost of transparency and some semantic problems (Kouba et al., 2000; Rivest et al., 2001; Pourabbas, 2003). One of the prominent research project based on this federated architecture is GOLAP (Kouba et al., 2000).

In the GOLAP project, the main component is a mediator — an integration module — which is responsible for the correspondence between a GIS and a DW/OLAP system, by using metadata. Although the system aims to be a generic solution, there is no interaction between the functions of the GIS tool and those of the DW/OLAP. The integration between these systems is restricted to the isolated use of GIS capabilities and related dimensions of the DW. The main drawbacks of this approach are the low performance, as there is no way to perform query optimization jointly on GIS and DW; and the loss of transparency, since for every new GIS and OLAP application, the mediator must be reconfigured.

On the other hand, the integrated architecture uses a singular and adapted environment in which queries involving both spatial and numerical data may be posed. This results in high flexibility and expression power of OLAP operations. Two proposals are highlighted: GeoMiner (Han et al., 1997) and Map Cube (Shekhar et al., 2001).

GeoMiner is a project of spatial data mining that includes three modules for complete numerical-spatial data integration: spatial data cube construction, analytical-spatial query processing, and spatial data mining. To reduce the query processing costs of queries, some algorithms are proposed to selective data materialization, considering the object access frequency. Nevertheless, the Spatial OLAP query module is very incipient: operations like roll-up and drill-down, fundamental in decision support interfaces, are not provided. Hence, GeoMiner cannot be considered a truly SDW.

MapCube is defined by an operator that has a base map parameter, together with data tables and some cartographic preferences, to produce an album of maps, arranged through aggregation hierarchies. It is based on conventional data cube, but it enables the visualization of the results as data tables and maps. Despite of allowing spatial observation (through maps) of summarized data, MapCube does not support spatial roll-up/drill-down OLAP operations. Therefore, MapCube, as GeoMiner, cannot be considered a truly SDW.

As it can be inferred from the previous classification and from the Introduction, our MapWarehouse project is based on an integrated architecture. This architecture is based on well-established standards: Open Geospatial Consortium (OGC, 2005) and Common Warehouse Model (CWM, 2005). The use of such standards aims to achieve interoperability through the integration of heterogeneous data sources.

Heterogeneity in information systems has been classified as semantic, schematic and syntactic (Bishr, 1998). Currently our approach encompasses schematic and syntactic levels. However, as there is a strong interest in semantic heterogeneity, especially with the advent of the semantic Web, SDW may be modeled as ontological commitments which enable interoperability at semantic level. Such ontologies should be used in the extraction, transformation and loading process from heterogeneous spatial and OLAP data sources (Vassiliadis, Simitsis, & Skiadopoulos, 2002). Hence, semantic translations would be employed in order to transform the original data model into OGC and CWM standards used in our approach.

There are several works which address semantic interoperability. Mackey (1999) focuses on the issue of semantic integration of environmental models, in which both GIS and decision support systems play an important role. Fonseca, Davis, and Camara (2003) propose an ontology-driven GIS which aims to integrate heterogeneous GIS without demanding the use of a unique standard. Reitsma and Albrecht (2005) claim the use of ontologies to model earth systems which may provide interoperability among models and simulators. They argue that in the occurrence of natural disasters, the use of the semantic Web enables the integration of models with spatial decision-support systems, providing quick response to the emergency rescue teams.

Nonetheless, none of these works have addressed the integration of GIS with spatial DW in order to obtain an enhanced decision support system which may provide OLAP and spatial capabilities to better retrieve the underlying information.

A SPATIAL MULTIDIMENSIONAL MODEL

Our spatial multidimensional conceptual model integrates completely the common warehouse model (CWM) for DW with the OGC geometry object model (OGC, 2005). Moreover, extensions of traditional OLAP operations (especially drill-down, roll-up) to deal with spatial objects are proposed. For spatial queries, the use of spatial operations such as contains, meets, covers, intersection, union, buffer and so on, is considered. Finally, query results may be presented as maps and tables.

A CWM Schema is a logical container of elements of an OLAP model. It consists of Cube classes, which contain Dimension classes. Dimension classes contain Hierarchy classes, which are level-based (LevelBasedHierarchy classes). A Dimension class generalizes specific dimension classes, such as TimeDimension.

In order to support spatial elements, we extended the CWM model with a new dimension class, SpatialDimension, which extends the Dimension class. A spatial dimension may contain SpatialLevel objects inside Hierarchy classes — SpatialHierarchies. A SpatialLevel object can be shared by several spatial hierarchies. Moreover, we introduce a SpatialMeasure class that is part of the Cube class.

The Geometry class from the OGC specification contains a class hierarchy which may represent vector spatial data as points, lines, areas and collections of these elements. The details of that class are outside the scope of the chapter; the interested reader could refer to OGC (OGC, 2005). Concerning our integration model, the OGC Geometry class is part of both the SpatialLevel and SpatialMeasure classes.

Spatial Model Semantics

Now, we discuss in more details the semantics of the following spatial elements of the model: spatial hierarchy, spatial dimension, spatial fact, and spatial cube. In the discussion, dimension classes apart from the SpatialDimension class are sometimes named NonSpatialDimension classes.

A SpatialLevel class is composed of geometric classes for which the application needs to keep its geometry. SpatialLevel classes can relate to each other through topological relationships such as contains, intersects, overlaps, and so forth. A SpatialHierarchy class contains one or more SpatialLevel classes. Formally:

Definition 1. Spatial hierarchy.

Let $<$ be a symbol for the inside topological relationship between classes. A SpatialHierarchy class SH is a four-tuple $(SL, <_{SL}, \top_{SL}, \perp_{SL})$, where $SL = \{ SL_j, j = 1, \ldots, n\}$ are the SpatialLevel classes of SH with $n \geq 1$, $<_{SL}$ is the inside topological operator on the SL_j´s, with $\top_{SL} \in SL$ and $\perp_{SL} \in SL$ being the top and the bottom element of the ordering, respectively.

Figure 1 is an example of a SpatialHierarchy object, composed of three SpatialLevel objects partially related to each other through the contains topological relationship.

A NonSpatialDimension class is an aggregation criterion for NumericalMeasure classes, all along its NonSpatialHierarchy classes. The unique difference between a SpatialDimension class and a NonSpatialDimension one is that the former includes at least a SpatialHierarchy class. Formally:

Definition 2. Spatial dimension.

A SpatialDimension class D is a three-tuple (SH, ~SH, OT), where SH is a set of SpatialHierarchy classes, ~SH is a set of NonSpatialHierarchy classes, and OT is a set of other classes (that is, different from SpatialHierarchy classes and from NonSpatialHierarchy classes).

An example of a SpatialDimension class called Location would be:

SH = {municipality_geometry < microregion_geometry < region_geometry < state_geometry}
~SH = {municipality_name < microregion_name < region_name < state_name}
OT = {municipality_area, estimated_population}

A SpatialMeasure class is composed of a (set of) Geometry class(es), and it can be aggregated according to either SpatialDimension or NonSpatialDimension classes. Figure 2 shows a CropArea — a SpatialMeasure class — object, which is a set of geometric objects (areas) associated with at least a Location — a SpatialDimension class — object, and a Plantation — a NonSpatialDimension class — object (bean). Figure 3 shows the map overlay of two CropArea objects.

A *SpatialMeasure* class can be formalized as follows:

Definition 3. Spatial measure.

Let SpatialDimension classes SD and NonSpatialDimension classes ~SD. A SpatialMeasure class SM is a tuple (G, R), where G is a non-empty set of geometric classes, and R is a geometric-dimension relation $\{(g_i, d_j), i = 1,\ldots m;\ j = 1, \ldots, n\}$, where $g_i \in G$ and $d_j \in (SD \cup {\sim}SD)$.

A SpatialDataCube class represents an n-dimensional array, in which each cell of the array is either a SpatialMeasure or a NumericalMeasure class, while the dimensions of the array are both SpatialDimension and NonSpatialDimension classes. We may now define formally SpatialDataCube classes.

Definition 4. Spatial data cube.

A SpatialDataCube class SDC is a tuple $(SD \cup {\sim}SD, SM \cup NM, GR, {\sim}GR)$, where SD is a set of SpatialDimension classes, ~SD is a set of NonSpatialDimension classes, SM is a set of SpatialMeasure classes, NM is a set of NumericalMeasure classes, GR is a set of Geometric-Dimension relations and ~GR is a set of NonGeometric-Dimension relations.

In the following section, we precise how one can implement SpatialDataCube classes and their extents.

Figure 1. A spatial hierarchy

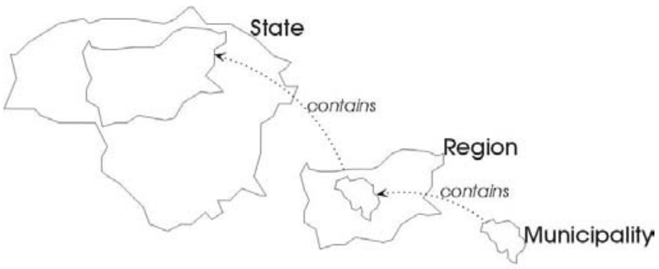


Figure 2. Spatial measures and their location

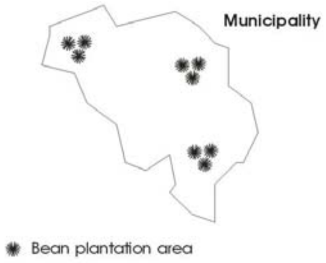
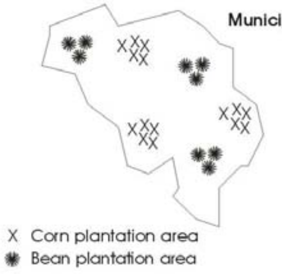


Figure 3. Geometric union of spatial measures



TOWARDS AN OBJECT-RELATIONAL SPATIAL DATA CUBE

A SpatialDataCube class can be implemented as an object-relational (O-R) type, in the following manner. Each Spatial(NonSpatial)Dimension class is mapped to a distinct O-R type — an O-RDimension type. The set of SpatialMeasure classes, together with the set of NumericalMeasure classes, and together with the set of Geometric(NonGeometric)-Dimension relations are mapped to another O-R type — the O-RFact type. The O-RDimension(Fact) type extents are respectively typed tables. We denote O-R spatial data cube this O-R simulation of a spatial data cube. An O-R spatial data cube is formally defined as follows:

Definition 5. O-R spatial data cube.
An *O-R Spatial Data Cube* is constructed from a SpatialDataCube class SDC as follows:

$\forall$ Spatial(NonSpatial)Dimension class $D_i \in$ SDC,
$f_{\text{D-mapping}}$: $D_i \rightarrow$ O-RD_i, where O-RD_i is an O-RDimension type;
$\forall$ SpatialMeasure class SM $\in$ SDC, NumericalMeasure class NM $\in$ SDC, Geometric-Dimension relation GR $\in$ SDC, NonGeometric-Dimension relation ~GR $\in$ SDC
$f_{\text{F-mapping}}$: (SM $\cup$ NM $\cup$ GR $\cup$ ~GR) $\rightarrow$ (O-RSM $\cup$ O-RNM $\cup$ O-RGR $\cup$ O-R~GR) = O-RFact, where O-RFact is an O-R type;
$\forall$ O-RD_i, $f_{\text{Dtable-mapping}}$: O-$RD_i$ $\rightarrow$ O-$RDTable_i$, where O-$RDTable_i$ is a typed table of O-RD_i;
For the O-RFact, $f_{\text{Ftable-mapping}}$: O-RFact $\rightarrow$ O-RFactT, where O-RFacT is a typed table of O-RFact.
Figure 4 illustrates an O-R spatial data cube.

We can clearly visualize here something like the Kimball's Relational Star Schema (Kimball & Ross, 2002). That is only similar, not equal. Notice that the AgroDistribution fact table is not in 1^{ST} normal form, because of the non-atomic spatial measure crop_area and the non-atomic non-spatial measure crop-quantity. Shortly, our *O-R Spatial Data Cube Schema* — or *O-R Spatial Star Schema* to pay homage to Kimball — is not 1NF-normalized. Also, we emphasize the REF types in the AgroDistribution table, so eliminating foreign keys, which are truly artificial columns.

As for relational star schemata, by embedding spatial or non-spatial hierarchies, dimension tables may not be 3NF-normalized; for instance, the dimension tables Location and Time in Figure 4 are not 3NF-normalized, in view of their embedded hierarchies.

In order to avoid redundancies of large geometry objects in non-3FN-normalized dimension tables, these objects may be only referenced in the dimension tables (see the Location table, Figure 4) — this elegant solution is not directly supported by relational star schemata.

Like relational star schemata, O-R star schemata obliterate spatial (non-spatial) hierarchies. Observe in table Location, Figure 4, that the spatial hierarchy municipality_geometry ← micro-region_geometry ← region_geometry ← state_geometry, as well as the non-spatial hierarchy farm_name ← municipality_name ← micro-region_name ← region_name ← state_name, are obliterated, due to the still poor semantics of the O-R model, when compared with our conceptual model, in which hierarchies are explicitly defined.

Spatial OLAP Operations

Spatial or geometric aggregate functions for operating through spatial or non-spatial hierarchies are mandatory for O-R spatial star schemata with spatial OLAP interfaces. In particular, we remark the *spatial roll-up* and *drill-down* operations. The action of *spatial roll-up* is straightforward: it creates geometric aggregate values that roll up from the most detailed level to the least detailed level, following a spatial or non-spatial hierarchy. *Spatial drill-down* is the reverse operation of roll-up. Using the UML-Object Constraint Language formalism (Warmer & Kleppe, 1998), we may define these operators as specified in Rule 1.

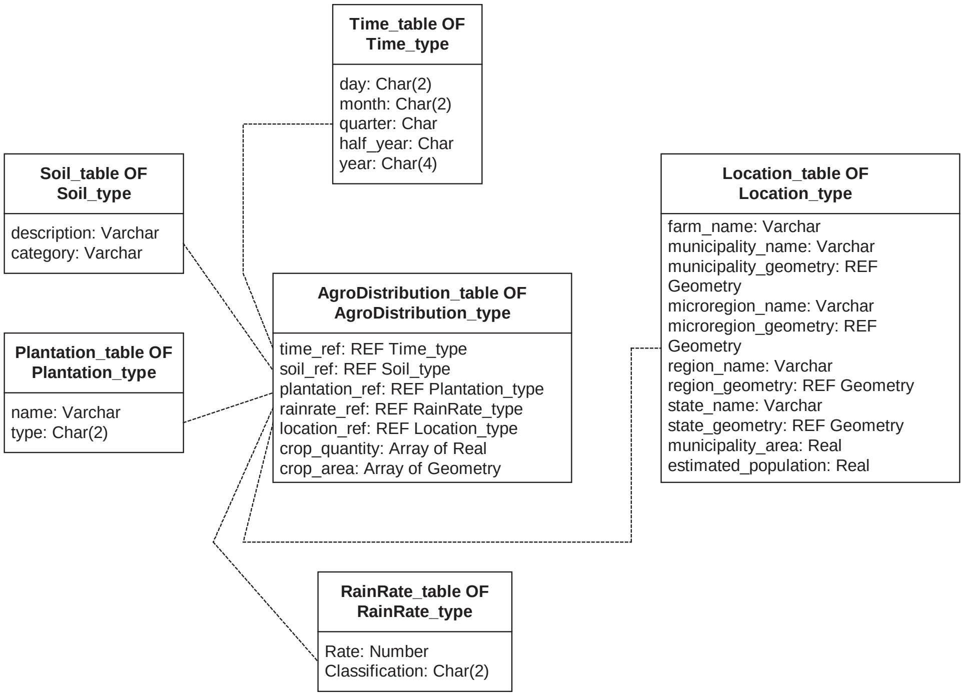
The formalism for the spatial drill-down operation is similar to the roll-up one as specified in Rule 2.

An example of a *spatial roll-up* operation is given in next section.

Querying the O-R Spatial Star Schema

Although there is no SQL implementation for spatial OLAP, we have proposed an O-R SQL query language suitable for O-R spatial star schemata. In order to show the expression power of the language, we give an example that uses a spatial roll-up operation. This query, over the spatial star schema in Figure 4, is “Retrieve the corn crop areas for each micro-region and for each region of the state of Paraíba, during May 2003”.

Figure 4. A spatial data cube example



Rule 1. Spatial roll-up

```
   Parameters:
    d      imRLUP: set of dimensions which rolls up n levels according to the set nLevels
    n      Levels: bag of integer which indicates how many levels to rollup in the hierarchy
         m: set of measures to be aggregated
    a      ggFunc: set of aggregation functions
   Returns:  a new data cube

   context Cube:: spatial_rollup(dimRLUP: Set(Dimension), nLevels:Bag(Integer), m:
Set(Measure), aggFunc:
                     Set(String)): Cube
   pre:      -- verify whether all rollup dimensions are in the current Cube
             self.containsDimensions-> includeAll(dimRULP) and
             -- verify whether all  measures to be aggregated are in the current Cube
             self.containsMeasures-> includeAll(m)  and
             -- make sure that all rollup dimensions are not in the last level
             dimRLUP-> forAll(d1 | d1.currentLevel.hierarchyOwn.childOf <> null) and
             -- make sure that exists at least a spatial dimension or spatial measure
             (dimRLUP-> exists(d2 | d2.isSpatial = true) or m-> exists(m1 | m1.isSpatial = true))
  and
             -- verify whether the dimension set size is equals to the levels of rollup set size
             dimRLUP-> size()  =  nLevels -> size()
             -- verify whether the measure set size is equals to the aggregation function set size
             m-> size()  =  aggFunc -> size()
   inv:    -- update dimension levels
            let dimNewLevels: Set(Dimension) = dimRLUP -> iterate(d:Dimension; resultSetD:
  Set(Dimension)
                   = Set{} | resultSetD.including(d| upLevel(nLevels -> at (dimRLUP ->
  indexOf(d)))))
             in  createNewCube(m->iterate(i:Measure; resultSetM: Set(Cube) = Set{} |
             if m.isSpatial then
             resultSetM->including(self.aggregateSpatialFunction(aggFunc->at(m-> indexOf(i), i,
  dimNewLevels)
              endif   ))



   post:
         result.oclNew()
```

```
Select rl.region_geometry, rl.microregion_geometry,
rl.crop_area
From Location_table l, Plantation_table p, Time_table
t, AgroDistribution_table a, Roll-up(l.region_geometry,
l.microregion_geometry, Geometric_Union(a.crop_area))
rl
Where l.municipality_name = a.location_ref.municipal-
ity_name
And t.month = a.time_ref.month And t.year = a.time_ref.
year And p.name = a.plantation_ref.name And t.year
= '2003' And t.month = '05' And p.name = 'corn' And
l.state_name = 'Paraíba'
```

The main important new feature of the language is its FROM clause. The new interpretation of this clause is as follows: in it, we define single scan variables, each one associated to its collection — typed table, function returning an object-collection type value, etc. —; more precisely, the state of a scan variable, at any time, is

Rule 2. Spatial drill-down

```
    Parameters:
     d   imDROWN: set of dimensions which drills down n levels according to the set nLevels
        nLevels: bag of integer which indicates how many levels to drill down in the hierarchy
         m: set of measures to be aggregated
        detFunc: set of detailed functions
    Returns:  a new data cube


    context Cube:: spatial_drilldown(dimDROWN: Set(Dimension), nLevels:Bag(Integer), m:
Set(Measure),
            detFunc: Set(String)): Cube
 p    re:    -- verify whether all drilldown dimensions are in the current Cube
             self.containsDimensions-> includeAll(dimDROWN) and
             -- verify whether all measure to be aggregated are in the current Cube
             self.containsMeasures-> includeAll(m)  and
             -- make sure that all drill-down dimensions are not in the  last level
             dimDOWN-> forAll(d1 | d1.currentLevel.hierarchyOwn.parentOf <> null) and
             -- make sure that exists at least a spatial dimension or spatial measure
             (dimDOWN-> exists(d2 | d2.isSpatial = true) or m-> exists(m1 | m1.isSpatial = true))
and
             -- verify whether the dimension set size is equals to the levels of drill-down set size

             dimDOWN-> size()  =  nLevels -> size()
             -- verify whether the measure set size is equals to the detailed function  set size
             m-> size()  =  detFunc -> size()
    inv:     -- update dimension levels
             let dimNewLevels: Set(Dimension) = dimDOWN -> iterate(d:Dimension;
 resultSetD: Set(Dimension)
                  = Set() | resultSetD.including(d| downLevel(nLevels -> at (dimDOWN ->
indexOf(d)))))
        in  if self.Schema.findCube(dimNewLevels) = null then
                createNewCube(m-> iterate(i:Measure; resultSetM: Set(Cube) = Set{} |
                    if m.isSpatial then
                       resultsetM -> including(self.detailSpatialFunction(detFunc-> at(m ->
 indexOf(i), i,
                                      dimNewLevels))
                    else   resultSetM -> including(self.detailNumericFunction(detFunc-> at(m->
 indexOf(i), i,
                                      dimNewLevels))
                    endif
                ))
            else
                self.Schema.findCube(dimNewLevels)
            endif

   post:      result.oclNew()
```

one and only one of the objects of its associated collection. Formally, the FROM clause is a set of pairs <collection> <scan_variable>. In the example-query, l (p) (t) (a) scans Location_table (Plantation_table) (Time_table) (AgroDistribution_table), while rl scans the collection returned by the function roll-up.

The roll-up function arguments are, in this order: (1) the virtual top element in the spatial hierarchy, (2) the virtual bottom element, and (3) the geometric aggregation function. This function returns a collection, more precisely a table from which the columns are respectively <tableScan_variable>.<top_element>, <tableScan_variable>.<bottom_element>, and <tableScan_variable>.<aggregationFunction_argument>. In the query example, the returned table is scanned by the variable rl, and this table is the result of the query itself.

Figures 5 and 6 are the visualization of the query outputs at the micro-region and region levels for the state of Paraíba, respectively. In these figures, crop areas are represented by geometric points, while that micro-regions and regions are represented by polygons. Gray areas in the maps indicate those municipalities inside their micro-regions (regions) with corn plantations, while that blank areas indicate absence of corn plantations.

QUERY OPTIMIZATION

In this section, we consider the problem of guaranteeing the good performance of the OLAP spatial queries submitted to MapWarehouse, through its GUI. First, we characterize what we call *the spatial optimization problem*.

The Spatial Optimization Problem

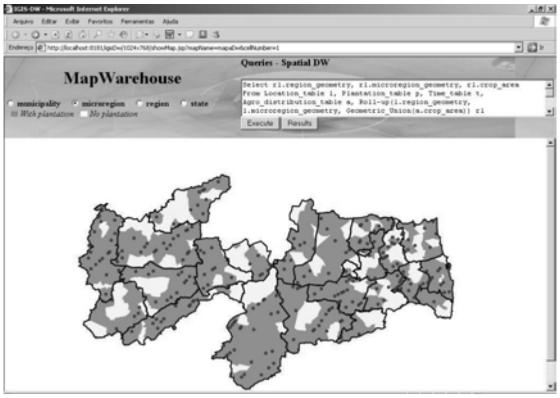
The spatial optimization problem may so be characterized. Consider, for example, only the geography of Brazilian State of Paraíba. Its political division is depicted in Figure 7.

Suppose that only the base-level data and its dimension data are pre-stored. We have thousands of plantations (corn, bean, rice, etc.). Regarding uniquely the example-query (corn plantations in the state of Paraíba — section *Querying the O-R Spatial Star Schema*), and supposing there exists in average 50 plantations by municipality, this gives approximately 11,150 geometries, so distributed:

11,150 crop areas;
223 municipality geometries;
23 micro-region geometries;
4 region geometries;
1 state geometry;
Total: 11,401 geometries, approximately.

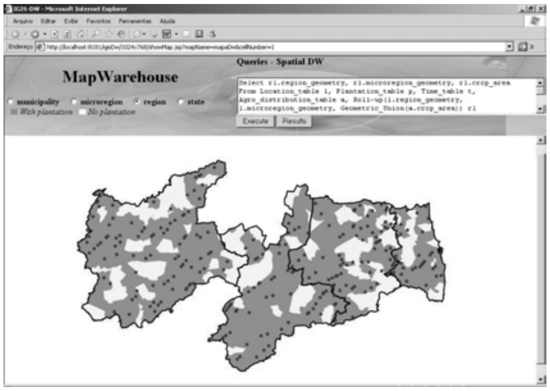
In addition to this, new maps must be dynamically generated, resulting from unions of crop areas and municipality geometries, from unions of

Figure 5. Roll-up operation plantation ← micro-region



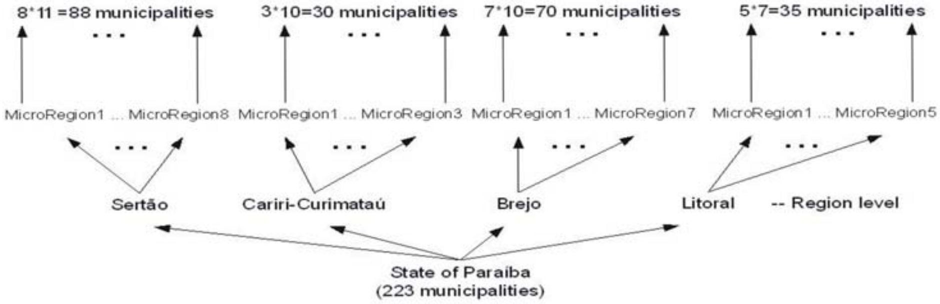
```
Select rl.region_geometry, rl.microregion_geometry, rl.crop_area
From Location_table l, Plantation_table p, Time_table t,
Agro_distribution_table a, Roll-up(l.region_geometry,
l.microregion_geometry, Geometric_Union(a.crop_area)) rl
```

Figure 6. Roll-up operation micro-region ← region



```
Select rl.region_geometry, rl.microregion_geometry, rl.crop_area
From Location_table l, Plantation_table p, Time_table t,
Agro_distribution_table a, Roll-up(l.region_geometry,
l.microregion_geometry, Geometric_Union(a.crop_area)) rl
```

Figure 7. Instantiation of the example´s spatial hierarchy



municipality and micro-region geometries, and from micro-region and region geometries. The question that should be answered is: how many spatial union operations are necessary for the query in section *Querying the O-R Spatial Star Schema*? For this, we have:

223 * 50 = 11,150 union operations crop-municipality;
8*11 + 3*10 + 7*10 + 5*7 = 223 union operations (crop-municipality) - micro-region;
1*8 + 1*3 + 1*7 + 1*5 = 23 union operations (crop-municipality-micro-region) – region;
Total: 11,396 union operations, approximately.

The next step consists in calculating the cost of these 11,396 union operations.

The spatial optimization problem may be generically stated as follows: *given a spatial query, how many concerned spatial aggregation operations must be previously computed, in order to accomplish the query response time requirement?*

Very importantly, the database administrator (DBA) must assume the query performance control, or the DBA must not fight the DBMS optimizer. These considerations lead to an optimization logical model.

The Spatial Logical Optimization

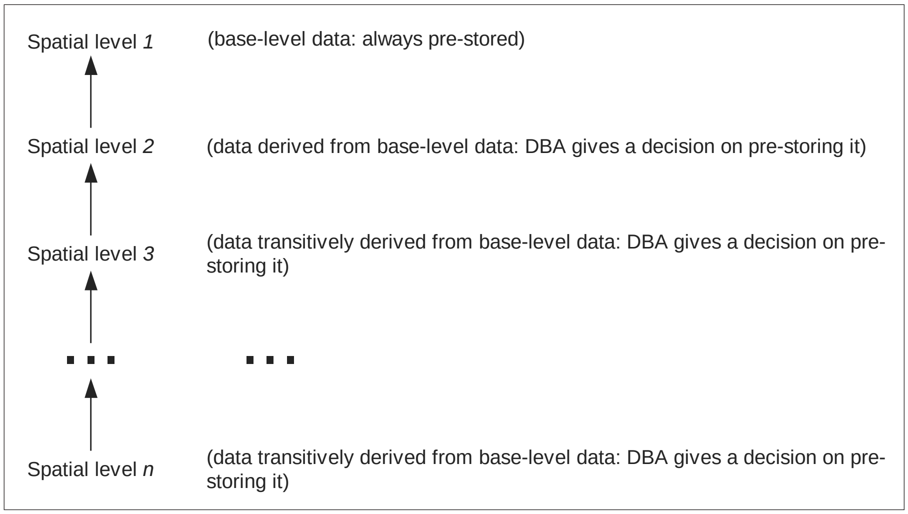
Our spatial optimization logical model is based on the mechanism of pre-storing spatial aggregates — pre-stored spatial aggregates — an extension of the notion of Kimball's pre-stored summary aggregates (Kimball & Ross, 2002). According to Kimball, an aggregate is a fact table record representing a summarization of base-level fact table records; an aggregate fact table record is always associated with one or more aggregate dimension table records.

The extension of this definition, suitable to the SDW context, is such as: a spatial aggregate is a spatial measure of an object in a base-level typed table representing a summarization of spatial measures of objects of the base-level typed table; a spatial aggregate is always associated with one or more aggregate objects in aggregate dimension typed tables. For example, referring to Figure 4, we can imagine the following spatial aggregates:

- Municipality-level crop area aggregates by plantation by day (a one-way spatial aggregate)
- Micro-region-level crop area aggregates by day (a one-way aggregate)
- Region-level crop area aggregates by micro-region (a two-way aggregate)
- Region-level crop area aggregates by micro-region by month (a three-way aggregate)

A pre-stored spatial aggregate is a spatial aggregate computed and stored before query executions which may use it. Pre-stored spatial aggregates are tightly related to spatial hierarchies — Figure 8.

Figure 8. Spatial hierarchy and pre-stored spatial aggregates

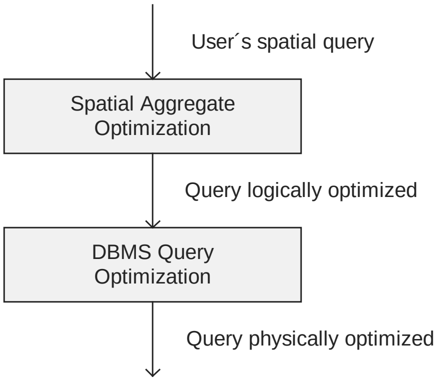


The rationale for our spatial optimization logical model makes the best of a good situation of using pre-stored spatial aggregates in order to ameliorate the performance of the spatial queries; in fact, queries are re-written for accessing the chosen pre-stored spatial aggregates. Once conveniently re-written, queries are still submitted to the specific DBMS's query optimizer — physical optimization — Figure 9.

Returning to our example, the critical factor for the performance of the query in section *Querying the O-R Spatial Star Schema* is the computation of the 11,150 spatial aggregates (here, union operations) at the level 2 — municipality-geometry – of the spatial hierarchy crop_area ← municipality-geometry ← micro-region-geometry ← region-geometry ← state-geometry. Supposing that all corn spatial aggregates at the municipality level — typed table **MunicipalityAgroDistribution_table** (a new fact table) linked to the typed table **Municipality_table** (a new dimension table) and the dimension tables in Figure 4 except Location_table, a one-way spatial aggregate transparent to the user — have been pre-stored, the query is so automatically rewritten:

```
Select rl.region_geometry, rl.microregion_geometry, rl.crop_area
From Municipality_table l, Plantation_table p, Time_table t, MunicipalityAgroDistribution_table a, Roll-up(l.region_geometry, l.microregion_geometry, Geometric_Union(a.crop_area)) rl
Where l.municipality_name = a.location_ref.municipality_name
And t.month = a.time_ref.month And t.year = a.time_ref.year And p.name = a.plantation_ref.name And t.year = '2003' And t.month = '05' And p.name = 'corn' And l.state_name = 'Paraíba'
```

Figure 9. Types of optimization supported by MapWarehouse



Notice that the two boldface items in the previous query are the items that are different between the base-level query and the municipality-aggregate-level query. Upon close inspection, we see that all the logical optimizer has done is to substitute the Location_table dimension table by the Municipality_table dimension table, and the AgroDistribution_table fact table by the MunicipalityAgroDistribution_table fact table.

THE MAP WAREHOUSE PROTOTYPE

In order to validate the previous ideas we have implemented a prototype called *MapWarehouse,* which implements O-R spatial star schemata in an object-relational DBMS, and with a logical query optimizer according to the discussion in the previous section. Particularly in this prototype, we have chosen the Oracle Object-Relational DBMS due to its support to spatial data, including the OGC Standard and the provision of OLAP infra-structure, by implementing CWM (Oracle, 2005).

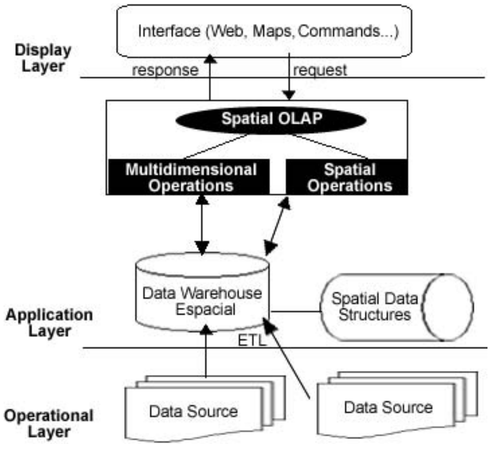
The Oracle spatial capabilities are implemented by the Oracle Spatial Cartridge, which uses the MDSYS schema; CWM is implemented via the CWMLITE metadata packages, the OLAPSYS schema and OLAP API.

The MapWarehouse project implements a new Java-based package known as CWM_OLAP_SPATIAL, which extends the CWNLITE package with spatial measures, dimensions, topological operations and spatial roll-up and spatial drill-down. Spatial data is indexed using R-tree.

The MapWarehouse architecture, as shown in Figure 10, is based on three layers:

- **Operational layer:** composed of the conventional and spatial data sources to model the Spatial DW through the extraction, transformation and loading process (ETL)

Figure 10. The MapWarehouse architecture

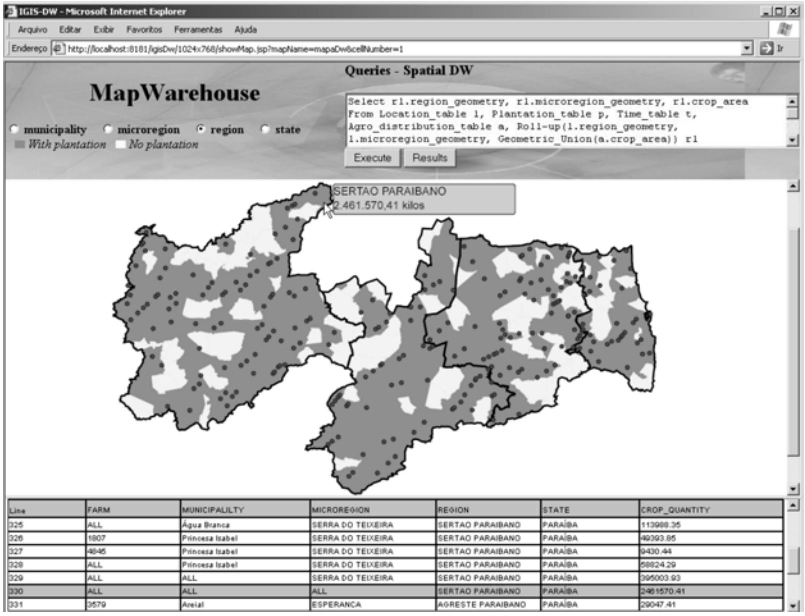


- **Application layer:** responsible for the Spatial OLAP user request processing. It accesses the CWM/OpenGIS metadata and datasources
- **Display layer:** defines the user interface, according to the previous mentioned requirements

The user interface (GUI) enables to visualize the query results through maps and tables. The maps are rendered using SVG format (SVG, 2005) and they are dynamically produced using the iGIS map server (Baptista, Leite Jr., Silva, & Paiva, 2004). iGIS is a framework for rapid application development of GIS applications on the Web. It may use different datasources, such as Oracle, Postgresql, IBM DB2 and GML. Also, iGIS may use different map rendering including SVG, SGV Tiny and JPEG. User interaction on maps includes zooming, panning, information, and tooltip. This user interface is presented in Figure 11. In this figure, the radio buttons indicate the spatial level (state, region, micro-region or municipality), so that user may execute spatial roll-up or spatial drill-down. In the text box, users may pose their queries using the proposed query language.

The map is presented according to the executed query and a table which contains numeric information about the query is presented. In Figure 11,

Figure 11. The MapWarehouse GUI



```
Select rl.region_geometry, rl.microregion_geometry, rl.crop_area
From Location_table l, Plantation_table p, Time_table t,
Agro_distribution_table a, Roll-up(l.region_geometry,
l.microregion_geometry, Geometric_Union(a.crop_area)) rl
```

Line	FARM	MUNICIPALILTY	MICROREGION	REGION	STATE	CROP_QUANTITY
325	ALL	Água Branca	SERRA DO TEIXEIRA	SERTAO PARAIBANO	PARAÍBA	113988.35
326	1807	Princesa Isabel	SERRA DO TEIXEIRA	SERTAO PARAIBANO	PARAÍBA	49393.85
327	4846	Princesa Isabel	SERRA DO TEIXEIRA	SERTAO PARAIBANO	PARAÍBA	9430.44
328	ALL	Princesa Isabel	SERRA DO TEIXEIRA	SERTAO PARAIBANO	PARAÍBA	58824.29
329	ALL	ALL	SERRA DO TEIXEIRA	SERTAO PARAIBANO	PARAÍBA	395003.93
330	ALL	ALL	ALL	SERTAO PARAIBANO	PARAÍBA	2461570.41
331	3579	Areial	ESPERANCA	AGRESTE PARAIBANO	PARAÍBA	29047.41

the user has pointed to the *Sertão* region and the tooltip is activated. Then, the equivalent tabular data is highlighted in the underlying table.

During the experiments, spatial data related to the Brazilian State of Paraiba was used. This state is divided into regions, micro-regions and municipalities. Beside the spatial location, this dataset is temporal, from 2002 to 2003 in which day is the minimum granularity, and it contains plantation type, soil type, and rain rate. The whole size of the database is approximately 250,000 tuples.

The server computer used during the experiments was an Athlon XP 2.5 GHz processor with 1024 MB RAM. The Web browser was the Microsoft Internet Explorer 6.0 with the Adobe SVG Viewer 3.0. The Apache Tomcat/5.0.16 was used as Application Server. We used Java technology (JSP and Servlets) to implement MapWarehouse business logic.

In the experiments we run several queries with and without query optimization. In the following the query: "retrieve the total of all crops (rice, bean, corn, etc) produced in June 2003 by municipality, micro-region, region and state" is detailed. This query can be posed using our extended SQL as:

```
Select rl.state_geometry, rl.region_geometry, rl.microregion_geometry, rl.municipality_geometry, rl.crop_area
From Location_table l, Plantation_table p, Time_table t, AgroDistribution_table a, Roll-up(l.state_geometry, l.municipality_geometry, Geometric_Union(a.crop_area)) rl
Where l.municipality_name = a.location_ref.municipality_name And t.month = a.time_ref.month And t.year = a.time_ref.year And t.year = '2003' And t.month = '06' And l.state_name = 'Paraíba'
```

Table 1 shows the costs of the previous query with and without query optimization. Notice that by using the query optimization the query is rewritten according to the technique explained in the section *Query Optimization*.

During the tests, we have noticed that by using query optimization based on pre-stored spatial aggregates the overall response time is reduced in

Table 1. Performance evaluation

Costs	Without Query Optimization	With Query Optimization
Cost of pre-storing spatial aggregates	25 sec.	0 sec.
Cost of map generation	25 sec.	25 sec.
Cost of map loading	10 sec.	10 sec.
Total cost	60 sec.	35 sec.

almost 50%. This performance gain is improved for large datasets.

CONCLUSION

Although data warehouse and geographical information system technologies are very useful in the decision making process, usually they are used separately. Research on integrating these two technologies is in its infancy. This integration coins new terms: spatial datawarehouse (SDW) and spatial OLAP (SOLAP). By using SOLAP, users may enhance their capacity to explore the underlying dataset once spatial methods incorporated into OLAP ones may be used.

In this chapter we have proposed an integrated architecture for a SDW. The main contributions of our proposal include: a formalized data model for SDW; a SQL extension query language which enables spatial roll-up and drill-down; optimization techniques which improve performance of complex spatial queries by pre-storing spatial aggregates; and a prototype, *MapWarehouse*, which validates the ideas proposed.

In order to achieve interoperability, we have chosen to use well-known standards such as OGC for dealing with spatial data and CWM for OLAP. This approach aims to facilitate the integration of *MapWarehouse* with other systems. However, we recognize that the interoperability provided is at schematic and syntactic level. Hence, it is important to mention that a new layer based on semantic Web concepts ought to be developed so that semantic interoperability may be achieved.

As further work, we plan to improve usability as currently user needs to know the query language syntax and the underlying schema in order to pose their queries. We plan to develop a visual query language for SOLAP to facilitate user interaction.

Also, the provision of ad-hoc dimensions, which are defined on-the-fly, is another important issue to be addressed. Nowadays, the spatial interaction is done via predefined hierarchies (e.g., State, Region, Micro-region and Municipality); however, sometimes user may choose an arbitrary area via a bounding box and he demands for aggregation on that specific area. In that case, the aggregation is done on-the-fly and new indexing mechanisms need to be investigated.

Finally, another interesting work is to extend the *MapWarehouse* architecture to Web services. Thus, distributed SDW may be provided and SOLAP becomes a service which may be automatically discovered and invoked.

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Chapter 8.9

A Multi-Agent Decision Support Architecture for Knowledge Representation and Exchange

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ABSTRACT

Organizations rely on knowledge-driven systems for delivering problem-specific knowledge over Internet-based distributed platforms to decision-makers. Recent advances in systems support for problem solving have seen increased use of artificial intelligence (AI) techniques for knowledge representation in multiple forms. This article presents an Intelligent Knowledge-based Multi-agent Decision Support Architecture" (IKMDSA) to illustrate how to represent and exchange domain-specific knowledge in XML-format through intelligent agents to create, exchange and use knowledge in decision support. IKMDSA integrates knowledge discovery and machine learning techniques for the creation of knowledge from organizational data; and knowledge repositories (KR) for its storage management and use by intelligent software agents in providing effective knowledge-driven decision support. Implementation details of the architecture, its business implications and directions for further research are discussed.

INTRODUCTION

The importance of knowledge as an organizational asset that enables sustainable competitive advantage explains the increasing interest of organizations in KM. Many organizations are developing knowledge management systems (KMS) that are specifically designed to facilitate the sharing and integration of knowledge, as opposed to data or information, in decision support activities (Bolloju, Khalifa, & Turban, 2002). Decision support systems (DSS) are computer technology solutions used to support complex decision-making and problem solving (Shim, Warkentin, Courtney, Power, Sharda, & Carlsson, 2002). Organizations are becoming increasingly complex with emphasis on decentralized decision-making. Such changes create the need for DSS that focus on supporting problem solving activities on distributed platforms by providing problem specific data and knowledge to a decision maker anywhere, using Internet-based technologies. This trend necessitates enterprise DSS for effective decision-making with processes and facilities to support the use of knowledge management (KM).

Recent advances in systems support for problem solving and decision-making witness the increased use of artificial intelligence (AI) based techniques for knowledge representation (Goul, 2005; Whinston, 1997). Knowledge representation takes multiple forms including the incorporation of business rules, decision analytical models and models generated from the application of machine learning algorithms. Intelligent decision support systems (IDSS) incorporate intelligence in the form of knowledge about the problem domain, with knowledge representation to inform the decision process, facilitate problem solving and reduce the cognitive load of the decision maker. Weber and Aha (2003) identified requirements for organizational KMS where the central unit is a repository of knowledge artifacts collected from internal or external organizational sources. These KMS can vary based on the type of knowledge artifact stored, the scope and nature of the topic described and the orientation (Weber & Aha, 2003). Ba, Lang and Whinston (1997) enumerate the KM principles necessary to achieve intra-organizational knowledge bases as: (1) the use of corporate data to derive and create higher-level information and knowledge, (2) provision of tools to transform scattered data into meaningful business information. Knowledge repositories play a central and critical role in the storage, distribution and management of knowledge in an organization. Interestingly, Bolloju et. al. (2002) proposed an approach for integrating decision support and KM that facilitates knowledge conversion through suitable automated techniques to:

1. apply knowledge discovery techniques (KDT) for knowledge externalization,
2. employ repositories for storing externalized knowledge, and
3. extend KDT for supporting various types of knowledge conversions.

This article is motivated by these principles and attempts to develop and present an intelligent knowledge-based multi-agent architecture for knowledge-based decision support using eXtensible Markup Language (XML) related technologies for knowledge representation and knowledge exchange over distributed and heterogeneous platforms. The proposed architecture integrates DSS and KMS using XML as the medium for the representation and exchange of domain specific knowledge, and intelligent agents to facilitate the creation, exchanges and use of the knowledge in decision support activities. This is the primary contribution of this research to the existing body of knowledge in DSS, KMS and multi-agent research.

This research builds on existing bodies of knowledge in intelligent agents, KM, DSS and XML technology standards. Our research focuses on achieving a transparent translation between XML and Decision Trees through software agents. This creates the foundation for knowledge representation and exchange, through intelligent agents, to support decision-making activity for users of the system. We use a knowledge repository to store knowledge, captured in XML documents, that can used and shared by software agents within the multi-agent architecture. We call this architecture an *Intelligent Knowledge-based Multi-agent Decision Support Architecture* (IKMDSA). IKMDSA integrates KDT and knowledge repositories for storing externalized knowledge. It utilizes an intelligent multi-agent system with explanation facility to provide distributed decision support using Internet-based technologies. The implementation incorporates, and is built upon XML and its related technologies to achieve knowledge representation, storage and knowledge exchange among participating intelligent agents to deliver decision support to the user. The proposed IKMDSA incorporates mechanisms whereby agents can provide distributed intelligent decision support by exchanging their knowledge using XML and its related set of standards. Implementation details of the implementation of the architecture and their implications for further research in this area by academics and practitioners are provided.

In the second section, we review relevant literature in intelligent agents and the role of decision trees in inductive learning and knowledge representation in terms of decision rules. In the third section, we discuss the role of XML in representing and facilitating knowledge exchange for intelligent agents. The fourth section provides a detailed description of the various components of the IKMDSA architecture and their interrelationships in facilitating the creation, representation, exchange and use of domain specific knowledge for decision support tasks. In the fifth section, we provide a detailed description of the implementation of the architecture through the use of an illustrative example. The sixth section 6 includes a discussion of the implications of integrating KMS and DSS support in business, and the role of the proposed IKMDSA architecture. The seventh section concludes with limitations and future research directions.

LITERATURE REVIEW

Software Agents and Intelligent Decision Support Systems (IDSS)

An intelligent agent is "a computer system situated in some environment and that is capable of flexible autonomous action in this environment in order to meet its design objectives" (Jennings & Wooldridge, 1998). While the terms agents, software agents and intelligent agents are often used interchangeably in the literature, all agents do not necessarily have to be intelligent. Jennings and Wooldridge (1998) observe that agent-based systems are not necessarily intelligent, and require that an agent be flexible to be considered intelligent. Such flexibility in intelligent agent based systems requires that the agents should be: (Bradshaw, 1997; Jennings & Wooldridge, 1998)

- cognizant of their environment and be *responsive* to changes therein;
- reactive and proactive to opportunities in their environment;
- autonomous in goal-directed behavior;
- collaborative in their ability to interact with other agents in exhibiting the goal-oriented behavior; and
- adaptive in their ability to learn with experience.

Agent-based systems may consist of a single agent engaged in autonomous goal-oriented behavior, or multiple agents that work together to exhibit granular as well as overall goal directed behavior. The general multi-agent system is one in which the interoperation of separately developed and self-interested agents provide a service beyond the capability of any single agent model. Such mutli-agent systems provide a powerful abstraction that can be used to model systems where multiple entities, exhibiting self directed behaviors must coexist in a environment and achieve the system wide objective of the environment.

Intelligent agents are action-oriented abstractions in electronic systems entrusted to carry out various generic and specific goal-oriented actions on behalf of users. The agent abstraction manifests itself in the system as a representation of the user and performs necessary tasks on behalf of the user. This role may involve taking directions from the user on a need basis and advising and informing the user of alternatives and consequences (Whinston, 1997). The agent paradigm can support a range of decision making activity including information retrieval, generation of alternatives, preference order ranking of options and alternatives and supporting analysis of the alternative-goal relationships. In this respect, intelligent agents have come a long way from being digital scourers and static filters of information to active partners in information processing tasks. Such a shift has significant design implications on the abstractions used to model information systems, objects or agents, and on the architecture of information resources that are available to entities involved in the electronic system. Another implication is that knowledge must be available in formats that are conducive to its representation and manipulation by software applications, including software agents.

Decision Trees and IDSS

Models of decision problems provide analytical support to the decision maker by facilitating a greater understanding of the problem domain and allowing the decision maker to assess the utility of alternative decision paths with respect to achieving the objective of the decision task. Decision trees are a popular modeling technique with wide applicability to a variety of business problems (Sung, Chang, & Lee, 1999). The performance of a particular method in modeling human decisions is dependent on the conformance of the method with the decision makers' mental model of the decision problem (Kim, Chung, & Paradice, 1997). Simplicity of model representation is particularly relevant if the discovered explicit models are to be internalized by decision makers (Bolloju et al., 2002). Decision Trees represent a natural choice for IDSS whose goal is to generate decision paths that are easy to understand, to explain and to convert to natural language (Sung et al., 1999). The choice of decision trees as the modeling methodology affords the ability to incorporate inductive learning in the IDSS. Decision trees are among the most commonly used inductive learning techniques used to learn patterns from data (Kudoh, Haraguchi, & Okubo, 2003; Takimoto & Maruoka, 2003). The ID3, C4.5, and SEE5 algorithms provide a formal method to create and model decision rules from categorical and continuous data (Quinlan, 1996; Sung et al., 1999) compared multiple machine learning techniques in predicting bankruptcies and found that the decision tree technique had the most interpretive power. In this research, the C4.5 (ID3) method is used due to the popularity of the algorithm (Kiang, 2003).

Additionally, decision trees solutions lend themselves to automatic generation of structured queries to extract pertinent data from organizational data repositories (Adriaans & Zantinge, 1996). This makes them particularly useful in providing insights and explanations for the non-technical user (Apte & Weiss, 1997). Decision trees are especially suitable for decision problems that require the generation of human understandable decision rules based on a mix of classification of categorical and continuous data (Quinlan, 1996; Sung et al., 1999). They provide clear indication of the importance of individual data fields to the decision problem and are therefore useful in reducing the cognitive burden of the decision maker. It is clear that decision trees represent a powerful and easily interpretable technique for modeling business decisions that can be reduced to a rule-based form. The benefits of the technique highlighted above provide a strong basis for choosing decision trees as a component for intelligent DSS.

USING XML AND DECISION TREES FOR KNOWLEDGE REPRESENTATION AND EXCHANGE

XML and Document Type Definitions (DTDs)

Since the advent of the Internet, the World Wide Web has become very popular because of the simplicity provided by HTML for its usage and content presentation. HTML provides a fixed set of tags that are used to markup content (information) primarily for consumption by human beings. Despite its efficiency for presenting information in human readable format, HTML is very limited in extensibility and customization of markup tags and description of the data contained in those tags. This constraint limits the use of HTML by application software for information sharing in a distributed computing environment where application programs, including intelligent agents are expected to work with available data, rules and knowledge without human intervention.

The use of XML and its related set of standards, developed by the World Wide Web Consortium, (W3C http://www.w3c.org), have helped overcome some of these limitations. XML allows for the creation of custom tags that contain data from specific domains. XML is a meta-language that allows for the creation of languages that can be represented by customized XML tags. For example, a company in the furniture industry may develop customized tags for the representation of content to serve its business domain. By creating custom tags, the company can represent the data in a more meaningful and flexible way than it could using HTML. The company may also develop documents that represent business-rules using XML that can shared either with human agents or with software agents. Unambiguous understanding of the content of customized XML tags by interested parties requires description of both the content and structure of XML documents. This description of structures in XML documents is provided by the XML schema which can be written following the set of standards called XML Schema and/or the Document Type Definition (DTD) language as adopted and standardized by the W3C. XML schema describes specific elements, their relationships and specific types of data that can be stored in each tag. XML documents can be validated and parsed by application software provided either the DTD or the XML Schema of the corresponding document is made available. XML parsers written in C, C++ or Java can process and validate XML documents (containing business rules and data) based on XML schemas written based on either the DTD or the XML Schema specification. Application software appropriate parser utilities are able to read and/or write to XML documents following the W3C standards and specification. This provides the foundation technology, built upon an agreed and accepted standard from W3C, for the capture, representation, exchange and storage of knowledge represented by business rules and related data in XML format that can be potentially used and shared by software agents.

Recent initiatives to develop technologies for the "Semantic Web" (Berners–Lee, Hendler, & Lassila, 2001) make the content of the Web unambiguously computer-interpretable, thus making it amenable to agent interoperability and automatic reasoning techniques (McIllraith, Son, & Zeng, 2001). Two important technologies for developing Semantic Web are already in place — XML and the resource description framework (RDF). The W3C developed the RDF as a standard for metadata to add a formal semantics to the Web, defined on top of XML, to provide a data model and syntax convention for representing the semantics of data in standardized interoperable manner (McIllraith, et al., 2001). The RDF working group also developed RDF Schema (RDFS), an object-oriented type system that can be effectively thought of as a minimal ontology modeling language. Recently, there have been several efforts to build on RDF and RDFS with more AI-inspired knowledge representation languages such as SHOE, DAML-ONT, OIL and DAML+OIL (Fensel, 1997). While these initiatives are extremely promising for agent interoperability and reasoning, they are at their early stages of development. In this article, we focus on the use of more mature and widely used and available standardized technologies such as XML and DTDs to represent knowledge. This approach, along with other initiatives, should allow researchers to develop intelligent agent-based systems that are both practical and viable for providing intelligent decision support to users in a business environment.

XML and Decision Trees for Knowledge Representation

The W3C XML specification allows for the creation of customized tags for content modeling. Customized tags are used to create data-centric content models and rule-based content models. Data-centric content models imply XML documents that have XML tags that contain data, for example from a database, and can be parsed by application software for processing in distributed computing environments. XML documents containing rule-based content models can be used for knowledge representation. XML tags can be created to represent rules and corresponding parameters. Software agents can then parse and read the rules in these XML documents for use in making intelligent decisions. Before making intelligent decisions, the software agents should be able to codify or represent their knowledge. Decision Trees and inductive learning algorithms such as ID3, C4.5 can be used by agents to develop the rule-based decision tree. This learned decision tree can be converted into an XML document with the corresponding use of a DTD. This XML document, containing the learned decision tree, forms the basis for knowledge representation and sharing with other software agents in the community. We demonstrate architecture for agent-based intelligent information systems to accomplish this.

XML and Decision Trees for Knowledge Representation and Exchange

Software agents for knowledge exchange and sharing in the agent community can exchange decision trees represented in XML documents. For example, a new agent can learn from the knowledge of the existing agents in the community by using the decision tree available in XML format in a knowledge repository. The existence of this knowledge repository allows knowledge to be stored and retrieved as needed basis by the agents and updated to reflect the new knowledge from various agents in the community. The explanatory power of decision trees from their ability to generate understandable rules and the provide clear indication of important fields for classification allows the incorporation of explanation facility, similar to expert systems, among the agents in this type of architecture (Sung et al., 1999). Moreover, explanation is essential to the interaction between users and knowledge-based systems (KBS), describing what a system does, how it works, and why its actions are appropriate (Mao & Benbasat, 2000). Among 87 KBS shell capabilities, users rated explanation facilities and the capability to customize explanations as the fourth and fifth most important factors, respectively (Stylianou, Madey, & Smith, 1992). Explanation can make KBS conclusions more acceptable (Ye & Johnson, 1995) and builds trust in a system. The ability of the agents to explain the decision rules used in the decision making process makes agents powerful tools to aid human agents in complex decision tasks. Such intelligent agent architecture, built around well-grounded and well-researched decision models along with standards-based widely available technologies (such as XML, DTDs), is a significant contribution to furthering research on agent-based distributed computing and DSS. In the following section, we present the details of IKMDSA and discuss its knowledge externalization, knowledge representation, knowledge management and knowledge delivery mechanism for decision support.

Integrated Intelligent Knowledge-Based Decision Support Architecture (IKMDSA)

A KMS has facilities to create, exchange, store and retrieve knowledge in an exchangeable and usable format for decision-making activity. IKMDSA utilizes ID3 algorithms to create knowledge from raw data to a decision tree representational form. A domain knowledge object represents information about a specific problem domain in IKMDSA. The domain knowledge object contains information about the characteristics of the various domain attributes important to the problem domain. The domain knowledge object describes the problem context and provides rules for making decisions in the problem context. The domain knowledge object represents the abstraction used for creating, exchanging and using modular knowledge objects in IKMDSA. IKMDSA uses intelligent software agents as the mechanism for encapsulation and exchange of knowledge between agents at the site of knowledge creation and the site of knowledge storage. Intelligent agents deliver knowledge to the user interface to support intelligent decision-making activity. The agent abstraction is built upon basic objects that take on additional behaviors, as required by its function (Shoham, 1993). Knowledge exchange and delivery in IKMDSA is facilitated through the exchange of the domain knowledge objects among intelligent agents. Figure 1 illustrates this basic building block of IKMDSA, where an agent has a composition relationship with the domain knowledge object, and thereby has access to knowledge in the form of standard XML document object model (DOM) objects.

Every agent can share its knowledge through the domain knowledge component by invoking its share knowledge behavior. The domain knowledge object contains behaviors to inform agents of the name of the problem domain, share information about the various domain attributes that are pertinent to the specific knowledge context, and share rules about making decisions for their specific problem domain. We use these core components to develop the functionality of IKMDSA to learn rules and domain attributes from raw data, create domain specific knowledge, share it with other agents and apply this knowledge in solving domain specific problems with a user. Once the attributes and domain rules are captured in the domain knowledge object, using standard XML DOM format, they can be exchanged between agents. Figure 2 provides a schematic of this activity sequence where knowledge is created from raw data and ultimately delivered in usable form to the decision maker.

Learning agents interact with a raw data repository and extract raw data used to generate domain specific knowledge. Our model does not specify the storage representation and the data contained in the repository may be of multiple representation formats including flat files, data stored as relational tables that can be extracted using multiple queries into a recordset, or raw data represented using XML documents. The learning agent extracts the raw data and applies machine learning algorithms to generate decision rules

Figure 1. Agents have access to domain knowledge objects that abstract domain specific knowledge

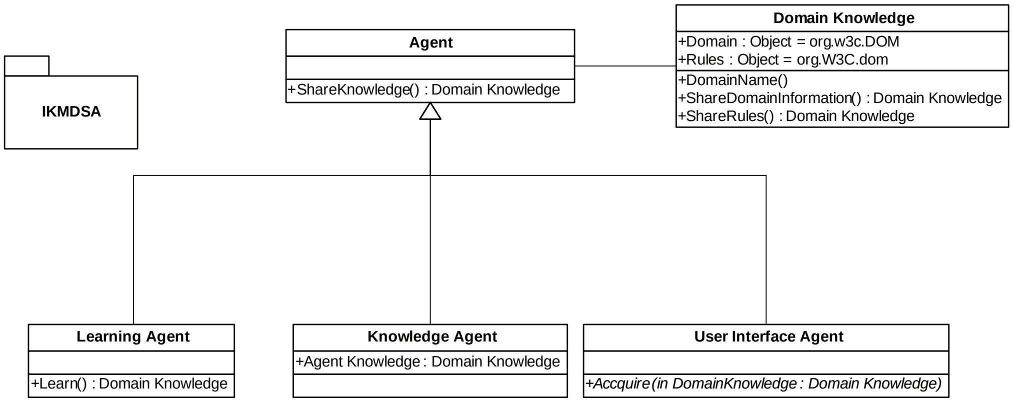
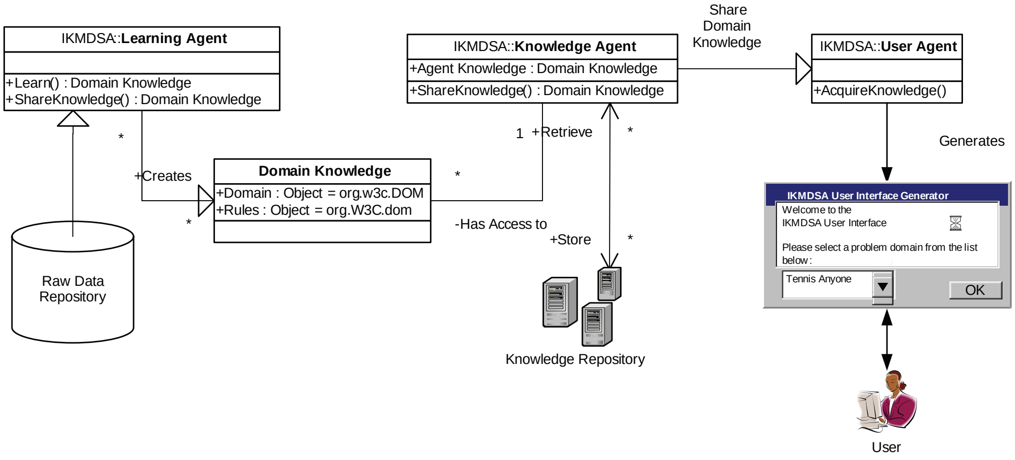


Figure 2. A schematic showing the generation, exchange, storage, retrieval and use of knowledge in IKMDSA



for the problem domain. The repository contains information about the context and syntactical representation of the information. This information provides the domain attributes pertinent to the decision problem. This generates domain specific knowledge in the form of domain attribute information and rules for making decisions in the specific problem context. The system ensures that this knowledge is generated in a format conducive for sharing and use of the information across a distributed and heterogonous platform.

We use the domain knowledge object as the modular abstraction for knowledge representation and knowledge exchange facilitation in IKMDSA. Domain knowledge objects are made available to agents by the learning agent sharing the object with the knowledge agent. The knowledge agent manages the knowledge available in IKMDSA and allows for other agents in the system to know of, request and receive the domain knowledge in the system. The system utilizes the domain knowledge object as the modular knowledge abstraction for communication of knowledge across the multiple agents of the system. Therefore, when the domain knowledge object is shared with an agent of the system, the agent becomes aware of the problem context descriptions, in addition to the rules that govern decision-making in the specific problem context. The knowledge agent is also responsible for the maintaining the collection of domain knowledge available in the system through interactions with a knowledge repository. The Knowledge Agent contains methods to generate rules to support ad-hoc queries by the user agent. This is supported through the interactions of the Knowledge Agent with the knowledge repository of the system that is implemented as a set of XML documents that can be stored in a repository that is capable of storing XML documents such as the Oracle 9i family of information management products. This knowledge repository allows for the easy storage and retrieval of the knowledge contained in a domain knowledge object. Thus, the knowledge is available to all the agents in the system through the activities of the KM behaviors of the knowledge agent object. In this respect, the interactions among the agents in this system are modeled as collaborative interactions, where the agents in the multi-agent community work together to provide decision support and knowledge-based explanations of the decision problem domain to the user.

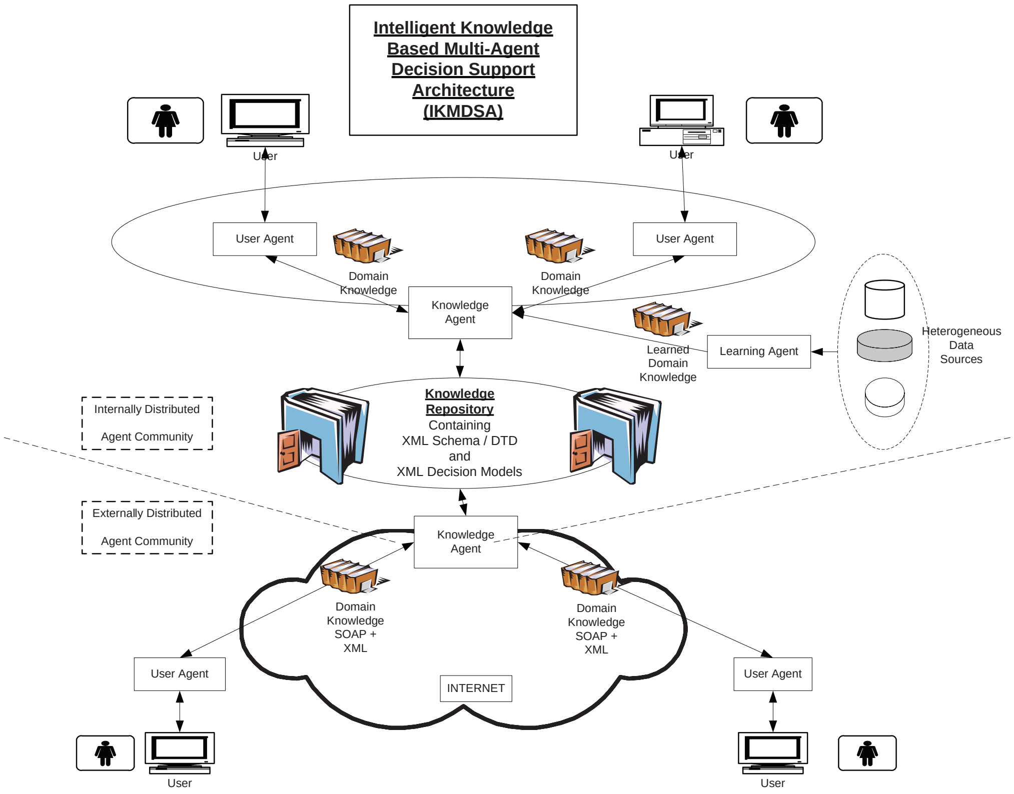
As shown in Figure 2, users of IKMDSA interact with the system through User Agents that are constantly aware of all domain knowledge contexts available to the system, through a list of names of the domain knowledge objects that is published and managed by the knowledge agent. This allows every user agent, and hence every user, to be aware of the entire problem space covered by the system. The user agent requests and receives the knowledge available for a specific problem domain by making a request to the knowledge agent, at the behest of the user. The knowledge agent, upon receiving this request, shares a domain knowledge object with the user agent, thereby making problem domain information and decision rules available to the user agent. The knowledge agents also serve as the means to service any ad-hoc queries that cannot be answered by the user interface agents, such as queries regarding knowledge parameters that are not available to the user interface agents. In such cases, the Knowledge agent, with direct access to the knowledge repository can provide such knowledge to the user agents, for the benefit of the user. This information is shared in the form of two W3C compliant XML document object model (DOM) objects, Domain and Rules, which represent an enumeration and explanation of the domain attributes that are pertinent to the problem context and the rules for making decisions in the specified problem context. Once the domain knowledge object is available to the user agent, the user agent becomes problem domain aware and is ready to assist the user through a decision making process in the specific problem domain.

The user agent contains methods to generate a user-friendly interface to inform the user about problem domain attributes that are pertinent to the decision problem under consideration. The user interface offers explanations about each domain attribute and provides the user with contextual information on the different values that each domain attribute may take. This serves the purpose of informing the user and increasing their knowledge about the various factors that affect a decision in the problem domain under consideration. The user agent also contains methods to generate a decision making interface that allows a decision maker to consider and choose values for pertinent attributes. This selection process creates an instance of an observation that can be compared against the rules available to the user agent through the domain knowledge. The user interacts with the User Interface agent by asking question about the decision problem and receives responses containing decision alternatives and explanation of the choices made by the agent. This is achieved through parsing the decision rules based on the parameters supplied by the user. The agent compares the users' selections with the known rules and decides on the rule(s) that are fired for the given instance. These rules are formatted in a user-friendly format and made available to the user. This provides the user with a decision, given their selection of domain attributes and provides the user with explanations of the decisions made, given the selections made by the users.

The above sections provide a complete description of the process of knowledge creation, knowledge representation, knowledge exchange, KM and the use of the knowledge for decision making employed by IKMDSA. Figure 3 provides a schematic of this overall process. As shown in Figure 3, IKMDSA is designed for a distributed platform where the knowledge available to the agents in the system can be made available on an intranet and an Internet based platform by enclosing the domain knowledge objects in SOAP wrappers that enables the knowledge broker functions of the knowledge agent by making its knowledge available as a Web service.

IKMDSA consists of intelligent agents as discussed above that are able to provide intelligent decision support to the end-users. All of the agents in the architecture are FIPA compliant in terms of their requirements and behavior. The learning agents create knowledge from the raw data in a data repository, knowledge agents primarily acquire this knowledge from learning agents and manage this knowledge through a knowledge repository,

Figure 3.The intelligent knowledge-based multi-agent decision support architecture (IKMDSA)



while user agents help the users make decisions on specific problems using the knowledge contained in the decision trees. The exchange of knowledge between agents and between users and agents is achieved through sharing of content information using XML. The agents work on a distributed platform and enable the transfer of knowledge by exposing their public methods as Web Services using SOAP and XML. The rule-based modular knowledge can be used and shared by agents. Capturing the modular knowledge in XML format also facilitates their storage in a knowledge repository - a repository that enables storage and retrieval of XML documents. The architecture allows for multiple knowledge repositories depending upon the problem domain. The benefits of such knowledge repositories are the historical capture of knowledge modules that are then shared among agents in the agent community. This minimizes the learning curve of newly created agents who are instantiated with the current knowledge that is available to the entire system. This is achieved in IKMDSA since agents have captured rule-based knowledge modules and have stored such knowledge modules in XML format in the knowledge repository for the benefit of the entire agent community and the system.

IKMDSA also provides a decision explanation facility to the end-users where agents are able to explain how they arrived at a particular decision. This has three important benefits:

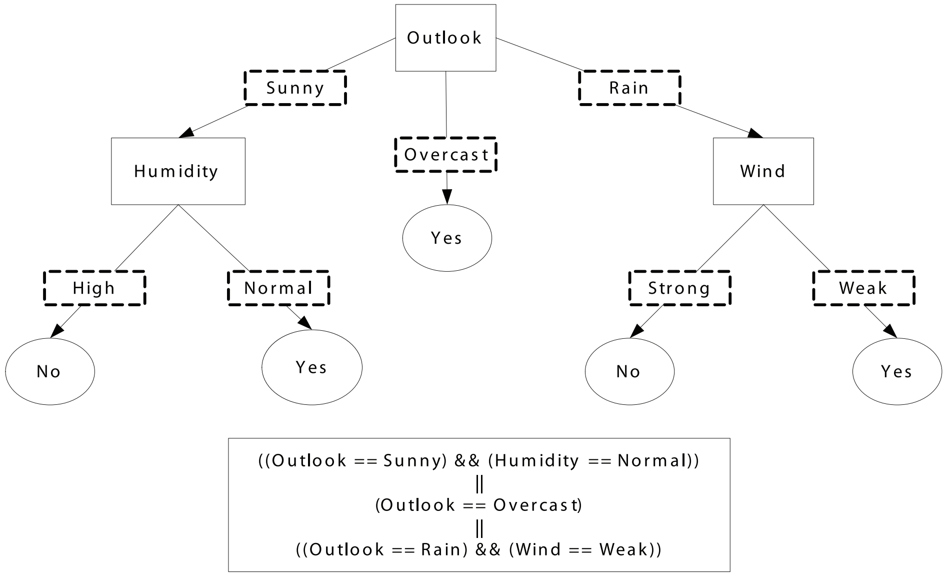
- the end-user can understand how the decision was made by the software agent,
- the end-user can make a clear assessment of the viability of the decision, and
- the end-user can learn about the problem domain by studying the decision paths used by the agent.

Agents are able to explain the rules and parameters that were used by the agent in arriving at the stated decision. This explanation facility is a natural extension of using decision trees in general for solving rule-based decision problems. Non-technical end-users are able to easily understand how a problem was solved using decision trees compared to other existing problem-solving methods such as neural networks, statistical and fuzzy logic-based systems (Sung et al., 1999). The IKMDSA architecture can provide intelligent distributed decision support that may be internal to the company and the other focusing on providing intelligent distributed decision support that may be external to the company. In the second case, the proposed architecture incorporates the W3C Web Services architecture that uses the simple object access protocol (SOAP) and XML. The incorporation of this architecture creates a flexible means of exposing the services of the agents using the Web Services architecture by a company to its potential or existing global population of customers and suppliers.

Implementation of the IKMDSA Architecture and Illustrative Example

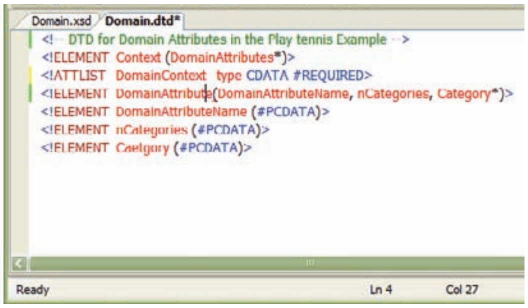
The problem domain selected for the initial proof of concept is the play tennis decision problem (Mitchell, 1997) using the ID3 decision tree method. The selection of the problem domain was due to it being widely adopted (Mitchell, 1997) to represent decision problems in the ID3 decision tree research and also for its simplicity in illustrating the proposed architecture. The decision problem for this problem domain is to decide whether, or not, to play tennis on a particular day based on climatic conditions such as the day's weather outlook, the level of humidity, the temperature, and the wind conditions. Figure 4 shows a schematic of the decision solutions under consideration. The leaf nodes of the decision tree represent the final outcome of the decision of whether to play tennis on a certain day, based on what the weather is like. The problem is simple to understand; yet it illustrates the fundamental requirements of the system and provides an elegant way to test the various features of the agents and the architecture.

Figure 4. Decision Tree representation of the play tennis problem (adapted from Mitchell, 1997)



The end-user provides the existing weather condition to the user agent as input and the agent makes a decision and presents the decision to the end-user whether or not tennis can be played that particular day given the conditions entered by the user. The user is given information about each of the atmospheric conditions and their categories. These atmospheric conditions form the domain attributes for the play tennis problem and define the context specific information that is pertinent to this decision problem. The agent provides information on each domain attribute thereby informing the user through the process of selection of the attributes that are pertinent on any given day. The representation of the domain attributes generated by the agents shows the DTD and the XML files (see Figures 5 and 6) for the representation of information about the context of the problem domain. The XML representation of the domain attributes is dynamically parsed by the user agent to generate a context specific user interface (as shown in Figure 7). This allows the user to make a decision about each pertinent domain attribute. After the user makes a selection from all the domain attributes, the user agent has enough information to make a decision about the problem domain. This is accomplished by parsing the set of domain rules that specify a final decision based on observations of domain attributes. As mentioned earlier, the user agent has access to an XML representation of domain rules about a given problem context, through the XML DOM object contained in the Domain Knowledge object for a decision problem. The structure for this set of rules is shown as a DTD in Figure 8, while Figure 9 shows the XML representation of the rules used by IKMDSA for the play tennis problem. The user agent parses these rules and identifies the rules that are fired for the given set of observations. These rules are then presented to the user in user-friendly format as explanation from the decision made by the user agent.

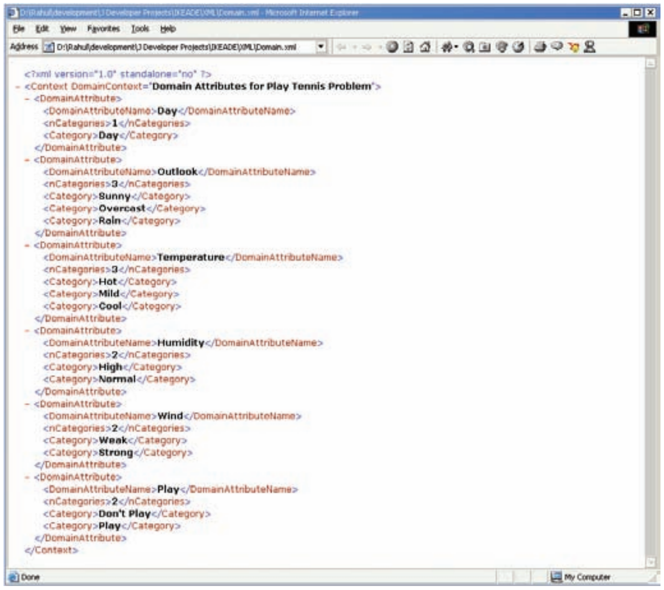
Figure 5. DTD for the representation of domain attribute in the play tennis problem



```
<!-- DTD for Domain Attributes in the Play tennis Example -->
<!ELEMENT Context (DomainAttributes*)>
<!ATTLIST DomainContext type CDATA #REQUIRED>
<!ELEMENT DomainAttribute(DomainAttributeName, nCategories, Category*)>
<!ELEMENT DomainAttributeName (#PCDATA)>
<!ELEMENT nCategories (#PCDATA)>
<!ELEMENT Category (#PCDATA)>
```

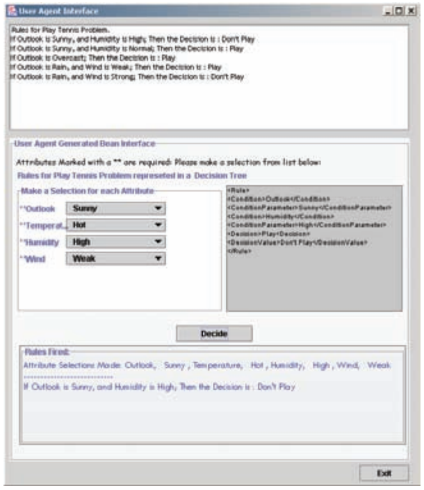
In the prototype implementation of the proposed IKMDSA architecture, we use the Java programming language to implement the agents as extensions of objects. The choice of Java was based upon the widely accepted advantage of Java providing portable code and XML providing portable data. In addition, we use Oracle 9i Database and Application Server platforms (http://www.oracle.com) to implement the knowledge repository and use the Sun Microsystems Java XML API toolkit to interface the agents with the XML repository. The decision tree implementation consists of tree nodes with branches for every category of the node variable. Each traversal from the root node of the decision tree to a leaf node leads to a separate decision path as illustrated in Figure 4. The agents contain methods to traverse the decision tree and obtain a decision path that can then be translated into an XML object and an XML document using a DTD file. These form the basis for the generation of decision alternatives and for the explanations of decisions by the agents. The agents are implemented as java beans and their explanations are available to the user through calls made to their public methods that are exposed as services, and presented to the user as dynamically generated web content by using Java Server Pages technology (http://java.sun.com/products/jsp/index.html).

Figure 6. XML document showing domain attributes for the play tennis problem



```
  <?xml version="1.0" standalone="no" ?>
- <Context DomainContext="Domain Attributes for Play Tennis Problem">
  - <DomainAttribute>
      <DomainAttributeName>Day</DomainAttributeName>
      <nCategories>1</nCategories>
      <Category>Day</Category>
    </DomainAttribute>
  - <DomainAttribute>
      <DomainAttributeName>Outlook</DomainAttributeName>
      <nCategories>3</nCategories>
      <Category>Sunny</Category>
      <Category>Overcast</Category>
      <Category>Rain</Category>
    </DomainAttribute>
  - <DomainAttribute>
      <DomainAttributeName>Temperature</DomainAttributeName>
      <nCategories>3</nCategories>
      <Category>Hot</Category>
      <Category>Mild</Category>
      <Category>Cool</Category>
    </DomainAttribute>
  - <DomainAttribute>
      <DomainAttributeName>Humidity</DomainAttributeName>
      <nCategories>2</nCategories>
      <Category>High</Category>
      <Category>Normal</Category>
    </DomainAttribute>
  - <DomainAttribute>
      <DomainAttributeName>Wind</DomainAttributeName>
      <nCategories>2</nCategories>
      <Category>Weak</Category>
      <Category>Strong</Category>
    </DomainAttribute>
  - <DomainAttribute>
      <DomainAttributeName>Play</DomainAttributeName>
      <nCategories>2</nCategories>
      <Category>Don't Play</Category>
      <Category>Play</Category>
    </DomainAttribute>
  </Context>
```

Figure 7. The user interface presented to a user by the IKMDSA user agent



Rules for Play Tennis Problem.
If Outlook is Sunny, and Humidity is High; Then the Decision is : Don't Play
If Outlook is Sunny, and Humidity is Normal; Then the Decision is : Play
If Outlook is Overcast; Then the Decision is : Play
If Outlook is Rain, and Wind is Weak; Then the Decision is : Play
If Outlook is Rain, and Wind is Strong; Then the Decision is : Don't Play

Attributes Marked with a ** are required: Please make a selection from list below:

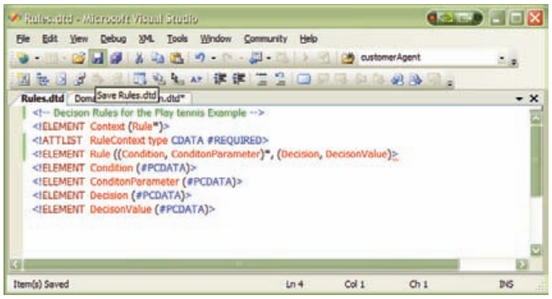
Rules for Play Tennis Problem represeted in a Decision Tree

**Outlook: Sunny
**Temperat...: Hot
**Humidity: High
**Wind: Weak

```
<Rule>
<Condition>Outlook</Condition>
<ConditionParameter>Sunny</ConditionParameter>
<Condition>Humidity</Condition>
<ConditionParameter>High</ConditionParameter>
<Decision>Play<Decision>
<DecisionValue>Don't Play</DecisionValue>
</Rule>
```

Attribute Selections Made: Outlook, Sunny , Temperature, Hot , Humidity, High , Wind, Weak
----
If Outlook is Sunny, and Humidity is High; Then the Decision is : Don't Play

Figure 8. DTD representation of the structure of rules

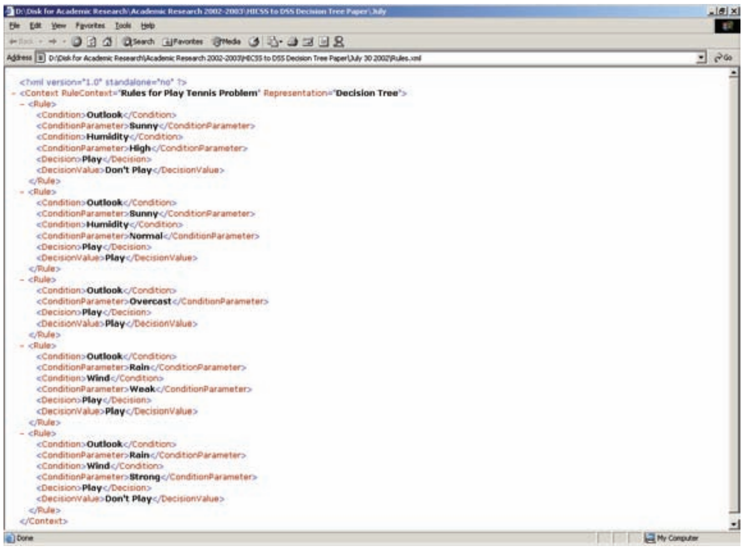


```
<!-- Decison Rules for the Play tennis Example -->
<!ELEMENT  Context (Rule*)>
<!ATTLIST  RuleContext type CDATA #REQUIRED>
<!ELEMENT  Rule ((Condition, ConditonParameter)*, (Decision, DecisonValue)>
<!ELEMENT  Condition (#PCDATA)>
<!ELEMENT  ConditonParameter (#PCDATA)>
<!ELEMENT  Decision (#PCDATA)>
<!ELEMENT  DecisonValue (#PCDATA)>
```

BUSINESS APPLICATION

Organizations are taking advantage of "data mining" techniques to leverage the vast amount of data to make better business decisions (Fan, Lu, Madnick, & Cheung, 2002; Padmanabhan & Tuzhilin, 1999). For example, data mining has been used for customer profiling in CRM and customer service support (Hui & Jha, 2000), credit card application approval, fraud detection, telecommunications network monitoring, market-based analysis (Fayyad, Piatetsky-Shapiro, & Smyth, 1996), healthcare quality assurance (Tsechansky, Pliskin, Rabinowitz, & Porath, 1999) and many other decision-making areas (Brachman, Khabaza, Kloesgen, Piatetsky-Shapiro, & Simoudis,

Figure 9. Decision tree representation of the rule-based knowledge module for the play tennis problem in XML format



```
  <?xml version="1.0" standalone="no" ?>
- <Context RuleContext="Rules for Play Tennis Problem" Representation="Decision Tree">
  - <Rule>
      <Condition>Outlook</Condition>
      <ConditionParameter>Sunny</ConditionParameter>
      <Condition>Humidity</Condition>
      <ConditionParameter>High</ConditionParameter>
      <Decision>Play</Decision>
      <DecisionValue>Don't Play</DecisionValue>
    </Rule>
  - <Rule>
      <Condition>Outlook</Condition>
      <ConditionParameter>Sunny</ConditionParameter>
      <Condition>Humidity</Condition>
      <ConditionParameter>Normal</ConditionParameter>
      <Decision>Play</Decision>
      <DecisionValue>Play</DecisionValue>
    </Rule>
  - <Rule>
      <Condition>Outlook</Condition>
      <ConditionParameter>Overcast</ConditionParameter>
      <Decision>Play</Decision>
      <DecisionValue>Play</DecisionValue>
    </Rule>
  - <Rule>
      <Condition>Outlook</Condition>
      <ConditionParameter>Rain</ConditionParameter>
      <Condition>Wind</Condition>
      <ConditionParameter>Weak</ConditionParameter>
      <Decision>Play</Decision>
      <DecisionValue>Play</DecisionValue>
    </Rule>
  - <Rule>
      <Condition>Outlook</Condition>
      <ConditionParameter>Rain</ConditionParameter>
      <Condition>Wind</Condition>
      <ConditionParameter>Strong</ConditionParameter>
      <Decision>Play</Decision>
      <DecisionValue>Don't Play</DecisionValue>
    </Rule>
  </Context>
```

1996). There is a growing need to not only mine data for decision support, but also to externalize knowledge from enterprise data warehouses and data marts, to share such knowledge among end users through automated knowledge discovery and distribution system for effective decision support. In other words, there is an increasing need for the integration of KMS and DSS systems to meet the needs of the complex business decision situations. According to Bolloju et al. (2002) "Such integration is expected to enhance the quality of support provided by the system to decision makers and also to help in building up organizational memory and knowledge bases. The integration will result in decision support environments for the next generation" (p. 164). The proposed IKMDSA architecture illustrates such a next generation integrated KMS and DSS system. The detailed presentation of the implementation of the architecture is intended to further the research that combines multiple but related set of research streams such as data mining, automated knowledge discovery, knowledge representation and storage using XML, knowledge exchange among participating intelligent agents using knowledge context, and explanation facility (from expert systems research). The authors are currently extending the architecture in various business domains such as credit approval processing, bankruptcy prediction, electronic commerce and consumer behavior and Web mining.

Emergent Internet technologies have significant impact on business processes of organizations operating in the digital economy. Realizing the potential benefits of emergent technologies is dependent on the effective sharing and use of business intelligence and process knowledge among business partners to provide accurate, relevant and timely information and knowledge. This requires system models to support and enable information integration, knowledge exchange and improved collaboration among business partners. Such systems must provide collaborating partners with intelligent knowledge management (KM) capabilities for seamless and transparent exchange of dynamic supply and demand information. Implementing and managing such integration over distributed and heterogeneous information platforms, such as the Internet, is a challenging task; yet, realizing this task can have significant benefits for organizations embracing such collaborations. An application of the IKMDSA for Collaborative Commerce to enable collaborative work in B2B e-Marketplaces would have significant benefits in developing information partnerships by creating the foundation for knowledge representation and exchange by intelligent agents that support collaborative work between business partners.

CONCLUSION, LIMITATIONS AND FUTURE DIRECTION FOR RESEARCH

In this research we have presented a methodology to represent modular, rule-based knowledge using the eXtensible Markup Language (XML) and the Document Type Definition (DTD) standards from the World Wide Web Consortium (W3C). Using this methodology, we have shown how such an approach can be used to create problem-specific knowledge modules that can easily be distributed over the Internet to support distributed IDSS design. Such an approach will facilitate intelligent decision support by providing the required knowledge representation and the decision analytical support. We had presented the conceptual architecture of such a distributed IDSS, and have provided details of the components of the architecture, including the agents involved and their interactions, the details of the knowledge representation and implementation of knowledge exchange through a distributed interface. We also provided indication of how such architecture might be used to support the user and how it might assume the role of an expert and provide explanations to the user, while retaining the benefits of an active DSS through extensible knowledge generation by incorporating machine learning algorithms. The example used in this article is simple, intuitive, and elegantly achieves its purpose of illustrating the use of the architecture while minimizing complications inherent to a more complex problem domain. We continue to do research on elaborating this architecture for a variety of problems that lend themselves to rule-based, inductive decision making with a need for user interactions and which benefit from greater understanding of the problem domain by the user.

The limitations of this research derive from the use of decision trees and inductive learning algorithms and techniques. The limitations inherent to decision trees and such techniques are also the limitation of this architecture. Therefore, further research needs to be conducted to understand how this architecture can be expanded to incorporate other types of learning and rule induction or rule creation to be shared and used by software agents. Despite this limitation, this research contributes significantly to the advancement of our understanding of how emerging technologies can be incorporated into intelligent agent-based architecture to enhance the value of such systems in distributed intelligent DSS that incorporates knowledge.

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Chapter 8.10

The Future of Supply Chain Management:

Shifting from Logistics Driven to a Customer Driven Model

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ABSTRACT

This chapter initiates the concept of a customer-centric model in supply chain systems. It discusses various constraints of present-day supply chain systems resulting from their roots being in logistics management and suggests an alternative next-level paradigm of a customer-centric matrix model. This chapter further demonstrates how this model would add value to the customer by taking the example of a healthcare information management system. The chapter also delves into the limitations of and anticipated issues and challenges in implementing the suggested model. Finally, the chapter hints at some broad directions for future research and action in the field. Emergent behavior is what happens when an interconnected system of relatively simple elements begins to self-organize to form a more intelligent and more adaptive higher-level system (Johnson, 2001).

INTRODUCTION

Supply chain systems have come a long way from their initial days when their sole purpose was to support the inventory management function in terms of controlling inventory carrying and fulfillment costs, while making inventory management more efficient and effective. However, as the roots of Supply Chain Management (SCM) lie in managing supplies or inputs to a process or an enterprise, most of the developments (solutions, tools, and technologies) in this field obviously have been around effective management of supply chain toward better, faster, and more cost-effective fulfillment of customer demand.

While this focus on logistics and inventory management has certainly helped business, it still falls short of making the best use of the current tools and technologies for businesses. In order to provide this SCM advantage to businesses, the next level of evolution for the concept of supply chain would be to focus on the needs of the ultimate consumer in contrast to the needs of interim customers (i.e., manufacturers) that are the present-day focus. This chapter seeks to explore the possibilities of elevating the focus of SCM from a logistics-driven model to the next level of customer-driven model, thereby enhancing the value delivered to the end customer. The issues and challenges expected in the process also are delved into.

The chapter reviews some of the latest literature available on SCM, describes various models of supply chain since its origin, enumerates the limitations of the existing supply chain model, and suggests a customer-centric model. Furthermore, it goes on to discuss the challenges in the implementation of this model and the constraints of this model that will have to be addressed. Supply and procurement of healthcare services as well as a health care information management software developed by the author for the creation and management of virtual healthcare communities in line with the suggested customer-centric model is used as an illustration throughout the chapter.

ORIGINS

As per one definition, SCM is the coordination of the demand and supply of products and services between a supplier's supplier and a customer's customer. It involves the flow of products, information, and money between the trading partners of a company's supply chain. The proactive improvement in the efficiency and effectiveness of the flow of goods, services, and knowledge across all stakeholders achieves the goal of reducing total costs and obtaining a competitive advantage for all parties.

Supply chain is the network of facilities (warehouses, factories, terminals, ports, stores, and homes), vehicles (trucks, trains, planes, and ocean vessels), and logistics information systems connected by an enterprise's suppliers' suppliers and its customers' customers. Supply chain flow is optimized when material, information, and money flow simultaneously in real time and without paper.[5]

SCM revolves around efficient integration of suppliers, manufacturers, warehouses, and stores. Other definitions are more comprehensive and detailed:

> *The challenge in supply chain integration is to co-ordinate activities across the supply chain encompassing these various players, whose systems are bound to be disparate right from the beginning. It is only with such integration that the enterprises can improve performance, reduce costs and increase their service levels to the end-user, the customer. These integration challenges are met not only by coordinating production, transportation, and inventory decisions but more generally by integrating the front-end of the supply chain, customer demand, to the back-end of the supply chain, the production and manufacturing portion of the supply chain.* (Simchi-Levi et al., 2003)

As it can be seen from our discussion thus far and from the voluminous literature on supply chain, the focus is constantly on the network of facilities, logistics, supplies, and suppliers. This is due to two main reasons: (1) the origins of the concept of supply chain lie in logistics and in inventory. and (2) the supply chain is related mostly to manufacturing or tangible goods, and thereby, the developments in the services sector and in the knowledge economy are overlooked.

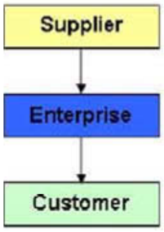
Some thoughts are emanating gradually on the use of supply chains for customer satisfaction. For instance, "efficient integration of suppliers, manufacturers, … so that enterprise can increase service level" (Simchi-Levi et al., 2003) and "maximize customer service and minimize cost of the same" (Frazelle, 2002). The closest one gets to customer focus is in the following statement:

> *[A] supply chain consists of all parties involved, directly or indirectly, in fulfilling a customer*

request. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers and customers themselves … the customer is an integral part of the supply chain. The primary purpose for the existence of any supply chain is to satisfy customer needs. (Chopra & Meindl, 2004)

However, most of the integration referred to in most SCM literature is the vertical integration of suppliers, manufacturers, distributors and other business partners for the ultimate purpose of customer consumption and satisfaction. Thus, essentially, SCM has focused on vertical flow of goods and services toward order fulfillment, as described in Models A, B, and C in Figures 1, 2, and 3, respectively. But, as the delivery models of products and services become more complex (Model D), as shown in Figure 4, with the objective of fulfilling end-to-end requirements of a customer, supply chain systems will have to focus on integrating processes laterally, as well. The spread of such lateral processes across heterogeneous enterprises and geographical boundaries is becoming almost mandatory with the rapid globalization of enterprises, consequently adding to the challenge of managing supply chains.

Figure 1. Simple vertical model (1-1-1 relationship)



MODEL A: Simple Vertical Model (1-1-1 Relationship)

This model is based on an enterprise with a single product, single supplier, and single customer. Such a scenario exists in the case of contractual outsourcing or certain niche industries, products, or markets. Here, an enterprise fulfills the demands of its customer by adding value to the inputs from its supplier. The only contribution made by SCM in this model is the control of inventory-carrying

Figure 2. MODEL B: Simple vertical model (many-1-many relationships)

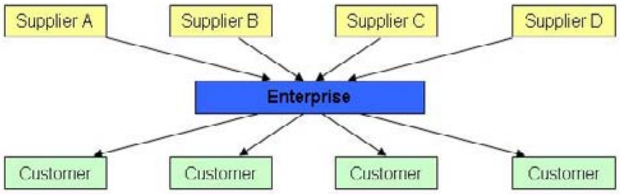


Figure 3. MODEL C: Complex vertical model (many-many-many relationships)

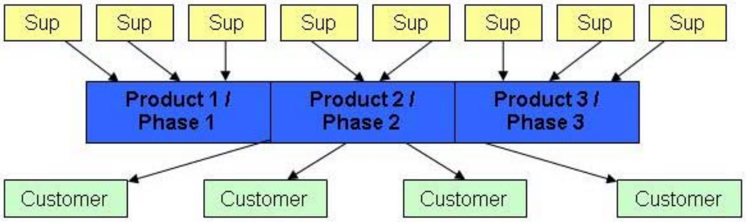
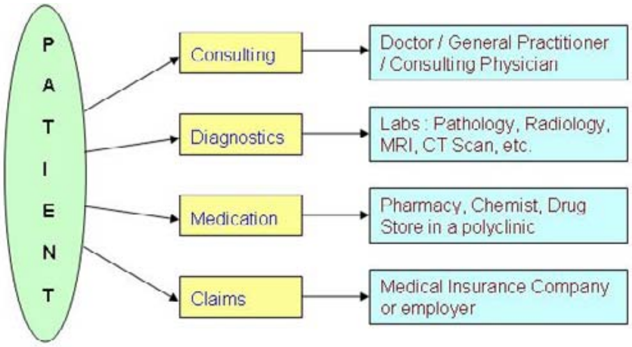


Figure 4. Healthcare services procurement by a patient



costs, if at all. This is only a marginal improvisation over JIT (just-in-time) inventory systems.

MODEL B: Simple Vertical Model (Many-1-Many Relationships)

In this model, the enterprise still has a single product and phase of production but has many suppliers and customers. Many of the enterprises that are creating and/or providing goods and services (e.g., component manufacturers for automobiles or home appliances, PCB fabs, etc.) would fall under this category. Here, an enterprise fulfills the requirements of its (many) customers by adding value to the inputs from its (many) suppliers. The contributions made by SCM in this model are more than just control of inventory carrying costs. SCM contributes to the overall inventory management of an enterprise, depending on the level of integration among the systems of the suppliers and the enterprise.

MODEL C: Complex Vertical Model (Many-Many-Many Relationships)

In this model, the enterprise has multiple products and phases of production and also has many suppliers and customers. A large number of enterprises that are creating and/or providing goods and services would fall under this category. This would include enterprises offering relatively complex products and services like white goods, home appliances, automobiles, IT and telecom equipment, real estate, banking, healthcare, and so forth.

Here, an enterprise either offers a variety of goods and/or services or has multiple phases of a complex production cycle that produces products to fulfill the requirements of its (many) customers by adding value to the inputs from its (many) suppliers. The contributions made by SCM in this model are enormous. A supply chain system in such a model is normally well-integrated with the inventory as well as with production planning and control systems of an enterprise and, thus, facilitates all the suppliers under the ambit of the SCM to support the inventory and PPC functions of the enterprise. Apart from controlling inventory-carrying and fulfillment costs, such an integrated approach also addresses issues related to timely deliveries (at different phases), quality of deliveries, exception handling, real-time changes in requirements, and so forth.

THE PROBLEM

While all the models mentioned earlier (A-C) contribute to customer satisfaction through reduced costs and faster deliveries, they add little direct value to the customer in terms of increased convenience, choice, or higher value for money.

This is further compounded by the trends of globalization, restructuring of various industries, fragmentation of supply chain ownership, and the nature and structure of new industries evolving in the knowledge economy.

For a moment, let us step back to the physical world of goods and services as it existed a few decades ago. Taking the example of various services offered by governments to their citizens, a citizen had to go from pillar to post filling out various forms and documents for obtaining some service, and, after a few days if not weeks or months and a lot of agony, the citizen would get out of the bureaucratic maze with some positive result. This is quite akin to Model C with one major exception: the various stages of the process were not so efficiently integrated in case of a typical government organization.

To add to the convenience of their citizens, to introduce transparency into their work processes, and also to deliver faster positive results, many government organizations introduced the single-window system, whereby the end customer—the citizen—had to submit a set of documents only once at a window and collect deliverables in the form of some document, certificate, or money on a predetermined date or, sometimes, even instantaneously. As a result, the end customer could receive faster service with a lot of convenience. At the same time, the efficiency and effectiveness of various processes manned by specialist or expert bureaucrats was not compromised. It was either replaced with technology solutions or carried out in the back office without affecting the consumer.

Similar scenarios and examples exist today in services like travel and healthcare. The domain of healthcare services is replete with many of the issues and problems discussed earlier. For example, if a patient needs attention and requires the services of any of the healthcare service providers, at the very least, patients have to visit a doctor and a pharmacist. However, and more often than not, a number of visits to multiple service providers is required, especially if lab tests and diagnostic results are required. The prevailing bureaucratic governmental restrictions and the rigid health service practices add to the misery and suffering of patients by delaying their treatment. Typical stages of healthcare service procurement of a patient are shown in Figure 4.

As shown in Figure 4, the patient has to approach numerous service providers to get treated. Typically, the steps required are as follows:

- Patient visits the doctor.
- The doctor may suggest further diagnostic tests (the probability of this increases with the advancement of medical science).
- Patient goes to the respective laboratory for getting the diagnostic tests done.
- Patient visits the laboratory again to collect the diagnostic reports.
- Patient visits the doctor again with the diagnostic reports.
- The doctor prescribes medication to the patient.
- Patient visits the pharmacy to buy the medication.
- Patient approaches the insurance company or concerned agency for reimbursement of medical expenses. Alternatively, the medical agencies (like the physician) approach the insurance company for reimbursement.

It is clear from this example that it is quite an exercise to move people and documents all over the place, sometimes in circles, to access one important and critical service most people require continuously. This is true for most of the service sector industries.

The ERPs, CRMs, and SCMs of today's world need to integrate and elevate to provide a single-window solution to the end customer in various areas, especially the service sector. One way of doing this is to offer all the products and services related to a solution through a single enterprise—creating a Web-based single window.

The government services department example can be extended here. One also can think of travel service firms offering all related services, like hotel bookings, car bookings, and so forth, or hospitals and healthcare polyclinics providing all the healthcare services in one place.

However, there are some significant limitations to this approach:

- Such an integration of services may not be possible in all domains.
- Integrated offering of all services may result in a loss of focus for an enterprise and thereby inhibit the enterprise from developing expertise in any field. As a result, the end customer may not get the best possible service, may get it at a premium, or both.
- The end customer does not get multiple options—if customers want to avail of the single-window convenience, they will have to hire a car through the same travel agent who books their tickets, although there could be better options elsewhere.
- Such a solution also creates a constraint of physical proximity, especially with respect to services like banking and healthcare. The consumer always has to visit or transact with a particular single-window service provider (e.g., a hospital). Thus, after procuring a product or service from a vendor, if consumers move to some other location, they will have no or limited access to the products and services of that particular vendor. For instance, after getting treated at a hospital or polyclinic, when a patient moves to another place, the patient not only will be unable to avail of the services provided by that hospital but also will not have his or her medical history to get faster and better treatment from a hospital at the new location.

THE SOLUTION

As seen in the example of healthcare services, solutions and services in today's world are offered by a chain of multiple enterprises within an industry, and customers personally have to navigate through a mesh of network to procure an end-to-end solution to their requirements, which is obviously not very convenient. Since the mesh of network is the cause of the problem, a corresponding solution ought to be network-based.

MODEL D: Matrix Model (Many-Many-Many Relationships Spread Across Different Enterprises/ Geographical Locations)

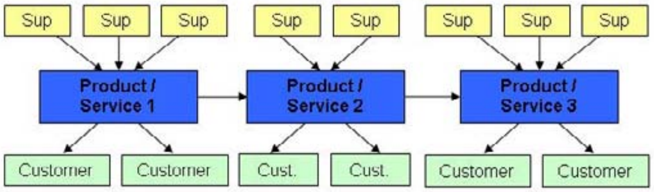
One way of offering the single-window solution to the end customer is by creating virtual communities (mesh of network) of service providers on the Web. These communities can share and exchange data on a need-to-know basis and provide the single-window advantage to the consumer without any of the limitations discussed earlier.

The introduction of a horizontal flow of supply chain in addition to a vertical flow is of major significance in the matrix model. This assumes greater importance when subset products or services of the same set are offered either by different business units of the same enterprise spread across different geographies or by different enterprises all together.

Before getting into more details of the solution, let us also harp upon why such a solution is required. The reasons for such a shift are as follows:

- The changing method of product or service provisioning is one reason. With the globalization of almost every industry and the increasing quality-consciousness of the consumer, it is critically important to any industry to respond appropriately. One major

Figure 5. MODEL D: Matrix model (Many-many-many vertical and horizontal relationships spread across different enterprises or geographical locations)



response of many industries has been their focus on specialization and customization of customer requirements and needs. With this, the end-to-end solution is provided to the consumer by multiple enterprises—physical and virtual. In the absence of a comprehensive solution, consumers have to approach more than one enterprise to fulfill their requirements. This is also known as multiple funnel delivery.

- With the fragmentation of supply chain ownership, it is becoming increasingly difficult for the consumer to get the best value for money in a convenient manner. If at all, the consumer is required to put in considerable effort to get good value.
- Intangibles occupy a prominent position in the consumption and commerce that happens worldwide today. The dynamics of commerce and the consumption of intangibles are quite different from those of tangibles. So are the supply chains. This, too, necessitates a different solution.
- With the growth of the Internet and other facilitating infrastructures, the customer expects 24/7 service based on a direct delivery model wherein services are delivered directly from the manufacturer or provider of services.
- Flexible pricing, product portfolio, promotions, and discrimination on service make the selection and procurement of a product or service a very complex decision for the consumer in the absence of an integrated solution.
- General expanse in the domain knowledge and increasing complexity in most domains of products and services add to the woes of the customer.
- An increasing number of alternatives in every sphere of products and services also compounds the problem.

All these and the primary requirement of providing the best value for money to the customer with utmost convenience create the need for a customer-centric SCM.

Virtual Communities

As mentioned earlier, the solution has to be network-based. A software solution created by the author for the formation and management of virtual communities for provisioning end-to-end healthcare services will be used as an example.

There are two potential solutions: (1) as mentioned earlier, hospitals and polyclinics (remember the single-window example); and (2) the creation of virtual communities of healthcare service providers, even globally.

While hospitals and polyclinics offer a viable solution, they are fraught with the limitations discussed earlier. Quite often, they also happen to be quite expensive. This necessitates the creation of a solution that would provide best services from distributed supply chains to the customer (here, the patient) with increased convenience.

The most compatible solution in such a scenario can be the creation of virtual communities of all the agencies involved in healthcare services provisioning. A virtual community is a collection of related individuals or organizations that connect with one another with the help of various communication media (e.g., the Internet) to fulfill a common objective or achieve a common goal. All are aware of different types of virtual communities like portals, newsgroups, chat groups, and so forth. However, most of them do not provide for transaction facility (if at all, it is permitted only within a closed user group), and most of them also are moderated or owned by an individual or an organization.

The virtual community proposed here is different on these two parameters. One, its primary function will be to facilitate transactions, and two; it will have shared moderation and ownership.

How will a virtual community help the customer?

- It becomes a one-stop shop for all the products and services in a particular segment.
- The customer can receive faster service.
- It is independent of location and, therefore, creates no physical proximity constraint. As the medical history of a patient is stored in the virtual space, a patient can obtain services from almost any part of the world.
- It reduces unnecessary physical movement of the customer (here, the patient).
- Customers can avail of the best services from the service provider of their choice.
- It can be integrated with various data-capturing tools, including equipment like those used for self-diagnostics.

Applying the matrix model to healthcare services provisioning, the flow would look like Figure 6.

This model certainly will enhance the convenience of the patient, since now, the various service providers also are interconnected. A meshed solution as follows (Figure 7) will create the maximum impact.

The networked model interconnects all the service providers who, in turn, can interact with one another on a need-to-know basis. For instance, after a patient has gone through the diagnostic tests, they do not have to revisit the laboratories to collect the reports; these can be collected by the patient as well as the doctor over the Web. Similarly, the medication also can be delivered to a patient's home by the nearest pharmacy, based on the prescription posted by the doctor on the Web and subsequently collected or received by the pharmacist.

This substantially reduces the number of steps that a patient has to go through to get treated. In most of the cases, only two steps are required:

Figure 6. Application of matrix model in healthcare services provisioning

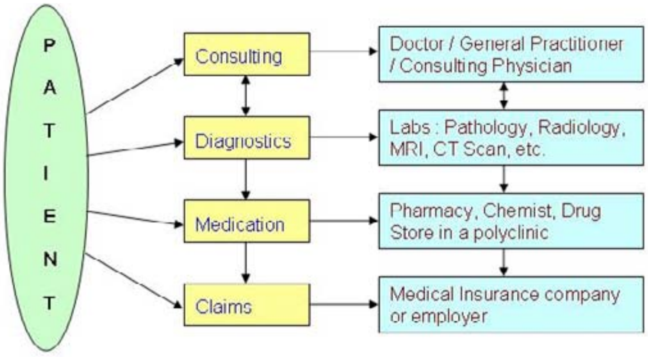
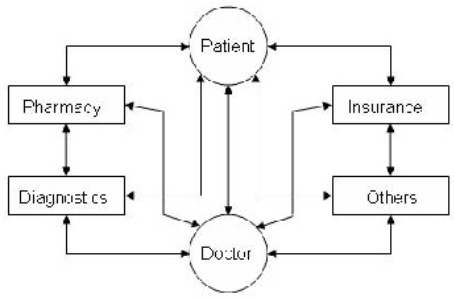


Figure 7. Networked model in health care services provisioning



1. Patient visits the doctor for consultation.
2. Patient visits diagnostic labs for tests.

HOW DOES THE SOLUTION WORK?

In a virtual community, as the suppliers of all the interrelated products and services are interconnected logically, in spite of being separate geographically (in the form of different locations of the same enterprise) or legally (in the form of different enterprises), they are able to provide an end-to-end solution to the consumer faster and with enhanced convenience.

In the example of healthcare services, the core engine of virtual communities takes care of most of the steps. Here is how it works:

- Patient visits the doctor for consultation.
- If diagnostics are required, the doctor submits a prescription of tests to be conducted to the intelligent engine and database of the virtual community, where it is picked up by the diagnostic lab chosen by the patient. If diagnostic tests are not required, a prescription of medicines is submitted.
- Patient visits the diagnostic lab of its choice for conducting the tests.
- The lab pulls the test prescription from the database of the virtual community to conduct tests. Patients are not required to worry about the prescription.
- Diagnostic labs submit test reports to the same engine and database of the virtual community; where it is picked up by the doctor. The patient is spared a second visit to the lab.
- On receipt of test reports, the doctor submits a prescription of medicine. In most cases, patient will not have to visit the doctor again to obtain the prescription.
- The pharmacy of the patient's choice gets the prescription of the patient and manages to deliver the necessary medicines at the patient's doorstep. Again, this step does not require any movement on the part of the patient.
- Depending on the insurance plan, the doctor and/or patient can submit necessary documents electronically for claims processing and get paid by the insurance company directly into their bank account.

As all these steps happen over fiber (communication or Internet), the pace of transactions is much faster than physical movements of people and paper.

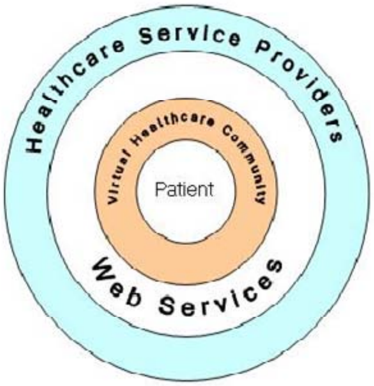
The availability of technologies like Web services and wireless networks not only make the solution feasible but make it even more capable.

The high-level architecture of such customer-centric model, wherein all the healthcare service providers can serve the patient by using the virtual healthcare community infrastructure through Web services, is shown in Figure 8.

BENEFITS OF A CUSTOMER-CENTRIC MODEL

A customer-centric model creates a win-win situation for all the stakeholders in the model. While it certainly benefits the customers and the suppliers involved in the model, it also creates some benefits

Figure 8. High-level architecture of customer-centric model for supply of healthcare services



at a higher level for the entire community. Some of the benefits generated by this model for various stakeholders are specified hereafter.

Generic Benefits

Greater value-add in the form of best price performance, procurement of end-to-end products and/or services, and greater customer convenience through provisioning of ease in the procurement of end-to-end products and services is the primary objective of the customer-driven model.

Be it supply of healthcare services or other services like travel, finance, and so forth, this enhanced supply chain model has certain inherent benefits for the customer as well as suppliers.

Benefits to Customers

- The community becomes a one-stop shop for all the interrelated products and services in a particular domain.
- The customer gets the best of both worlds—better and specialized services without the associated overheads of an integrated physical model.
- The customer also has the luxury of making choices among various service providers.
- There is no constraint of physical proximity. The customer can procure a product or service virtually anytime, anywhere.

Benefits to Suppliers

- Suppliers now can focus on their areas of specialization and yet offer their products and services at competitive prices to their customers.
- Depending on the nature of their product or service offering, suppliers need not be constrained by geographical proximity.
- In cases like pharmacies, suppliers can do away with physical stores altogether. Drugs can be shipped straight from their warehouse, based on prescriptions received.
- As participants of virtual community, suppliers can gain from mutual coordination and exchange of aggregated information

Benefits to Community

- The virtual community also creates quite a few extra benefits that can be shared by individual suppliers as well as customers. Such benefits are in the form of:
  - Creation of aggregated information and knowledge related to the industry.
  - Making the processes and workflows more efficient and effective, resulting into cost savings at individual entity levels.
  - Providing a platform to conduct industry-related research. For instance, medical schools and colleges as well as pharmaceutical companies can use the virtual healthcare community to conduct industry-specific research on aggregated data.

Thus, a customer-centric SCM would be beneficial to all the stakeholders in the supply chain. As mentioned earlier, the supplies, especially information supplies, in this model would flow vertically as well as horizontally. In the example of healthcare services, for instance, the diagnosis reports would flow vertically to the patient as well as horizontally to the doctor. Similarly, a prescription would flow vertically to the patient and horizontally to the pharmacy.

In addition to forward integration with ERPs, the existing supply chain systems need to incorporate the horizontal flow of information in order to facilitate the creation of such virtual communities and thereby enable enhanced customer satisfaction.

LIMITATIONS OF THE MODEL

Like any good solution, this one also comes with a set of its own limitations. Some of the limitations of this solution are as follows:

- As the model is heavily dependent on information and communication technologies, any interruption in the availability of these in the form of communication media like the Internet and so forth can cause disruption in providing basic services like healthcare. Many people on the east coast of the US experienced such an inconvenience due to major power outages during late 2003. This happened due to people's heavy reliance on electricity as the major source of energy.
- While the model would deliver better products and services to the customer faster and at a reasonable price, on the downside, it can have a sociological impact on persons for whom a personal visit to any product or service provider also creates an opportunity for social interaction. For instance, many of the older people in Australia have been objecting to the installation of ATMs that lead to closure of several bank branches. Though ATMs provide better and faster service 24/7, a personal visit to the bank for cash withdrawals or deposits is a far more important opportunity, especially for the retired and elderly, from a social interaction standpoint.
- In services like healthcare, such a heavily automated model also can lead to the creation of some information gaps. Repeated interactions with the patient provide the doctor with quite a bit of relevant information that cannot be obtained through a structured approach.
- Also, in services like healthcare, a relationship of mutual trust and faith between the patient and the doctor is of vital importance. As repeated interactions have a bearing on the depth and expanse of such a relationship, the technology-based solution certainly would hamper that.

ISSUES AND CHALLENGES

Coordination among various partners in a supply chain is a huge challenge even today in the present state of SCM solutions. With the increased complexity of the solution, more issues and challenges are expected to arise.

According to Chopra et al. (2004), over the past several decades, most firms have become less vertically integrated. As companies have shed non-core functions, they have been able to take advantage of supplier customer competencies that they did not have. This new ownership structure also has made managing the supply chain more difficult. With the chain broken into many owners and each having its own policies and interests, the chain is more difficult to coordinate. In their book, Chopra and Meindl (2004) go on to list the causes of difficulties in coordination as well as the impact of lack of coordination in integrated supply chain models.

The following are two points to be noted: (1) reducing vertical integration with the new ownership structure and (2) increased difficulty in coordination.

The customer-centric model proposes horizontal integration of broken supply chain ownerships at a much higher level and spread across geographies, potentially making it a global solution.

Some of the challenges that can be anticipated for the customer-centric supply chain management system are listed hereafter. Wherever possible, potential solutions to challenges also are mentioned, together with the issues.

- **Diversity:** The model is an attempt to provide a universal solution that is independent of geographical constraints. In other words, it seeks to provide a uniform solution to diverse environments. The diversity could be in the form of the following:
  - **Standards:** Different countries follow different standards and codes pertaining to various industries like healthcare. Addressing all of these in a single solution could be a major challenge. Some ways of making this happen can be through the adoption of standards like HIPAA (Health Insurance Portability and Accountability Act) of the US by various countries or cooperative creation and implementation of global standards under the aegis of a UN body like WHO (World Health Organization), and so forth.
  - **Laws:** Laws related to the conduct of various industries like healthcare are widely different in various countries. These also need to be aligned at a broad level in order for a universal solution to work. While this is very difficult and far-fetched, if all the countries in the world can sign charters and conventions on pollution control, IPRs and many such issues, and create a common legal framework at a higher level for the benefit of mankind (e.g., in the area of healthcare) this certainly can be made possible in the long term.
  - **Language:** A global solution also has to address the need of multiplicity of languages. This, though, is the least of problems, as quite a few solutions (from Microsoft Windows to small accounting packages like Quickbooks and MYOB) already have addressed this issue. Unicode-based solutions also can be considered to address this issue.
- **Creation of a Common Framework:** Given the diversity of laws, standards, and many other practices related to an industry, creation of a universal solution or a framework in itself would pose an enormous challenge. However, good news is that common global XML standards are emerging in most of the industries, from news to banking to healthcare to entertainment. In the healthcare sector, for instance, HL7 is almost a universally accepted standard, and most of the software solutions created for healthcare industry (no matter who creates them where) are HL7 compliant. In fact, the author and his team have created a common software framework of reusable components that can be used to construct a global solution for the healthcare industry.
- **Ownership and Control of Virtual Communities:** While the components of a supply chain have a broken ownership, the solution that ties them up needs to have some command and control structure. This, too, would be a challenge to reckon with. To address this, one either can fall back upon the proven model of managing the Internet and assigning IP addresses and domain names (Internet Corporation for Assigned Names and Numbers [ICANN]) or attempt to create a new model, based on the paradigm of ant colonies. An emergent system is smarter than the sum of its parts. There is no master planner or executive branch—the overall group creates the intelligence and adaptability. Randomness is a key component. Almost all emergent systems are networks or grids. They tend to be flatter and more

horizontal. Experimentation is another key component (Exact Software, 2004).

- **Data Trusteeship and Use:** Needless to say, a software solution that facilitates and manages such virtual communities in any industry will also create large databases of immense value to the industry. However, as the aggregated data would belong to the community as a whole and not to any individual participant in the community, it has to be held and maintained under trusteeship in order to prevent any leakage or misuse. This responsibility also can be undertaken by the same body that owns and controls the virtual communities on a distributed or centralized basis.
- **Data Sharing:** Another challenge pertaining to data would be sharing it among different entities of the community on authorization by the owner of the data. An interesting paradigm shift that happens here is the split between the owner and the possessor of data. Taking the example of healthcare, a patient's data in the form of medical history are currently possessed as well as owned by the doctor. Therefore, whenever a patient moves from one place to another, there is a rare chance that the patient or the doctor at the new place will have access to historical medical records of the patient. However, the customer-centric model can shift the ownership of data to patients, who then can provide access to the doctor or medical institution of their choice.
- **Security and Privacy:** Since the solution depends on information and communication technology, it also is prone to the security and privacy threats faced by such networks. The threat is all the more perceptible, given the sensitivity of certain types of data, like financial data, medical records, and so forth. However, this is a manageable challenge, given the number of high-quality encryption solutions available now.

CONCLUSION

This chapter has initiated the concept of a customer-centric model in supply chain systems. The chapter also has discussed how the model can work and how it addresses various constraints of the existing, essentially vertical supply chain systems by putting forward a matrix model. Apart from the global trends in various industries and supply chain that necessitate such a paradigm shift, the chapter seeks to ascertain the high value addition of the customer-centric model and how it will enhance the present-day supply chains to the next level. It further has enumerated the limitations of the new model and the issues and challenges that are anticipated in implementing the customer-centric supply chain model. While discussing the issues and challenges, the author has attempted to suggest some potential solutions to the challenges. Finally, the chapter has provided some directions for future research and action.

THE FUTURE

As discussed earlier in this chapter and also noted in the literature surveyed, there is a definite shift from vertical integration to matrix relationships among various partners in the supply chain. This, in conjunction with globalization, specialization, and broken ownerships of various components of the supply chain, certainly creates a need for a paradigm shift in the models and solutions of supply chain management conceived and practiced so far. In the opinion of the author, whether this paradigm shift will happen in the future probably is not a question; when it will happen is worth speculating and preparing for.

In the years to come, one can expect more aggressive initiatives toward this paradigm shift. This also throws up multiple business and research opportunities in a completely new direction. Such opportunities will be created in both areas—the respective domains of various industries as well as the domain of information and communication technology. Given the wide scope of the suggested solution, there could be opportunities in the areas of international relations and creation of global standards, as well.

Some specific opportunities for the immediate future are the following:

- Creation of globally acceptable standards related to operations, transactions, workflow, and information flow in various industries, especially in those belonging to the knowledge economy.
- Creation of software components, frameworks, and libraries that can facilitate the implementation of a customer-centric supply chain management system.
- Innovating new concepts to address the challenges around data management and sharing.
- Conceptualization of management models for ownership and control of virtual communities.
- Creation of a legal framework that would govern the working virtual communities.

Finally, I believe that mankind has all the necessary knowledge, tools, and technologies to make this happen. Does it have the will in the larger interest of mankind? Will we do it? Let time answer these questions.

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Chapter 8.11

Strategic Decisions for Green Electricity Marketing:

Learning from Past Experiences

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ABSTRACT

Green electricity (GE) has emerged as one of the most interesting instruments for promoting renewable electricity in liberalized markets, at least in theory. Indeed, some experiences have already been carried out, mostly in the U.S. and Europe. However, most of them have been largely unsuccessful. In this chapter, we look at previous surveys and studies carried out on customer response, and provide a review of the most relevant results achieved by GE experiences, in order to learn from them. As a result, we provide what we believe are the key strategic recommendations for green electricity retailers to launch a successful GE program. Although the green electricity market remains a difficult one, several improvements can be achieved by learning from past mistakes and carefully analysing the alternatives and the boundary conditions.

INTRODUCTION

Now that the risks of the current energy mix are being recognized and awareness of the benefits of electricity production from renewable energy sources has become widely extended, there is a general consensus on the need to stimulate technical progress and development of renewable electricity sources. However, there is still controversy about which should be the instrument chosen to achieve these objectives. Indeed, a wide array of support schemes and policies have been introduced with the aim of stimulating competition with conventional technologies, the most used of which are feed-in tariffs, subsidies, or renewable energy quotas (see e.g., Del Río & Gual, 2004).

One of these instruments, which in principle is well suited to liberalized markets, is green electricity. This consists basically of the possibility for electricity retailers to offer a differentiated product, electricity produced from "green" sources, charge a premium for it in order to account for the extra cost of these green sources, and let the customer decide whether to accept the offer and pay this extra amount or to not accept it. It is a voluntary mechanism based on product differentiation and relying exclusively on market forces.

Green electricity may take the form of "green pricing" (Moskovitz, 1993) in regulated markets, whereby consumers may pay a premium to their electric utility in order to be supplied with electricity from renewable energy sources or increase the contribution of renewable energy into the system. In competitive markets, this is also known as "green power marketing," the difference being that customers may have a choice of different suppliers and products, and therefore switch between them. However, the concept is essentially the same, and hence we will consider both under the same "green electricity" name.

On first inspection, it seems that green electricity programs are then a quite straightforward and market-based approach to promoting renewables. The problem is, this is not as easy as it may seem.

A first problem is how to define "green." Usually, green means renewable electricity: hydro (large and small), wind, biomass, solar, and other minor ones such as geothermal, wave, or tidal energy. Of course, it would be arguable that some renewables are "green" in the sense that they do have large impacts on the environment. In fact, some programs exclude large hydro due to this reason. In addition, sometimes other nonrenewable electricity is also included in "green" programs: co-generation is sometimes included because of the environmental benefits it provides to the system (due to its higher efficiency in energy conversion). The fact is that there may be differences in customer response depending on the type of energy included in the program, but in the end, most of the analysis applies to all types described. So, for practical purposes, we will consider "green" equivalent to "renewable."

But the major problem is that, although many experiences have been carried out with green electricity retailing in different countries, none of these experiences has been truly successful, due to the complex issues lied to this option: green energy definition and certification, customer response, specificities of the electricity markets, and compatibility with other renewable electricity support policies.

Let us put as an example the green electricity programs launched in Spain during 2004. The major Spanish utilities offered their customers the possibility of consuming electricity only from renewable sources, mostly hydro and wind, at a quite small premium (around 15%). Each of them devised large publicity campaigns and built customer service centers specially devoted to this issue. Given that Spain is one of the European countries with the largest contribution of renewable electricity, and that the electricity retail market was just being liberalized, it seemed a good business opportunity. However, after some months, the real participation in the program was less than 1%, and in fact all programs were discontinued after less than 1 year. It seems that many elements in this strategy were mistaken, as has happened with many other programs around the world.

In this chapter, we aim to learn from these experiences in order to provide recommendations on how to successfully market green electricity. We first look at the most salient of the considerable number of surveys and studies carried out regarding green electricity and consumer willingness to pay for it. Second, we provide a review of the results achieved in the most relevant real green electricity programs. By looking at these programs in the U.S. and the European Union, concrete examples of how these instruments were designed, how successful green electricity as a product was, and how much new renewable capacity was installed as a result of these markets are analyzed. The final part of the chapter provides some strategic recommendations for green electricity retailers in liberalized markets. Although the green electricity market remains a difficult one, several improvements can be achieved by learning from past mistakes and carefully analyzing the alternatives and the boundary conditions.

BACKGROUND

In principle, there are many reasons for the attractiveness of green electricity programs: they may provide benefits for utilities, for companies, and, possibly, for individual customers.

Utilities find green electricity programs interesting in that they help them improve their environmental performance and corporate image (especially interesting for those with environmental management systems or under regulatory constraints); differentiate from the competition and provide niche markets; retain or gain environmentally-minded customers; and also may be thought as a defensive strategy against critical stakeholders (usually from the environmental community) (Kotchen, Moore, & Clark, 2001; Wüstenhagen, Markard, & Truffer, 2003). They also have the potential to encourage learning processes, which are certainly welcome given the recent liberalization context.

For companies, buying green electricity is a way of signaling their concern for the environment, of reinforcing their corporate image (Fouquet, 1998). They can also help meet corporate and institutional goals related to corporate social responsibility.

Incentives for individual customers to participate, however, are less understood. Green electricity is an impure public good, in that it provides both private (electricity consumption) and public benefits (the improvement of the environment compared to the use of conventional energy). But because the latter is the essential characteristic of green electricity, it should be expected that individuals will have little incentive to provide such a public good and instead free-ride (Clark, Kotchen, & Moore, 2003). In fact, RE advocates have opposed the concept (Swezey & Bird, 2001): since this is a public good, all consumers should share the cost of RE development. A survey by Wiser (2007) reinforces this idea by showing that collective payment methods are generally preferred by consumers, that is, that consumers prefer all to pay for this good.

But then, environmental concerns, altruistic attitudes, or even egoistic reasons may exist that explain why, as will be shown in the following section, individual customers are willing to engage in these programs. Some authors (e.g., Ek, 2005) have pointed out that when people deal with public issues, they may adopt public rather than private preferences. In addition, these programs provide an opportunity for individuals to express personal preferences and thus are beneficial to them. Indeed, they may also help them form preferences, attitudes, and consumer behavior (Markard & Truffer, 2006). Green electricity programs also integrate consumers into the RE support process.

Several studies have analyzed both the willingness to pay (WTP) of individual consumers for increased renewable energy contribution in the system, and also the success of the different green electricity programs implemented. A good review of WTP estimates may be found in Menger (2003), whereas Swezey and Bird (2001), Bird, Swezey, and Aabakken (2004), Bird, Wustenhagen, and Aabakken (2004), Bird and Kaiser (2007) and Wiser, Olson, Bird, and Swezey (2004) provide good overviews of green electricity programs. In this section, we bring these two issues together, and we update them with the most recent results and findings, in order to draw meaningful recommendations for the green electricity marketer.

The Willingness to Pay for Green Electricity

As mentioned before, green electricity, although having public good characteristics, shows a certain attractiveness to consumers, which are hypothetically willing to pay a premium over normal electricity prices. In fact, empirically observed levels of provision of public goods such as green electricity usually exceed levels predicted by rational-choice theories. This is usually explained by some kind of pro-environmental behavior, derived from a combination of egoistic, social altruistic, and biocentric value orientations (Kotchen et al., 2001).

Therefore, most studies show positive WTP values. Fouquet (1998) cites a survey indicating that 5% of residential customers in the UK would pay a 20% premium for environmentally friendly electricity. In Switzerland, Truffer, Markard, and Wustenhagen (2001) state that 20% of the households are willing to pay a 10-20% premium. Farhar (1999), in a market survey, found that there is a consistent pattern for the U.S. in that 70% of residential customers would pay $5/month, 40% would pay $10/month, and 20% would pay $15/month. Wüstenhagen et al. (2003), based on results from Germany, Sweden, the UK, and Switzerland, estimates that 20% of consumers would pay a 20% premium, whereas almost none would pay a 40% premium.

These WTP estimates are averages. However, they will depend on many parameters (including those related to pro-environmental behavior mentioned above). Roe, Teisl, Levy, and Russell (2001) identified several differences in WTP across regions in the U.S. They also found that a higher income, a higher education level, and affiliation with an environmental organization would increase the hypothetical premium. These results are consistent with those obtained by Rowlands, Scott, and Parker (2003), which identified as the major drivers for WTP the following: ecological concerns, altruism, education, perceived effectiveness, age (younger people have higher WTP), income, and involvement in community services or environmental organizations.

WTP estimates may also be conditioned by the type of renewable energy offered. Borchers, Duke, and Parsons (2007) found a positive WTP for green electricity in the U.S., but also found that the energy source affects this WTP. Thus, they found that solar is better, wind is similar to a generic offer, and that biomass and biogas achieve lower WTP estimates.

Finally, most of the estimates correspond to residential customers, because no studies have been found on the WTP of firms or institutions to buy green electricity. This is unfortunate, because these clients may be powerful drivers for the green electricity market.

So, to summarize: there is a positive willingness to pay for green electricity, and this WTP will depend on some issues which should be contemplated carefully by green electricity retailers, such as the client profile, the type of renewable offered, and the premium at which the green electricity is sold.

Green Electricity Programs Across the World

As has been shown, there are a large number of households and firms willing to pay a premium for green electricity. However, when it comes to actually signing in for green electricity programs, participation rates plummet: Market penetration rates for green electricity programs around the world are generally 1% (Bird et al., 2004). Although some programs have been more successful (up to 15% in some cases), this is much lower than the rates expected from the WTP studies. Some factors which may explain this are:

- Failure in marketing research
- Overestimation of WTP due to its hypothetical nature

- Free-riding
- Education or communication failure

It should also be kept in mind that the personal attitude toward environmental or energy policy is not necessarily the same as the perception about the personal responsibility to fulfill environmental goals. This should not be considered free-riding, but rather a view on how public goods should be provided. This may also explain the different consumer response across countries with different public-private cultures. For example, in Europe, consumers usually consider the environmental impact of electricity generation as the responsibility of the regulator and utilities (Fuchs & Arentsen, 2002).

We will now review the major green electricity experiences across the world, briefly reflecting on their major characteristics. The basic data for these are summarized in Table 1.

As may be observed, most of the programs have achieved very small penetration rates. However, it may also be noticed that some of them have achieved significant rates, such as the Netherlands, Sweden, or Switzerland. We will briefly review these cases below.

The Dutch case is the most noticeable: Here market penetration rates were very large. This can be explained by a number of reasons: first, green electricity was offered at or below conventional electricity rates, due to an exemption from the common energy tax (in fact, this exemption was the major RE support mechanism); second, green electricity was liberalized well before the rest of electricity sources, that is, the Dutch government decided that, during the first stage of the liberalization process, green electricity was the only option for those customers who wanted to switch suppliers; finally, large-hydro power imported from France was in a first stage considered as green electricity by the Dutch government, and that allowed for a large supply of RE. However, the Dutch example is not usually considered a success story: most of the green electricity was imported and already existing, and therefore the growth in RE production was almost insignificant (Reijnders, 2002). In fact, partly as a result of this lack of delivery and the realization by the Dutch government that the real bottleneck was in domestic supply, not in demand, the tax exemption and the possibility to use imported hydro power were terminated in 2005, and replaced by a feed-in tariff only for domestic sources (Van Damme & Zwart, 2003; Van Rooijen & Van Wees, 2006). This also ended with the growth in green electricity share.

Sweden also features a large penetration of green electricity (9%). In this case, the major reason is the use of existing cheap hydro power, and also the large involvement of government and public companies, which signed up to a large extent for these programs (Ek, 2005). But again, in spite of the large market share, there was not a significant growth of renewable energy, because most of it was already existing power.

Finally, we should also look at the Swiss case. Here, penetration rates have not been very large (between 0 and 4.4% depending on the program), but the interesting point is that most of it is due to photovoltaic electricity, with its associated large premiums (prices 4 to 7 times higher than ordinary electricity). This case shows the possibility of using green electricity for small niches of price-insensitive, environmentally-concerned, customers (Wüstenhagen et al., 2003).

So we see that there are large differences between the different green electricity programs. Even in countries with low market shares, there are very successful programs (in the U.S., for example, there are programs which have achieved almost 5% penetration rates). It seems then that it is not only the market environment, but also how the program is designed, that really drives its success. In the next section, we review the major aspects to be considered in order to design a successful green electricity program.

Table 1. Green electricity programs in the world

	Electricity Market					Green Electricity Market							
	Total customers (mill)	Residential customers (mill)	Total consumption (Bill.kWh)	Residential consumption (Bill kWh)	Cost (c€/ kWh)	Generation Capacity (GW)	Number of green suppliers	Green customers	Green retail customers (%)	Price premium (%)	Market share (%)	New capacity installed (aprox.)	
AUSTRALIA	8.7	7.5	205.25	46.5	12.8	37.9	20	68000	0.9	31.25	0.3	200 MW	Due to certification systems, a great amount of new capacity installed
CANADA	14.9	11.9	572.99	129.5	6	109.8	<10	6500	1	40 to 100	0.03	80 MW	Only some states offer green products
GERMANY	43.5	38.4	566.89	130.5	15.9	107.8	140	325000	0.8	4 to 50	0.2	54 MW	Lack of regulation (free access to grid). Many regional small players.
FINLAND	2.9	2.3	81.6	31	9.1	16.1	>30	8000	0.4	0 to 10	0.2	n/a	
HOLLAND	7.2	5.8	92.7	20.8	13.2	14.2	15	775000	10.8	-3 to 10	3	50 MW	Favorable fiscal system
JAPAN	71	56.8	974.4	251.8	21.2	226.4	>10	38000	0.3	30 to 40	0.003	12 MW	Limited eligibility
SWEDEN	5.2	n/a	157.6	n/a	11.2	n/a	75	n/a	n/a	0-5	10.3	n/a	Existing hydro
SWITZERLAND	3.8	3	61.97	15.1	13.1	14.6	135	48000	1.3	10(hydro) to 500 (new solar)	0.3	10 MW	Environmentally conscious retail clients
U.K.	27.3	21.8	363.17	109.6	11.7	69.9	10	45000	0.21	10 to 60	0.04	30 MW	Limited success
USA	126	101.4	3979.04	1193.4	6.64	785.9	>100	375000	1	8 to 200	0.1	650 MW	

Sources: www.greenprices.org; Markard & Truffer (2006); www.iea.org; www.eia.doe.gov/fuelelectric.html

STRATEGIC DECISIONS

As mentioned before, a careful program design and marketing can increase largely its success in customer response (Swezey & Bird, 2001): Market penetration rates beyond 10% (Bird et al., 2002) or even up to 20% (Ethier, Poe, Schulze, & Clark, 2000) are achievable under favorable conditions.

In this section, we detail a number of issues which should be carefully considered by green electricity retailers when designing their products. Basically, these issues should help counteract the little knowledge existing among consumers about green electricity, and also its additional costs due to generation, administration, and certification.

Basic Design of the Program

There are basically two types of basic green-electricity program designs, contribution-based programs (also known as voluntary contribution mechanisms or VCM), and green tariff programs (GTM).

Contribution-based programs are those whereby households donate money to finance new renewable electricity capacity. Payments are independent of electricity consumption. In contrast, GTM programs link payments for green electricity with household consumption, by setting up a specific tariff per kWh. In some cases, this tariff may apply only to a fraction of the total household consumption.

Generally, it has been shown (Kotchen & Moore, 2007) that GTMs will generate lower demand levels than VCMs. But this is only if consumers are allowed to choose the fraction of demand to be supplied by green electricity. All-or-nothing GTMs (when demand is covered 100% by green electricity) can generate either lower or higher demand levels, depending on other issues. The comparison between them will depend on the green tariff: sufficiently low or high tariffs continue to favor the VCM, whereas for mid-range tariffs the all-or-nothing GTM may be preferred (Kotchen & Moore, 2007). Some surveys (Swezey & Bird, 2001) argue that contribution programs have resulted in only small amounts of new RE capacity, except for photovoltaics.

The type of program will also have an influence on the target client: VCM contribution is affected by environmental concerns, altruistic attitudes, household income, gender, and household size. However, GTM participation is not affected by household income, but essentially by the effective price of participation (Kotchen & Moore, 2007)

In addition to these basic program features, there may also be some elements which may contribute to a greater participation rate. For example, provision point mechanisms have been shown to improve participation rates. These mechanisms consist of providing a minimum threshold of participants in the program, so that the program will only be effectively started if this threshold is attained. The major effect of this mechanism is the reduction of free-riding, and so it has been shown to better reflect actual preferences, and to increase participation rates in real programs (Ethier et al., 2000; Rose, Clark, Poe, Rondeau, & Schulze, 2002). This mechanism also increases the perceived program effectiveness, which has also been shown as a driving factor for increased participation (Rowlands et al., 2003).

Other programs have also proposed money-back guarantees: if the project is not undertaken, then money will be returned to customers. This mechanism has been strongly favored in surveys, but seems not to be significant for joining into the program (Rose et al., 2002).

Finally, a last issue is the continuity of the program: Older programs tend to achieve higher levels of success, because they are able to increase their market share with time (Wiser et al., 2004). This may have to do with different issues, such as credibility, program effectiveness, or consumer awareness.

Renewable Electricity Types

Much of the green power sold has been supplied from existing sources, both in the U.S. (Bird et al., 2002) and Europe (Chappaz, 2003), in some cases even from either amortized or supported by long-term purchase contracts. This certainly allows for lower premiums, which are in principle desirable. However, it seems that consumers are eager to pay more for newly created generation, even if its total amount is not significant (Roe et al., 2001).

In addition, if we consider the amount of new RE capacity as a measure of the success of green electricity programs, then newly created generation should be a must. In some cases, this may be mandatory, as in Australia (ICON, 2004), whereas in other countries it relies entirely on the firm's decisions.

As for the type of RE source, a study by Borchers et al. (2007) found that solar energy was able to generate larger premiums from consumers than wind energy, and that biomass and biogas were the less valued energy sources for green electricity. No data have been found for large hydro or cogeneration.

The use of biomass, cogeneration, or large hydro is worth citing: Although some clients may have problems with them, because of their "impure" renewable characteristic (which can be avoided by using eco-labeling, as mentioned below), they are required if the retailer wants to provide real-time renewable energy to the customer (i.e., to follow his or her demand curve), because they are the only technologies able to regulate their production.

The case of large hydro is also relevant because of its large volume, and because it does not usually require a premium. Therefore, many utilities are considering it for their green electricity programs. However, in most countries this is a depleted technology (i.e., with no further expansion capacity), and introducing it into green electricity programs would merely displace it from some customers to others without creating additional environmental benefits (see the section on additionality). And then there is the question of the price at which this electricity should be offered: Because most of the large hydro plants are competitive, and in addition have been almost paid off, in principle the price should be low; on the other hand, hydro should be priced at the opportunity cost of the alternative electricity, which is the marginal electricity price, but that may be difficult to explain to customers.

It is obvious that the percentage of renewable included, the type of technologies used, and whether there are new plants or not will determine the final price of the product, as well as the possibility to balance generation and demand in real time. In most cases, retailers may offer different possibilities, adapting mixes to the price sensitivity and needs of the customer.

Customer Demand Coverage

At least in principle, the type of contract that leaves more purchase flexibility to the retailer, and minimizes the need of demand forecasting, is covering with renewables the aggregate of total annual consumption (or a percentage of it), because this method removes the need for real time generation-consumption balance. Therefore, the retailer can purchase cheaper electricity by avoiding buying electricity in peak hours. The only commitment would be to acquire a quantity of renewable energy equal to that consumed by the client at the end of the year, without taking into account when it was generated or acquired.

Nonetheless, there is a fundamental drawback: A well informed client could argue that there is an excessive dependency on nonrenewable generation to follow her demand in real time. The retailers that choose this option focus on the fact that the renewable generation is intrinsically very unpredictable, and that nowadays the installed capacity is insufficient to cover demand fluctuations in real time.

Coverage in real time with renewables is a more complicated option. Previous experiences in some countries confirm that this coverage would need a suitable method of forecasting demand as well as major flexibility in the mix of technologies (e.g., the use of cogeneration or biomass, which allows dispatch). The relative weight of each technology in the mix should fluctuate according to the needs, although it is possible to establish required margins of values.

The option not to cover the total consumption with a green tariff, but, for example, to cover only 20% and the 80% remaining with a normal tariff, might be translated in a significant final price reduction. This would have economic sense in case the client was more interested in enhancing its brand image than in the environmental benefit. This might be the case of the small industry and commercial sector.

Energy Purchases

Depending on the country, the green electricity retailer may choose among different alternatives when buying renewable electricity from producers. In most cases, the most interesting option will be a combination of them.

Wholesale Market

This is the more flexible but riskier alternative. It will be advantageous if the contract specifies that total green energy generated will equal total retail supply of green electricity on an annual basis. The retailer may then obtain better prices, provided it has the flexibility to choose when to buy the green electricity (avoiding peak hours).

However, not many green electricity producers sell their output on the wholesale market. The vast majority of them prefer bilateral contract agreements or alternatively, they are owned directly by the utility or retailer.

Consumers must have confidence that those products offer genuine environmental benefits. Wholesale market electricity has no way of identification, so green labels and certificates are crucial to guarantee the greenness of the electricity purchased (see below).

The main drawback of this option is the consumer perception of this scheme as excessively dependent on nonrenewable generation, and also the need to guarantee in a credible way the origin of the electricity.

Bilateral Contracts

These contracts make it easier to guarantee the green origin of the energy supplied. Nevertheless, it would be desirable for an independent third party to certify that the generation facilities comply with the necessary requirements to be considered “green.”

It is a less risky option, given that price is fixed in advance, but potential savings from buying during off-peak hours are not available. On the other hand, the reduced risk due to the long-term contract may help lower the price of this electricity.

However, given the lack of flexibility and predictability associated with renewable generation, it might be difficult to use this option to follow hourly demand if cogeneration, large hydro, or biomass is not included. Therefore, a certain trade in the wholesale market may be required.

Vertical Integration

In case the retailer does not only devote itself to green marketing, but also to generation (with any type of facilities, renewable or not) and distribution, this option would have a certain advantage when considering to acquire or to build green generation facilities, as opposed to a nonvertically integrated retailer. This initial advantage would come from the experience and the know-how in the generating business, as well as from the previous availability of the necessary means to operate the facilities. If this option is chosen, the retailer would have green energy at generating price, and it would know exactly the cost of generation. There would be no need for intermediate steps and negotiations, although risks of own capital investment must be taken into account.

Investing the profits obtained in new renewable generation to integrate vertically looks like a particularly attractive option for a green retailer, because this strategy allows putting this money at work and at the same time makes it easier to justify that clients' contribution is being used to improve the environment.

Tradable Green Certificate (TGC) Systems

There is another possibility, although only feasible in some countries: the establishment of a TGC system would allow the retailer to acquire the physical energy separately from the green certificate. The retailer should possess at the end of the year a number of TGCs equivalent to the quantity of energy consumed by clients (and to have acquired, though separately, the corresponding energy). This concept could be applied to any of the purchase options cited previously: to wholesale markets purchases (where it seems to be especially necessary), and to bilateral contracts (theoretically, it would be possible to have a bilateral contract with a nonrenewable facility, and purchase the number of equivalent certificates from another facility).

The major advantage of this system is the flexibility it provides for the retailer.

Target Clients

Different target clients may be identified, depending on the type of product to be supplied. A good analysis of the general client segments to be targeted may be found in Fuchs and Arentsen (2002).

The first customer segment to be targeted seems to be those clients more prone to pay high premiums. These are households with pro-environmental and altruistic attitudes, high income, few members, and high education levels. It has been shown that these aspects reliably predict participation in a green electricity program, according to several studies (Clark et al., 2003, Kotchen & Moore, 2007; Wiser, 2007).

Household income is important, but this depends on the type of program: For example, income does not affect participation in GTM programs, whereas for VCM programs it is the only factor influencing the amount contributed (Kotchen & Moore, 2007). Therefore, these authors propose to target households with higher income when using a VCM program, and to target households with lower electricity consumption (to lower effective prices) when using a GTM program.

Although some authors (Rowlands et al., 2003) argue that gender is not important, others (Kotchen & Moore, 2007; Wiser, 2007) have found that females tend to make larger contributions than males.

In addition to this major target group, it might also be interesting to direct efforts at the large group of "conventional" customers, because a small premium in this large group will be very significant overall. This group is usually very responsive to information, but also very sensitive to prices, although this can be modified when they are made to reflect on the low share of electricity consumption in their budget (see section on premiums).

Social and economic elites may also be interesting target groups, because of their high consumption level and their capacity to influence other groups. In addition, they are easy to target because of their small size.

Finally, private firms, governments, and institutions should also be target clients for green electricity programs. As already mentioned, they are increasingly recognizing the interest of this type of electricity for meeting their institutional goals, and can help much in the success of the program, by providing an example to residential customers, and also free advertising. In fact, nonresidential customers already represent about 25% of the total green power sold in the U.S. (Swezey & Bird, 2001).

Another important issue regarding the target client is its origin: Those more prone to enter into these programs are those already buying electricity from the same utility. In fact, most green electricity clients have purchased it without switching suppliers. This is easy to explain, because, given the very low switching rates experienced in most liberalized markets, requiring the customer to switch supplier will certainly decrease her participation rate in a green electricity program.

It has to be reminded that consumers are used to receiving their electricity from monopolies, with no room or need for making choices. Many find supplier choice, and the related information analysis demand, too encumbering, and prefer to stay with the original supplier (Salmela & Varho, 2006).

Premiums

In this point, evidence looks contradictory: Whereas some studies point to the significant influence of price in customer response (Bird et al., 2002), others (Swezey & Bird, 2001; Wiser et al., 2004) argue that there is no definitive relationship between the amount of the premium and participation rates. This may also be observed by looking at the Swiss case described in the section analyzing green electricity programs across the world, where a market share similar to other countries was achieved in spite of much higher premiums. Indeed, electricity purchases represent a very small percentage of household budgets, so one should not expect a large elasticity of demand here.

However, the success of green products when offered at prices below or similar to conventional electricity cannot be denied. All in all, it seems that premiums should range from 0 to 30%. A premium of more than 30% has been considered as too high in some surveys (Truffer et al., 2001; Salmela & Varho, 2006), although again the Swiss case shows that some customers are ready to pay much more.

Here the intelligent approach seems to rely on market segmentation: If a firm only offers a single program, it could be neglecting segments of customers willing to pay more. To this extent, posted prices seem not to be desirable, because they do not allow households to select the amount which better represents their preferences. A range of products with different prices helps meet the varying WTP.

An additional, but important concern expressed by consumers regarding premiums is that they should not be dominated by administrative and marketing costs (Swezey & Bird, 2001).

Finally, it should also be considered the possibility of offering green electricity at no premium, with the utility bearing the additional costs. This might be considered as a tool for retaining customers or as a way to improve its environmental profile.

Value Creation

Green electricity is not only about pricing, it is also about providing customers with values or private benefits which will drive them to pay more for it. These values may be monetary or not. Monetary ones may be tax deductibility or protection from fuel price increases. Nonmonetary ones include personal recognition, civic pride, promoting sustainability, or educational benefits. The important thing is to make these values visible to customers.

A critical issue then is to know which are the values more prized by green electricity program participants. The major reasons cited by Kotchen et al. (2001) in their study of a program in Michigan were: health of natural ecosystems, local pollution benefits, then personal health, global warming, and finally, warm glow. Altruism toward the environment is more important than toward regional residents or health-based egoism. Local environment is also more important to them than global environment.

Therefore, marketing campaigns should highlight the positive environmental impact of buying green electricity. And these benefits should be made as personal as possible, appealing to personal health rather than to a general improvement in the environment (Rowlands et al., 2003).

The most common methods of providing non-monetary values are program updates in periodic newsletters and window decals. In addition, programs may recognize businesses through program advertisements in media, or provide customers with plaques or other recognitions (Bird et al., 2004). A large visibility of the RE projects promoted by green electricity programs is also useful for creating value (Swezey & Bird, 2001).

Being precise about objectives may also increase the value creation of the program, by providing enhanced visibility of its benefits. According to Rowlands et al. (2003), several utilities have found that programs focusing on a well-defined RE project tend to be more successful in attracting customers than those promoting RE in general.

Information to Customers

Lack of knowledge of green electricity is widespread, and this may explain to a large extent the low participation rates. In fact, consumers are frequently uninformed even of their own electricity consumption and of the related costs and environmental impacts (Fuchs & Arentsen, 2002). This is not surprising in liberalized markets, given the multiplicity of products and technologies. Therefore, any effort to increase consumer awareness will certainly improve these rates.

For example, participation rates in a New York state program were 20%, when sufficient information was provided (Ethier et al., 2000). As another example, 15% of the Australian customers provided with the right information did sign up (ICON, 2004).

An important issue is that the information provided has to be credible, and true. The information provided might be misleading when, even being true, it is not complete or sufficient, so that the advertising might be deceitful not only for what it says, but also for what it does not. Misinforming the customer may backlash against the program, as shown in some experiences (CNE, 2004).

A very interesting way of raising awareness while enhancing credibility is by teaming with environmental or community organizations in order to reinforce messages.

As for the vehicle to provide this information, most utilities perceive telemarketing as the most useful way (Bird et al., 2004). However, most of them use cheaper, but less efficient ones, such as bill inserts and media advertisements. An important point is to keep it as simple as possible, not to overburden customers with excessive information which may deter them from analyzing it.

Credibility

In order to buy green electricity, consumers must have confidence in that the product offered features genuine environmental benefits, and value for money. This requires usually a certification or legitimating process.

Sometimes utilities may not be viewed as legitimate providers of environmental benefits, and therefore the credibility of the program may be greatly enhanced by engaging in partnerships with environmental organizations. Also, green electricity purchases by government or public firms may contribute to improve credibility, as well as to the overall success of the program. These same partnerships may also provide an additional benefit, free advertising.

In the U.S., Wiser (2007) found that private providers were able to elicit higher WTP than public ones because of their higher credibility. However, this may probably vary depending on the country, and in Europe the contrary might be expected.

Legitimacy may also be provided by eco-labeling, which can reduce the transaction costs associated to credibility issues (Truffer et al., 2001). The recognition of the eco-label will be enhanced if it is accepted as a standard not only by consumers but also by competitors, so a broadly accepted label should be sought after by green electricity programs. There are several labels applicable to renewable electricity, such as the Eugene label developed by the European Commission, which not only certify the renewable origin of electricity but also ask for additional environmental benefits, which is certainly relevant for RE sources such as hydro.

Relationship with Other RE Support Schemes

The existence of other support mechanisms for renewable electricity may have either positive or negative impacts on green electricity. For example, some authors (e.g., Markard & Truffer, 2006) argue that the existence of feed-in tariffs in Germany or Spain may be an explanation for the almost negligible role of green electricity in these markets. On the other hand, Menger (2003) argues that the amount that customers are willing to pay to prevent environmental damage is independent of the amount of damage prevented, and therefore, that there is a potential for voluntary demand in addition to mandatory support schemes.

What everybody agrees on (e.g., Menger, 2003) is that all green electricity programs should be additional: The funds collected from these programs should be clearly earmarked for new RE investments, additional to those which would have taken place anyway under the other RE support mechanisms.

This does not necessarily mean that green electricity and other RE support schemes should be incompatible. In fact, some argue (e.g., Swezey & Bird, 2001) that other support schemes should be sought by retailers in order to lower the premiums. The key point here is that this is done only to effectively lower the premium and not to increase artificially the profits of the retailer (e.g., by charging a premium for electricity which is already competitive and therefore does not need the premium to operate).

Although those plants which are economical under other support schemes might be sold without a premium, they would not comply with the requirement of being additional, because they would have been installed anyway. One possibility might be for these plants to decline to participate in the mandatory support scheme, and try to get the premium instead. That would certainly comply then with the additionality criterion. However, this should be handled with care, because such a combination of support mechanisms creates confusion among consumers, and burdens the administration of the system (Dinica & Arentsen, 2002).

Therefore, only those RE plants uneconomical under other RE support schemes, or those which decline to enter into them, should be allowed to be included in green electricity programs (e.g., by only certifying as renewable energy this type of plants). The premium in both cases should be carefully monitored so that it reflects the additional cost of the technology (plus the administrative and certification expenses required) and not undue profits for the retailer. Some countries (e.g., Spain) have already regulated these aspects for green electricity retailers, by requiring separate accounts and a specific use of premiums.

Another way of thinking of additionality is to use the premium to reduce the environmental impact of existing RE plants beyond the current regulations (e.g., helping windmills integrate in the landscape, providing additional fish stairs for small hydro). However, it is arguable whether consumers will respond equally favorably to this additionality concept, because they might argue that these measures should have been taken anyway.

SUMMARY AND CONCLUSION

Based on our review, we can conclude that there seems to be a considerable gap between being environmentally conscious and acting upon these convictions, which has hindered the success of past green electricity schemes, together with some strategic errors on the part of retailers.

Therefore, major improvements on retailing strategies are still required in order to achieve a larger penetration of green electricity, both by maximizing customer participation and also new RE development. As mentioned before, rates up to 20% may be achieved for selected market segments, when all recommendations are met. Below we summarize our major recommendations:

- Green tariff programs (GCM) are more effective, at the usual tariff levels, in providing new RE development, so they should be generally chosen to contribution-based ones (VCM).
- A provision point mechanism reduces free-riding, and can therefore increase participation rates.
- Persistence pays: Long-term programs see steady increases in customers.
- Whereas solar and wind seem to attract higher participation and premiums, they are not able to provide real-time coverage of demand. If this is the goal, biomass and cogeneration should be included. Hydro presents several problems which should be addressed carefully.
- Premiums should range between 0% and 30%. Variable premiums (based on different products) help account for the differences in WTP among clients.
- Bilateral contracts help lower costs, by reducing risks, and increase the credibility of the green origin of the electricity.
- It appears that the greater success will be obtained by targeting young-age, highly-educated households with greater concerns for the environment or stronger altruistic values.
- Teaming up with environmental and charitable NGOs may prove really useful, because that will also provide greater credibility for the program, help provide information and raise awareness, and may even provide free advertising.
- Relying on the existing utility client base enhances participation, by eliminating the switching barrier problem.
- The retailer must be able to define clearly, simply, and visibly the environmental advantages of the product, to offer something tangible that has added value and to provide arguments supporting the legitimacy of its right to receive a premium. Focusing on specific RE projects increase visibility and credibility. A local focus seems also to be more effective than broadly-based programs.
- Complete information on the characteristics and advantages of the program must be provided in a simple and effective way (e.g., via telemarketing) to consumers.

Of course, most of our conclusions are general, and therefore specific analysis should be carried out for different market conditions, because, as mentioned along this chapter, both cultural differences, energy policy, and electricity market design may influence to a large extent the issues to be considered (e.g., an analysis for the Spanish electricity market may be found in Pérez-Plaza, 2004). However, we consider them to be a necessary first step if successful green electricity programs are to be devised, and an analysis which had not been undertaken before.

FUTURE RESEARCH DIRECTIONS

There are several areas in which future research may improve significantly our knowledge of this issue, and therefore the effectiveness of green electricity programs.

First of all, an extension of the market surveys and WTP studies to other countries where green electricity programs might be implemented would be a very welcome future line of research. Most WTP studies have been carried out in the U.S., UK and northern Europe. However, many other countries show good potential for these programs, and estimations of WTP values would be the first input for the definition of marketing strategies in these countries.

Second, there is no data on the willingness to pay of firms and institutions for green electricity, in spite of the seemingly larger interest that this type of consumers may have on these programs. An extension of WTP studies to firms or institutions would therefore be very interesting.

Finally, it should be pointed out that most of the work done on the analysis of green electricity programs has been carried out from the energy policy or environmental economics fields, whereas it is clearly an issue to be studied within the marketing community, which have specific tools and methods to address this issue. Again, this research might prove critical for the success of green electricity programs.

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Chapter 8.12

Information Technology Service Management and Opportunities for Information Systems Curricula

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ABSTRACT

Historically, information systems (IS) programs have taught two of the three areas of information technology (IT) management: strategy and management, and applications development. Academic programs have ignored the third area, IT operations. IT operations management is becoming increasingly important as it is recognized as consuming as much as 90% of the IT budget and as acquisition of software becomes more prevalent than development of custom applications. Along with the shift of management focus to IT operations, standards such as the IT infrastructure library (ITIL) have been adopted by businesses to guide the development of processes for IT operations that facilitate evolution to IT service management. This shift to servitizing IT management, creates an opportunity for IS programs to align with business practices by innovating in the teaching of IT service management. Several methods of incorporating ITSM material into educational programs are explored. [Article copies are available for purchase from InfoSci-on-Demand.com]

INTRODUCTION

With increasing frequency, disruptive technology-related innovations cause a paradigm shift in IT practice and management. In the 1950s and 1960s, methodologies codified best practices in application development for analyzing and computerizing complex processes (De Marco, 1979; Yourdon, 1988). Subsequent generations of methodologies evolved to include data orientation, then object orientation, and most recently, event orientation. Relational database technology, introduced by Codd and Date, similarly disrupted data management in the 1970s (Codd, 1970; Date, 1999). The development of personal computers disrupted both industry and academia in the 1980s. Object orientation changed methods of teaching application development and programming in the 1990s (Jacobson et al., 1998). The Internet changed business conduct beginning with its privatization in 1993 but accelerating with technology maturity in the late 1990s and early 2000s. This decade is witnessing two disruptions relating to the servitizing of IT organizations, one technical in the form of service-oriented architecture (SOA) (Durvasula et al., 2008), and one process and management oriented in the form of IT Service Management (ITSM) (itSMF, 2007).

This article addresses the changes in the conduct of IT in business and the related need for academic programs to address those changes. Alternative approaches for developing academic programs are presented and discussed.

THE CONDUCT OF IT IN BUSINESS

In the last century, Information Technology (IT) and the Chief Information Office (CIO) often were separated from the business strategy-development team. Business strategy was developed and possibly discussed with the CIO, who developed an IT strategy, to the extent possible, that fit the business strategy. Enlightened organizations might allow the CIO to sit in the meetings so the later discussion was circumvented. Enlightened organizations might also conduct their critical decision making to prioritize and select projects for development or acquisition through an IT steering committee comprised of the CIO plus other executives who represented critical stakeholders to the decision process (cf. King, 1985). The outcome of a successful matching exercise should align the business and the IT strategy.

IT in Business: The Academic View

More recently, the need for more seamless integration of business and IT strategies has been described (Weill & Ross, 2004). Under the newer scheme, IT moves away from responding to single requests in a never-ending queue toward architecture-driven IT decisions that ensure improved organizational support and, eventually, improved organizational response to changing environmental conditions (Ross et al., 2006; Broadbent & Kitzis, 2005; Ross et al., 2006). Under these more recent schemes, the responsibility for alignment is shared between the C-level executives and the CIO, with successful organizations being those that most closely align IT with business strategy. However, alignment activities apply to matching applications to strategy and does not extend to operations, help desk, or other types of services.

One key issue in these writings and others like them is that the prescriptions give little guidance on how to actually conduct business within the IT department that mirrors and fulfills the alignment objectives decided. Frameworks, such as the IT Infrastructure Library (ITIL), Control Objectives for Information and related Technology (CobiT) or the Capability Maturity Model - Integrated (CMMI) might be alluded to with an implicit assumption that their application will provide the needed IT discipline for IT organizations to act as desired (SEI, 2006; ITGI, 2007; OGC, 2008).

These ways of thinking, rather than avoiding the issues of IT management, either assume that the important actions take place in the decision process or that day to day operation of the IT organization is not relevant to discussions of strategy. Further, books and academic programs that *do* address daily functioning of IT focus on applications development, such as object orientation, or technology, such as telecommunications with little regard to how they are configured and managed in a production environment.

IT in Business: Business Practice

Business organizations, whether public, private, profit, or non-profit, have realized that undisciplined, non-repeatable work can undermine the best governance architecture. To develop a process discipline along with a culture of service, organizations of all types are rapidly servitizing the IT organization and its offerings. Adoption of the IT Infrastructure Library (ITIL) has spread to about 70% of non-US organizations and about 60% of US organizations (Dubie, 2008). In the U.S., 87% of companies with more than 10,000 employees have adopted ITIL (All, 2008). ITIL is chosen over or in concert with Cobit, CMMI, and Six Sigma because as Evelyn Huber of Forrester Research says, “there is nothing else” (Anthes, 2008, pg 2.)

The adoption of service management tenets is idiosyncratic to each organization with significant contextualization of each adopted process and function (Conger & Schultze, 2008). In addition to the high global adoption rate for ITSM tenets and ITIL, in particular, the adopting companies generate a significant number of new jobs requiring service management and process understanding. One U.S. study of itSMF-USA (a practitioner organization) member companies found that about 15,000 jobs requiring ITIL knowledge and skills are created annually (Conger et al., 2008).

The combination of adoption rate and job growth has not gone completely unnoticed with about 15 programs in Australia, Europe, Africa, Mexico, and New Zealand (Cater-Steel & Toleman, 2007). By contrast there are two undergraduate and one graduate ITSM program in the U.S. These adopting universities are bucking established programs and courses to bridge the gap between business and academia. However, the gap is firmly institutionalized in academic program guidelines that hinder broad adoption. The divide between business practice and academic practice is an important one for it permeates IT education. The nature of the divide is explored in the next section.

IT IN EDUCATION

The Model Curriculum guidelines for undergraduate IS/IT education in the U.S. exemplify the business-IS/IT curriculum divide. U.S. curriculum is developed by the Joint Task Force on Computing Curricula, comprised of mostly academics through the Association for Computing Machinery (ACM), Association for Information Systems (AIS), and Institute for Electrical and Electronics Engineers (IEEE). While the 2005, currently official, version is discussed here, an update for 2008 was let for review recently. This discussion applies equally to the 2008 update which only uses the term ‘service’ in terms of student *service* projects, not mentioning IT management, IT operations, process, or service in any pedagogical discussion (The Joint Task Force, 2008).

The computing curriculum guidelines are summarized with weights applied to knowledge areas as shown in Table 1. Degree types and abbreviations include Computer Engineering (CE), Computer Science (CS), Information Systems (IS), Information Technology (IT), and Software Engineering (SE). The numbers ranges from zero to five and represent the relative emphasis at which program coverage is recommended (The Joint Task Force, 2005). Figure 1 shows the “organization” emphasis for information systems. These figures imply that there should be a preponderance of organizational information in IS programs. In fact, the Joint Task Force report says:

“The meaningful question is: ‘Has an IS program broadened its scope to include an integrated view of the enterprise with complex information needs and high-level dependency on IT-enabled business processes?’ ... IS students must learn how to assess and evaluate organizational information

Table 1. Comparative weights of program components

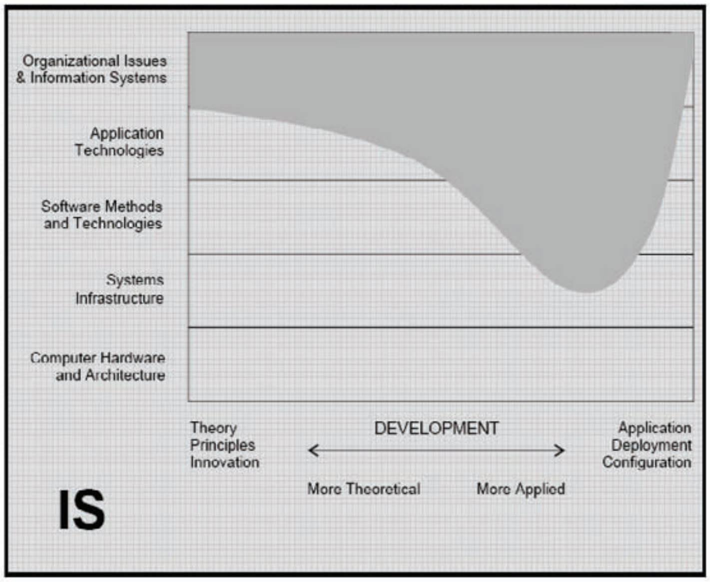
Knowledge Area	**CE**		**CS**		**IS**		**IT**		**SE**	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Programming Fundamentals	4	4	4	5	2	4	2	4	5	5
Integrative Programming	0	2	1	3	2	4	3	5	1	3
Algorithms and Complexity	2	4	4	5	1	2	1	2	3	4
Computer Architecture and Organization	5	5	2	4	1	2	1	2	2	4
Operating Systems Principles & Design	2	5	3	5	1	1	1	2	3	4
Operating Systems Configuration & Use	2	3	2	4	2	3	3	5	2	4
Net Centric Principles and Design	1	3	2	4	1	3	3	4	2	4
Net Centric Use and configuration	1	2	2	3	2	4	4	5	2	3
Platform technologies	0	1	0	2	1	3	2	4	0	3
Theory of Programming Languages	1	2	3	5	0	1	0	1	2	4
Human-Computer Interaction	2	5	2	4	2	5	4	5	3	5
Graphics and Visualization	1	3	1	5	1	1	0	1	1	3
Intelligent Systems (AI)	1	3	2	5	1	1	0	0	0	0
Information Management (DB) Theory	1	3	2	5	1	3	1	1	2	5
Information Management (DB) Practice	1	2	1	4	4	5	3	4	1	4
Scientific computer (Numerical methods)	0	2	0	5	0	0	0	0	0	0
Legal / Professional / Ethics / Society	2	5	2	4	2	5	2	4	2	5
Information Systems Development	0	2	0	2	5	5	1	3	2	4
Analysis of Business Requirements	0	1	0	1	5	5	1	2	1	3
E-business	0	0	0	0	4	5	1	2	0	3
Analysis of Technical Requirements	2	5	2	4	2	4	3	5	3	5
Engineering Foundations for SW	1	2	1	2	1	1	0	0	2	5
Engineering Economics for SW	1	3	0	1	1	2	0	1	2	3
Software Modeling and Analysis	1	3	2	3	3	3	1	3	4	5
Software Design	2	4	3	5	1	3	1	2	5	5
Software Verification and Validation	1	3	1	2	1	2	1	2	4	5
Software Evolution (maintenance)	1	3	1	1	1	2	1	2	2	4
Software Process	1	1	1	2	1	2	1	1	2	5
Software Quality	1	2	1	2	1	2	1	2	2	4
Comp Systems Engineering	5	5	1	2	0	0	0	0	2	3
Digital logic	5	5	2	3	1	1	1	1	0	3
Embedded Systems	2	5	0	3	0	0	0	1	0	4
Distributed Systems	3	5	1	3	2	4	1	3	2	4
Security: Issues and principles	2	3	1	4	2	3	1	3	1	3
Security: implementation and mgt	1	2	1	3	1	3	3	5	1	3
Systems administration	1	2	1	1	1	3	3	5	1	2
Management of Info Systems org.	0	0	0	0	3	5	0	0	0	0

continued on following page

Table 1. continued

Systems integration	1	4	1	2	1	4	4	5	1	4
Digital media development	0	2	0	1	1	2	3	5	0	1
Technical support	0	1	0	1	1	3	5	5	0	1
Non-Computing Topics										
Organizational Theory	0	0	0	0	1	4	1	2	0	0
Decision Theory	0	0	0	0	3	3	0	1	0	0
Organizational Behavior	0	0	0	0	3	5	1	2	0	0
Organizational Change Management	0	0	0	0	2	2	1	2	0	0
General Systems Theory	0	0	0	0	2	2	1	2	0	0
Risk Management (Project, safety risk)	2	4	1	1	2	3	1	4	2	4
Project Management	2	4	1	2	3	5	2	3	4	5
Business Models	0	0	0	0	4	5	0	0	0	0
Functional Business Areas	0	0	0	0	4	5	0	0	0	0
Evaluation of Business performance	0	0	0	0	4	5	0	0	0	0
Circuits and Systems	5	5	0	2	0	0	0	1	0	0
Electronics	5	5	0	0	0	0	0	1	0	0
Digital Signal Processing	3	5	0	2	0	0	0	0	0	2
VLSI design	2	5	0	1	0	0	0	0	0	1
HW testing and fault tolerance	3	5	0	0	0	0	0	2	0	0
Mathematical foundations	4	5	4	5	2	4	2	4	3	5
Interpersonal communication	3	4	1	4	3	5	3	4	3	4

Figure 1. Information systems profile of topic coverage



(ACM/AIS/IEEE The Joint Task Force on Computing Curricula, 2005, p. 19)

needs, specify information requirements, and design practical systems to satisfy these requirements" (ACM/AIS/IEEE The Joint Task Force on Computing Curricula, 2005, p. 32).

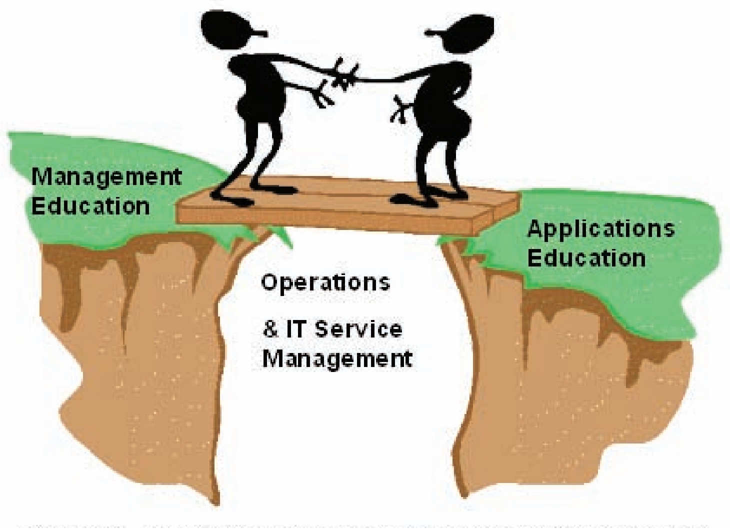
The lower half of Table 1 lists 'business' knowledge to be included in undergraduate curricula, including organization models, theory, structures, and functions along with system concepts and theories, skills in benchmarking, value chain analysis, quality concepts, valuation concepts, and evaluation of investment performance (ACM/AIS/AITP Joint Task Force on Computing Curricula, 2002, p. 14; The Joint Task Force, 2005). For graduate students, recommended 'business' knowledge includes financial accounting, organizational behavior, and marketing (ACM/IEEE The Joint Task Force on Computing Curricula, 2000, p. 18) in courses with no ties to or even discussion of information technology or its relationship to the topic area. That is, the emphasis, even in programs with a focus on organizational issues does not actually attend to the daily operation of an IT organization.

Neither undergraduates nor graduates in IS programs are required to learn basic information such as how to define, recognize, or analyze a process, let alone how to determine whether or not a process can be improved through automation. Process modeling is confined to creation of data flow diagrams, not process maps that include non-automated activities. Further, the specific management processes applied to the management of IS/IT organizations are missing.

There is nothing in IS/IT curricula about IT Operations or how this function delivers IT resources to organizational customers. This gap is depicted in Figure 2 in which the three key aspects of IT academic program gaps are depicted. On the one hand, IT management, discussing topics recommended in the curriculum guidelines, describes business functions (e.g., Marketing), information levels, and how information is used in organizations. From a service perspective, this discussion is lacking in discussion of the non-functional requirements that must come from business users, for instance, criticality of an application to the organization, and requirements for security, privacy, and recoverability. On the other side of the divide is the application development function for which academic programs discuss programming, requirements modeling, and use case development.

In the gap are Operations, which manages the organization's IT infrastructure and IT Service

Figure 2. IT in education with operations and ITSM as the missing links



Management, the discipline that provides process maturity to the entire IT organization. Scant infrastructure organization knowledge or its tasks are recommended in any programs (see Table 1). Further, what infrastructure topics are discussed tend to be 'silo' technology topics such as telecommunications or operating systems. There is no discussion of how the product an applications group delivers actually is placed into production or how it is managed in a production environment. There is no discussion of how to size an application, let alone capacity modeling or planning for a data center. There is no discussion of any of the processes involved in running a data center such as availability management, finance management, incident management, change management, continuity management, and so on. These areas of knowledge are the focus for IT Service Management, the emerging, disruptive IT-related set of management best practices that promises to bridge the gaps between applications and management. ITSM is the first step to servitizing an IT organization and thus, facilitating alignment of IT with its related business strategy.

IT SERVICE MANAGEMENT EDUCATION OPPORTUNITIES

Since infrastructure represents a significant gap in all computing education programs, and since management of IT is articulated within the IS academic discipline, IS curricula are the most likely place for ITSM programs. In this section, ITSM is briefly explained and linked to IT strategy. Then, three options for incorporating ITSM concepts into IS curricula are described.

IT Service Management

IT Service Management is generally used to refer to the management of processes within IT Operations so that, through efficient and effective execution of the processes, value accrues to the organization. Thus, companies can create value through application of best practices to IT Operations (Nieves & Iqbal, 2007). IT operations are critical to organizational effectiveness since as much as 90% of IT budgets is used to manage operations (Fleming, 2005).

The term "service" has no single definition and ranges from a change in condition or state of an entity caused by another to a set of deeds, processes, and resulting performances (Zeithaml & Bitner, 1996). From the ITIL perspective, a service is "a means of delivering value to customers by facilitating outcomes customers want to achieve without the ownership of specific costs and risks" (TSO, 2007, p. 45).

IT service management begins with business strategy, which when new or changed, causes reflection on the existing IT service offerings in the form of applications, computing resources and user services. The heart of service management is a series of processes and functions (e.g., service/help desk) where a "process is the set of activities (repeated steps or tasks) that accomplishes some business function" (Conger & Schultze, 2008, pg. 4). Thus, students of ITSM need to understand how business strategy is reciprocally created with IT strategy, and how the development of strategy can cause changes in any IT resources – human, financial, or capital (e.g., hardware), and how the changes are embodied in processes that ensure repeatability and quality.

The processes in ITIL relate to keeping an operations organization functional. The main ITIL processes relate to management of incidents, problems, changes, releases, configuration, availability, capacity planning, financial planning, continuity, and service levels. While the processes apply to any size organization, the benefits of scale are best attained in global organizations, such as Unilever or Proctor and Gamble. One important body of knowledge relates to the scaling of process management from small to large organizations.

ITIL tends to be implemented in the infrastructure organization first. However, many ITIL processes, for instance, incident and change management, though initiated within operations, are actually remedied or executed within another organization usually within IT, such as applications maintenance. Thus, service management processes have tendrils that permeate other organizational processes and coordination of activities throughout an organization is needed to ensure successful and encompassing ITIL implementation. This integration of operations with all other IT organizational activities includes a need for operational process understanding for applications, database, security, and all technology areas.

While ITIL is the only best practice framework that principally addresses IT Operations, there are many valuable alternatives to ITIL that a company might adopt. For instance, the Control Objectives for Information and Technology (CobiT©), the framework most closely related to financial reporting compliance (e.g., Sarbanes-Oxley in the U.S.), was initiated in the auditing world but has crossed over to management of the IT organization (ITGI, 2007). Another often-used framework is the Capability Maturity Model – Integrated (CMMI©), which was originally developed to support application development management has crossed over to use by operations organizations for such areas as project management (SEI, 2006).

Similarly, there are customized versions of ITIL by Microsoft – the Microsoft Operations Framework (MOF©), Hewlett-Packard, IBM, and others. These frameworks adopt ITIL as their base and build on them by customizing for a suite of support software that imbeds the process within the operational framework of software for help desk, network monitoring and the like.

For all of these frameworks, and for service management in general, the goal is creation of value to the organization through its IT operations function. A secondary goal and outcome of successful service management implementation is alignment with the strategy of the business since strategy is the starting point for the development of all service offerings.

Curricular Alternatives Incorporating IT Service Management

The three alternatives for incorporating ITSM into IS academic programs include the following:

- Part of an existing course(s)
- A single course
- A concentration or major set of courses (Beachboard et al., 2007).

Each of these alternatives is briefly discussed.

ITSM as Part of Existing Course(s)

If ITSM were incorporated into a single existing course, one likely course would be an IS Foundations course because it serves the broadest audience. A module on ITSM could discuss concepts of process and service, providing definitions and examples of each. In addition, a brief overview of IT Operations and its criticality to organizational functioning could be provided. Finally, a high level discussion defining various operational processes, such as capacity management, and describing their relationship to other operational processes could be included.

Other existing courses into which ITSM concepts could be interjected include any applications development, database, or telecommunications courses. For instance, during systems analysis and design (SAD), risk analysis and related security mitigations should be discussed. Also in an SAD class, the need for early capacity planning to ensure adequacy of testing and production facilities for hardware, data storage, and telecommunications could be included. A partial list of non-functional requirements and the need for their articulation and sharing with IT Operations would include, for example, transaction volumes and peaks, number of users and locations, security and privacy, compliance requirements, data integrity, organizational criticality, recoverability, help desk, and access requirements (Conger, 2008). Also in SAD, change management, both for users in terms of using a new application and for the developers in terms of moving the application from testing into a production environment and the work that such a move entails could be included.

Single Course in ITSM

A single course could address Fundamentals of ITSM. This course could discuss alignment of business strategy and IT strategy with the need for demand management driving the creation and presentation of services to the organization. If ITIL were the basis for the course, the five main areas of the framework, relating to strategy, planning, transition, operations, and continuous improvement could be structured into one to three sessions each with case studies and practical exercises for students to apply the concepts.

Concentration or Major in ITSM

A concentration in ITSM requires decisions on content and purpose of the major. If the goal of the program is to obtain the highest possible certifications for students, then alignment with ISO/IEC 20000 would allow students to obtain master's level certification (EXIN, 2008). The ITIL v3 certification scheme now requires over 10 courses and takes more than five years to obtain and is thus beyond the scope of most academic programs (Taylor, 2007). Under the EXIN scheme, the courses relate to ITIL version 2 (the basis for the international standard ISO/IEC 20000) and include Foundations of Service Management, Advanced Services Support and Advanced Service Delivery. One or two other courses could be electives, for instance, Systems Analysis and Design, Process Management, and/or Managing the IT Function.

One issue with a program based on the ITIL framework is that ITIL, per se, does not guarantee 'service management' (Conger & Schultze, 2008). Ultimately, servitizing requires proactive demand management. As in manufacturing operations, IT demand management is used to plan and deploy resources (i.e., applications, computing resources and user services). Once deployed, demand management concentrates on delivering a product that meets a contracted level of service. Under this more 'service management' approach, courses might include some combination of Foundations of Service Management, IT Service Management, Process and Service Design, Service Delivery, Demand Management, and IT Governance.

CONCLUSION

This article argues that IS academic programs are incomplete because of the absence of any content dealing with servitizing the IT function. This absence has caused a widening gap between business conduct and IT academic programs. Servitization includes not only the management of IT Operations but also courses on the processes required to actually manage an IT function. IT Service Management, in the form of ITIL, has become a significant activity in many organizations, and its body of knowledge directly addresses both the gap between IT academic programs and business practice and provides the 'how' to aligning business strategy with IT service delivery. Therefore, ITSM provides an opportunity to move toward explaining *how* to align IT with business strategy, provide students with an understanding of process and service orientations, and move toward developing courseware that comprehends the servitizing of IT.

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Chapter 8.13

System Dynamics Modeling for Strategic Management of Green Supply Chain

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ABSTRACT

Environmental issues are rapidly emerging as one of the most important topics in strategic manufacturing decisions. Perusal of the literature has shown many models to support executives in the assessment of a company's environmental performance. Unfortunately, none of these identifies operating guidelines on how the systems should be adapted to support the deployment of different types of green supply-chain strategies. This chapter seeks to investigate how system dynamics modeling can be supportive for management of feasible green supply-chain strategies. Besides conceptual considerations, we base our arguments on the development of efficient performance measurement systems for remanufacturing facilities in reverse supply chains, taking into account not only economic but also environmental issues. The behavior of the green supply-chain management under study is analyzed through a simulation model based on the principles of the system dynamics methodology. The simulation model can be helpful for green strategic management as an experimental tool, which can be used to evaluate alternative long-term strategies ("what-if" analysis) using total supply chain profit as measure of strategy effectiveness. Validation and numerical

experimentation further illustrate the applicability of the developed methodology, while providing additional intuitively sound insights.

INTRODUCTION

Environmental issues are rapidly emerging as one of the most important topics for strategic manufacturing decisions. The scarcity of natural resources and the growing concern in the market for "green" issues have forced executives to manage operations within an environmental perspective (Dimitrios Vlachos, Georgiadis, & Iakovou, 2007). Growing public awareness and increasing government interest in the environment have induced many Chinese manufacturing enterprises to adopt programs aimed at improving the environmental performance of their operations (Vincent, 2006; Zhu & Sarkis, 2004).

In the light of the strategic importance of environmental issues and of their effects on the corporate management system, a growing body of literature is focused on how companies should manage environmental issues. Two major lines of research are evident:

- Studies which analyze feasible green supply-chain strategies available to operations managers and describe how growing environmental concern impacts on the process of strategy formation; and
- General approaches aimed at supporting managers in the assessment of a company's environmental performance, such as life-cycle assessment methods, or models reporting physical indicators, environmental costs, contingent liabilities, and so forth.

Despite the availability of the various approaches to develop performance measurement systems (PMSs) in respect of distinct green supply-chain strategies, none of them attempted to quantify the effects of various environmentally friendly activities pursued by the manufacturing function. Such a shortcoming is, in our opinion, critical, since environmental behavior results from specific environment-related objectives and has its own managerial and financial implications on the corporate system.

In response to the issues identified in the above paragraphs this chapter presents a quantitative framework to:

- Define the basic green supply-chain strategies a company can implement and identify factors affecting environmental performance and their relationships for operations management
- Structure environmental performance measures hierarchically
  Quantify the effectiveness of a planned environmental strategy on environmental performance
- "What if" analysis on environmental performance and green supply-chain strategy selection

By bringing together existing contributions on strategic environmental management and performance measurement systems, the chapter aims to develop quantitative models for environmental performance measurement systems (QMEPMS) using supermatrix, cause and effect diagrams, tree diagrams, and the analytical network process. It describes how different green supply-chain strategies can be deployed and presents the technique that can be used to identify factors affecting environmental performance and their relationships, structure them hierarchically, quantify the effect of the factors on environmental performance, and express them quantitatively.

The chapter is divided into six major sections. First, we give a taxonomy of green supply-chain management (GSCM) and highlight the problem existing in a company's strategic management, describe research objectives and methodology to quantify the effect of the factors on an EPMS, and specify a quantitative model on how to structure critical factors hierarchically to support managers in the implementation for an EPMS. Then, we analyse how the suggested QMEPMS can be implemented in practice. Finally, we draw some conclusions from the suggested approach and indicate future directions for further environment-related research.

LITERATURE REVIEW

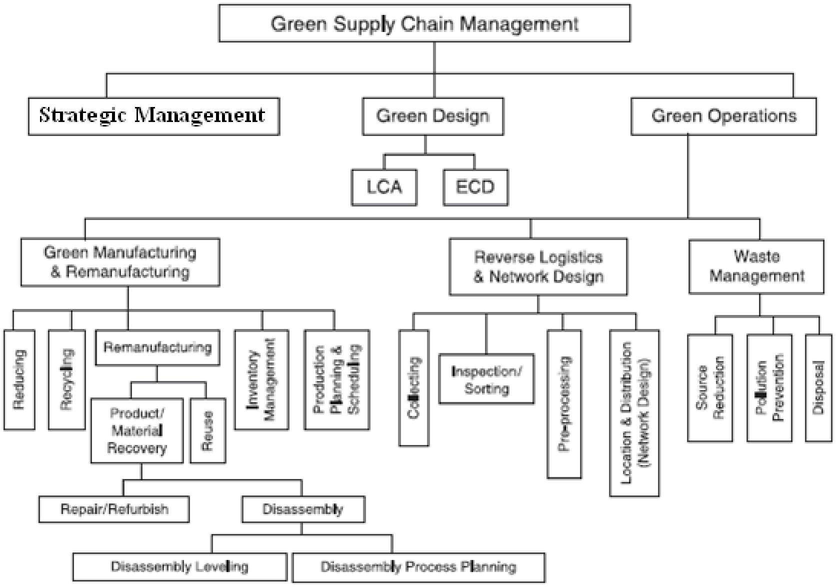
Sufficient literature exists about various aspects and facets of GSCM. Comprehensive reviews on green design (Zhang, Kuo, Lu, & Huang, 1997), repairable inventory (Guide, Jayaraman, & Srivastava, 1997, 1999), production planning and control for remanufacturing (Bras & McIntosh, 1999; Guide, 1997; Guide, Jr., 2000; Guide, Spencer, & Srivastava, 1997), issues in green manufacturing and product recovery (Guide, Spencer, & Srivastava, 1996; Gungor & Gupta, 1999), reverse logistics (RL) (Carter & Ellram, 1998; Fleischmann et al., 1997), logistics network design (Fleischmann, Beullens, Bloemhof-Ruwaard, & van Wassenhove, 2001; Fleischmann, Krikke, Dekker, & Flapper, 2000; Jayaraman, Patterson, & Rolland, 2003), and green product databases (Nimse, Vijayan, Kumar, & Varadarajan, 2007)have been published.

Earlier works and reviews have a limited focus and narrow perspective. They do not cover adequately all the aspects and facets of GSCM. Much of the work is empirical and does not focus adequately on strategic management, mathematical modeling, and network design-related issues and practices. The objective of this section is to present a comprehensive integrated view of the published literature on all the aspects and facets of GSCM, taking a "reverse logistics angle" so as to facilitate further study, practice, and research. To meet this objective, we define GSCM as "integrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life." We specifically focus on strategic management, reverse logistics (RL) and mathematical modeling aspects in order to facilitate further study and research. Qualitative analysis was applied to classify the existing literature on the basis of problem context and the methodology/approach adopted. We also map the tools/techniques vis-à-vis the problem context classification.

Classification Based on Problem Context

We classify the existing GSCM literature into three broad categories based on the problem context in supply chain design: literature highlighting the strategic management; literature on green design; and literature on green operations, as shown in Figure 1, which was adapted from Srivastava (2007). Green design may be looked into from the viewpoint of environment conscious design taking lifecycle assessment of the product/process into account. Similarly, green operations involve all operational aspects related to RL and network design (collection; inspection/sorting; preprocessing; network design), green manufacturing and remanufacturing (reduce; recycle; production planning and scheduling; inventory management; remanufacturing: re-use, product and material recovery), and waste management(source reduction; pollution prevention; disposal).We purposely do not consider literature and practices related to green logistics, as we feel that the issues are more operational than strategic in nature and may not be significant in the supply chain design per se. We also do not focus in detail on empirical studies on GSCM and literature on green purchasing,

Figure 1. Classification based on problem context in supply chain design



industrial ecology and industrial ecosystems, as it is delimited by our research design. We focus more on RL as the establishment of efficient and effective RL networks as a prerequisite for efficient and profitable recycling and remanufacturing. We also focus more on mathematical modeling aspects. Both of these have received less attention in the GSCM literature so far.

The classification is for the purpose of easier understanding of different problem contexts of GSCM—their interactions and relationships—in order to present a well defined and clear picture for further study and research. It is not rigid, and there may be many overlaps (e.g., reduce gets attention not only in green manufacturing and remanufacturing, but also elsewhere as in reverse logistics and waste management; green design, too, emphasizes reduced use of virgin material and other resources). Similarly, green design should take into account the whole product life-cycle cost, including those during manufacturing and remanufacturing, reverse logistics, and disposal. Figure 1 does not take account of all these complex relationships and interactions but presents a simplistic view. Further, we do not show some other relevant aspects and areas such as green purchasing, industrial ecology, and industrial ecosystems, as they are delimited by our research design.

Strategic Management

As in any emerging research area, the early literature focuses on the necessity and strategic management, defines the meaning and scope of various terms and suggests approaches to explore the area further. Fundamentals of greening as a competitive initiative are explained by Porter and van der Linde. Their basic reasoning is that investments in greening can be resource saving, waste eliminating, and productivity improving (Porter & van der Linde, 1995a, 1995b). Three approaches in GSCM, namely reactive, proactive, and value-seeking, are suggested (Hoek, 1999). In the reactive approach, companies commit minimal resources to environmental management, start labeling products that are recyclable and use “end of pipeline” initiatives to lower the environmental impact of production. In the proactive approach, they start to preempt new environmental laws by realizing a modest resource commitment to initiate the recycling of products and designing green products. In the value-seeking approach, companies integrate environmental activities such as green purchasing and ISO implementation as strategic initiatives into their business strategy.

The perspective then changes from greening as a burden to greening as a potential source of competitive advantage (Hoek, 1999). Owen (1993) discusses environmentally conscious manufacturing. Friedman (1992), Guide, Jr., and Van Wassenhove (2002), and Gupta and Sharma (1996) discuss the changing role of the environmental manager. Interactions among various stakeholders on integrated GSCM and advantages that may accrue to them have been described by Gungor and Gupta (1999). At the end of the 1990s, integrating these issues into the mainstream was identified as the future research agenda (Angell & Klassen, 1999). In a study linking GSCM elements and performance measurement, Beamon (1999) advocates for the establishment and implementation of new performance measurement systems. He suggests that the traditional performance measurement structure of the supply chain must be extended to include mechanisms for product recovery (RL) (Beamon, 1999).

During the present decade, related and emergent issues such as consideration of stages of the product life cycle during material selection (Kaiser, Eagan, & Shaner, 2001), impact of green purchasing on a firm’s supplier selection (Zhu, Geng, & Spring, 2002), waste management (Theyel, 2001), packaging and regulatory compliance (Min & Galle, 2001), greener manufacturing and operations (Sarkis, 2001), study of the environmental management system (EMS) implementation practices (Hui, Chan, & Pun, 2001), selection of environmental performance indicators (Scherpereel, van Koppen, & Heering, 2001), relationship between environmental and economic performance of firms (Wagner, Schaltegger, & Wehrmeyer, 2001), focus on third-party logistics providers (Krumwiede & Sheu, 2002; Meade & Sarkis, 2002), overview of management challenges and environmental consequences in reverse manufacturing (White, Masanet, Rosen, & Beckman, 2003) and extended producer responsibility (Spicer & Johnson, 2004), including OEM, pooled and third-party take-back, have been taken up by researchers.

Zhu and Sarkis (2004) describe empirical findings on relationships between operational practices and performance among early adopters of green supply-chain management(Zhu & Sarkis, 2004), while Bowen, Cousins, Lamming, and Faruk (2001) seek to resolve the apparent paradox between the desirability and the actual slow implementation of GSCM in practice (Bowen, Cousins, Lamming, & Faruk, 2001). Chouinard et al. (2005) deal with problems related to the integration of RL activities within a supply chain information system (Chouinard, D'Amours, & Aït-Kadi, 2005). Nagurney and Toyasaki (2005) develop a multi-tiered network equilibrium framework for e-cycling (Nagurney & Toyasaki, 2005), while Sheu et al. (2005) present an optimization based integrated logistics operational model for GSCM (Sheu, Chou, & Hu, 2005). Ravi et al. (2005) analyze alternatives in RL (Ravi, Shankar, & Tiwari, 2005), Mukhopadhyay and Setoputro (2005) derive a number of managerial guidelines for return policies of build-to-order products, while Srivastava and Srivastava (2006) suggest ways to manage end-of-life product returns. Kainuma and Tawara (2006) extend the range of supply chain to include re-use and recycling throughout the life cycle of product and services and propose a “lean and green” multiple utility theory approach to evaluate green supply chain performance from an environmental performance point of view (Kainuma & Tawara, 2006).

Green Design

The literature emphasizes both environmentally conscious design (ECD) and life-cycle assessment/analysis (LCA) of the product. The aim is to develop an understanding of how design decisions affect a product's environmental compatibility (Glantschnig, 1994; Navinchandra, 1991). Madu et al. (2002) present a very useful hierarchic framework for environmentally conscious design (Madu, Kuei, & Madu, 2002).

Sufficient literature exists on design for material and product recovery (Barros, Dekker, & Scholten, 1998; Ferrer, 1997a, 1997b; Ferrer & Whybark, 2001; Gatenby & Foo, 1990; Guide, Jr., & Van Wassenhove, 2001; Krikke, van Harten, & Schuur, 1999a, 1999b; Louwers, Kip, Peters, Souren, & Flapper, 1999; Melissen & de Ron, 1999; Seliger, Zussman, & Kriwet, 1994). Boothroyd and Alting (1992), Krikke, Bloemhof-Ruwaard, and Van Wassenhove (2003), Kroll, Beardsley, and Parulian (1996), Laperiere and ElMaraghy (1992), Lee, O'Callaghan, and Allen (1995), Moore, Gungor, and Gupta (2001), Scheuring, Bras, and Lee (1994), Seliger et al. (1994), and Taleb and Gupta (1997) discuss design for disassembly, whereas Gupta and Sharma (1996), He, Gao, Yang, and Edwards (2004), Jahre (1995), Jayaraman, Guide, and Srivastava (1999), Johnson (1998), and Sarkis and Cordeiro (2001) deal with design for waste minimization.

A common approach is to replace a potentially hazardous material or process by one that appears less problematic. This seemingly reasonable action can sometimes be undesirable if it results in the rapid depletion of a potentially scarce resource or increased extraction of other environmentally problematic materials. Several examples of such equivocal proposals are presented by Graedel (2002).

Green Operations

Some of the key challenges of GSCM such as integrating remanufacturing with internal operations (Ferrer & Whybark, 2001), understanding the effects of competition among remanufacturers (Majumder, Groenevelt, & Summer, 2001), integrating product design, product take-back, and supply chain incentives (Guide, Jr., & Van Wassenhove, 2001; Guide & van Wassenhove, 2002), and integrating remanufacturing and RL with supply chain design (Chouinard et al., 2005; Fleischmann et al., 2001; Goggin & Browne, 2000; Savaskan, Bhattacharya, & Van Wassenhove, 2004) are posed in this area.

In recent years, a lot of work related to quantitative approaches in RL has been published. Shih (2001) discusses in detail the RL system planning for recycling electrical appliances and computers in Taiwan. Hu, Sheu, and Huang (2002) present a cost-minimization model for a multi-time-step, multi-type hazardous-waste RL system. They present application cases to demonstrate the feasibility of their proposed approach. Nagurney and Toyasaki (2005) develop an integrated framework for modeling the electronic waste RL network which includes recycling, while the framework of Srivastava and Srivastava (2005) incorporates three types of rework facilities. Ravi et al. (2005) use analytical network process (ANP) and balanced score card for analysing RL alternatives for end-of-life computers. Listes and Dekker (2005) present a stochastic programming-based approach by which a deterministic location model for product recovery network design may be extended to account explicitly for uncertainties. They apply it to a representative real case study on recycling sand from demolition waste in The Netherlands. Their interpretation of the results gives useful insights into decision-making under uncertainty in a RL context. Pochampally and Gupta (2005) propose a three-phase mathematical programming approach, taking the above uncertainties into account, for strategic planning of a reverse supply chain network. Mostard and Teunter (2006) carry out a case study to derive a simple closed-form equation. They determine the optimal order quantity given the demand distribution, the probability that a sold product is returned, and all relevant revenues and costs for a single period model. Min, Ko, and Ko (2006) determine the number and location of centralized return centres using a nonlinear mixed-integer programming model and a genetic algorithm that solves the RL problem involving product returns.

Classification Based on Approach

The literature on GSCM may also be classified on the basis of methodology and approach used into: thought papers and perspectives; frameworks and approaches; empirical studies; mathematical modeling approaches; and reviews. This helps us to understand GSCM from a different perspective from the problem context described earlier. Thought papers and perspectives as well as frameworks- and approaches-related articles have been sufficiently covered in "Strategic management." Similarly, review papers have been covered in the introduction, and are not covered further. Therefore, empirical studies and mathematical modeling approaches are covered here.

Empirical Studies

Empirical research studies include case research, field surveys and interviews, field experiments, mail surveys, laboratory experiments, and game simulations. Several empirical studies in the area of GSCM have been published. They consist mainly of case studies and surveys. Most case studies deal with green design (product and logistics) and green operations (remanufacturing, recycling, RL, etc.). Goldsby and Closs (2000) describe the case study of a Michigan beverage distributor and retailer who collects empty beverage containers for recycling purposes. They discuss the reengineering of supply chain-wide processes using activity-based costing (ABC). Duhaime, Riopel, and Langevin (2000) describe value analysis and optimization of reusable containers at Canada Post. Ritchie, Burnes, Whittle, and Hey (2000) discuss the RL supply chain of a UK pharmacy. Warren, Rhodes, and Carter (2001) describe a total product system concept for a highly customized build-to-order product system. Scherpereel et al. (2001) use a case study to establish the relevance of selecting environmental performance indicators, while Khoo, Spedding, Bainbridge, and Taplin (2001) present a case study of a supply chain concerned with the distribution of aluminum. They use simulation to create a green supply chain. Tan, Yu, and Kumar (2002) take on a computer company in the Asia-Pacific region. De Koster, de Brito, and van de Vendel (2002) carry out an exploratory study with nine retailer warehouses regarding returns handling. Review of a number of case studies in RL is provided by de Brito, Flapper, and Dekker (2003). Flapper, van Nunen, and van Wassenhove (2005) address a number of case studies on closed-loop supply chains covering pharmaceuticals, electronics, breweries, containers, mail orders, tyres, photocopiers, cars, computers, cosmetics, and consumer durables.

Mathematical Modeling

A variety of tools and techniques have been used for problem formulation. A variety of the above tools and techniques have been used for problem formulation, solution, and analysis in papers published in edited books such as Dekker, Fleischmann, Inderfurth, and Van Wassenhove (2004), Dyckhoff, Lackes, and Reese (2003), and Fleishmann and Klose (2005). We map various mathematical tools/techniques vis-à-vis the contexts of GSCM. This depends much on the methodology used and also helps us to gauge their applicability/suitability. This is shown in Table 1.

Very few models have been used for strategic management of GSCM. AHP/ANP, Regression, DEA, and descriptive statistics (based on surveys/interviews) have been tried. Linear programming, nonlinear programming (NLP), and MILP have also been suggested in books but have not been

Table 1. Mapping of mathematical tools/techniques used vis-à-vis the contexts of GSCM

Mathematical tools/techniques	Strategic Management	Green Design	Green Operations
Algebraic		(Richter, 1996)	(Ashayeri, Heuts, & Jansen, 1996; Mukhopadhyay & Setoputro, 2005; Richter & Dobos, 1999)
AHP/ANP	(Sarkis, 1999)		(Madu et al., 2002; Ravi et al., 2005; Sarkis, 1998, 1999)
Computer programs			(Barros et al., 1998; Johnson & Wang, 1995; Louwers et al., 1999)
Descriptive statistics/ANOVA	(Chinander, 2001; Sarkis, 1999)		(Chinander, 2001; Haas & Murphy, 2002; Sarkis & Cordeiro, 2001; Swenseth & Godfrey, 2002)
DEA	(Sarkis, 1999, 2001)		(Haas & Murphy, 2002; Sarkis, 1999; Sarkis & Cordeiro, 2001)
Dynamic programming		(Inderfurth & van der Laan, 2001; Richter & Weber, 2001)	(Inderfurth, de Kok, & Flapper, 2001; Kiesmuller & Scherer, 2003; Klausner & Hendrickson, 2000; Richter & Sombrutzki, 2000)
Fuzzy/neuro-fuzzy			(Marx-Gomez, Rantenstrauch, Nurnberger, & Kruse, 2002)
Game theory		(Majumder et al., 2001)	(Mostard & Teunter, 2006; Nagurney & Toyasaki, 2005)
Heuristics		(Richter & Sombrutzki, 2000; Richter & Weber, 2001)	(Barros et al., 1998; Bloemhof-Ruwaard, Solomon, & Van Wassenhove, 1996; Jayaraman et al., 2003; Mourao & Amado, 2005)
I/O Model	(Ferrer & Ayres, 2000)		(Ferrer & Ayres, 2000)
LP and MILP	(Sarkis, 2001)	(Barros et al., 1998; Bloemhof-Ruwaard, Solomon et al., 1996; Bloemhof-Ruwaard, van Wassenhove, Gabel, & Weaver, 1996)	(Fleischmann et al., 2001; Haas & Murphy, 2002; Hu et al., 2002; Kroon & Vrijens, 1995) (Jayaraman & Srivastava, 1995; Louwers et al., 1999; Marin & Pelegrin, 1998) (Jayaraman et al., 1999; Jayaraman, Srivastava, & Benton, 1998; Ritchie et al., 2000; Srivastava & Srivastava, 2005)
Markov chain/queuing		(Van der Laan, Dekker, & Salomon, 1996; Van der Laan, Dekker, Salomon, & Ridder, 1996)	(Fleischmann, Kuik, & Dekker, 2002; Gupta, 1993; Kiesmuller & van der Laan, 2001; van der Laan & Salomon, 1997)
Metaheuristics			(Min et al., 2006; Minner, 2001)
Nonlinear programming	(Sarkis, 2001)		(Jayaraman et al., 1998; Richter & Dobos, 1999; Sarkis, 2001)
Petri net			(Moore, Gungor, & Gupta, 1998; Moore et al., 2001)
Regression	(Klassen, 2001; Sarkis, 2001; Zhu & Sarkis, 2004)	(Minner, 2001)	(Ferrer, 1997a; Haas & Murphy, 2002; Sarkis & Cordeiro, 2001; Zhu & Sarkis, 2004)
Scenario/sensitivity analysis			(Klausner & Hendrickson, 2000; Linton & Johnston, 2000; van der Laan, Salomon, & Dekker, 1999; van der Laan, Salomon, Dekker, & van Wassenhove, 1999)
Simulation			(Ashayeri et al., 1996; Khoo et al., 2001; Marx-Gomez et al., 2002; Vlachos & Tagaras, 2001)
Software and spreadsheets	(Nagel & Meyer, 1999)		(Krikke, Harten, & Schuur, 1998; Louwers et al., 1999)

used to a great extent. Green design has seen very little application in terms of mathematical tools, techniques, and methodologies. Lately, LP, MILP formulations, and software packages and spreadsheets for solution have been used. Green operations have used mathematical models, tools, and techniques to a much larger extent. MILP, simulation, computer programming, software packages, spreadsheets, and dynamic programming have been used extensively. Other traditional tools and techniques such as simulation, Markov chains, algebraic equations, ANOVA, heuristics, metaheuristics, and regression have also been used. Fuzzy reasoning, neuro-fuzzy, and game theory too have been tried.

One of the biggest challenges facing the field of GSCM is the developing of strategic and tactical tools. The inherent complexity of environmental issues—their multiple stakeholders, uncertain implications for competitiveness, and international importance—present significant challenges to researchers. Much research is needed to support the evolution in business strategy towards greening along the entire supply chain. Effective approaches for data sharing across the supply chain need to be developed. Researchers might take advantage of the emergent ICT for more effective collaboration and cooperation.

Although the current development in GSCM research is encouraging, a few studies link GSC strategy and performance measurement. Beamon (1999) suggests the traditional performance measurement structure of the supply chain must be extended and include mechanisms for product recovery (reverse logistics) and the establishment and implementation of new performance measurement systems. Yet, overall environmental performance measurement and supporting systems, across supply chains has not been as extensively studied (Hervani, Helms, & Sarkis, 2005).

RESEARCH OBJECTIVES AND METHODOLOGY

The objective of the research adopted under the heading of quantitative models for environmental performance measurement systems (QMEPMS) was to identify tools and techniques that would facilitate:

- Identification of factors affecting environmental performance
- Identification of the relationship between factors affecting environmental performance
- Quantification of these relationships on one another, and on the overall performance of the production processes
- Establishment of "What if" analysis on process performance and strategy selection

The introduction of a green supply-chain strategy is a very complex issue, since it presents a multidimensional impact on performance and often induces a significant modification in management procedures. In the light of these issues, it is important to analyze feasible patterns of strategic environmental behavior, under which conditions these are a sustainable option and the implications on operations management.

The introduction of factors describing a company's strategic attitude towards the environment, that is, how executives consider "green" issues, and of external variables describing the stakeholders' environment-related pressures, allows us:

- To highlight in which context(s) a specific green supply-chain strategy may be considered a sustainable option; and
- To identify the key elements of an efficient EPMS.

A company's strategic attitude heavily depends on managers' environmental awareness. For example, managers:

- Could have an ethical objective: in this case, the reduction of the company's impact on the natural environment is a more important task than the improvement of economic performance;
- May consider the environment as a means of achieving a competitive advantage: the introduction of new "green" product development procedures or the definition of a unique blend of "green" competencies identifying would be appropriate managerial solutions;
- Might concentrate on ensuring compliance with current environmental regulations or leading "green" movements/customers by developing products which are consistent with their requirements;
- May take no initiative to improve environmental performance; this behavior essentially reflects short-term vision and a resistant management.

Many authors (DePass, 2006; Rentmeester, 2005; Srivastava, 2007) have tried to identify the drivers of environmental pressures. It has been claimed that cost control, total quality management, communities, investors, and environmental regulations are the main pressures faced by companies.

Such environmental drivers do not affect a company's pattern of environmental behavior in equal measure. Their influence depends on industry- and country-specific factors. In our opinion, the major external influences concern:

- "Green" movements or regulators: specifically, the binding pressure of regulations and the importance of "green" movements are significant variables that could explain the adoption of a green supply-chain strategy; and
- The company's relationships with the other supply value chain partners (Dickinson, Draper, Saminathan, Sohn, & Williams, 1995; Hervani et al., 2005).

In the light of the above issues, we distinguish between (see Table 2).

This framework reflects the extensive literature on environmental strategies. Nevertheless, it differs from other state of the art approaches, as it introduces a more detailed taxonomy of strategic patterns of environmental behavior. The reasons for this choice are to identify precisely the operat-

Table 2. Main characteristics of the green supply-chain strategies

Strategy	Context	Characteristic
"evangelist" strategy	ethical objective and radical approach to environmental issues	Futurity
Pro-active green strategy	"systemic" initiatives affecting the whole value chain and relationships with suppliers	High bargaining power of the company Strategic perspective
Responsive strategy	bargaining power vs. suppliers/shredders is low the regulators' pressures are low	High/low bargaining power of the company Technical perspective
Reactive strategy	comply with environmental regulations or customers' environmental requirements	External oriented: High pressures from regulators and Technical perspective Market driven: High pressures of "green" customers and Technical perspective
Unresponsive strategy	limited financial resources, passive pattern of environmental behaviour and delay "green" programmes	High importance of cost based strategy

ing objectives associated with the implemented environment-related initiatives and to define the key requirements that an effective EPMS might respect in order to assess these.

Effective operating EPMSs to support the implementation of the above green supply-chain strategies and assess the resulting environmental performance might respect two general requirements:

- Measurability of the output, in order to have measures that can be used in identifying both to assess the company's "green" efficiency and to reward effective EPMSs employees;
- Long-term orientation, such a requirement is particularly important if the EPMS is adopted to support the implementation of "evangelist," pro-active, and responsive strategies.

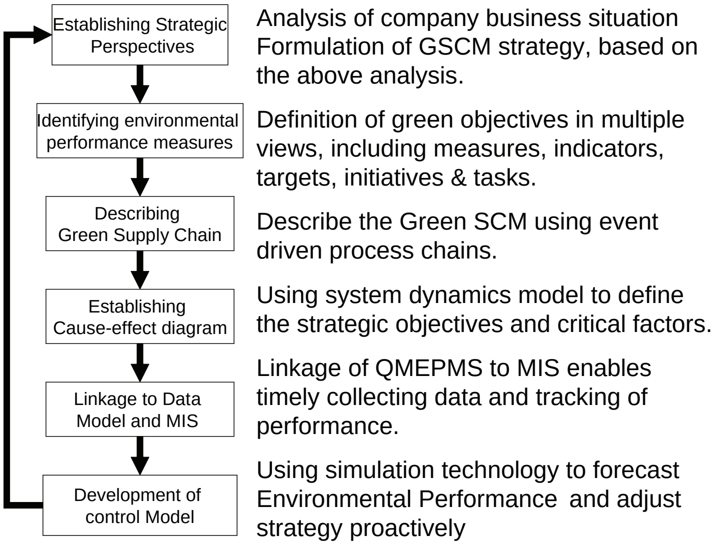
Completeness, timeliness, and cost of the analysis are significant elements of an effective operating EPMS, but their importance varies with the different green supply-chain strategies. Completeness means the extent to which the model can take account of all the relevant performance factors in the environmental field; timeliness aims to describe how long the EPMS takes to analyze the collected data; while cost refers to the amount of time and human resources needed to implement the EPMS.

In the light of these issues, it is clear that the development of a complete and timely model represents the best solution, but this implies great computational costs. Hence, on the basis of the main characteristics of the identified green supply-chain strategies, we attempt to define EPMSs that, within each context, ensure the best trade-off between completeness, timeliness, and cost.

The six steps of the approach were developed as a result of the QMEPMS methodology implementation as depicted in Figure 2. The details of this approach have been explained through a case study.

The QMEPMS methodology, which is adopted in this research, is a modeling and simulation technique specifically designed for long-term, chronic, dynamic management problems. It focuses on understanding how the physical processes, information flows, and managerial policies interact so as to create the dynamics of the variables of

Figure 2. QMEPMS methodology implementation



Analysis of company business situation
Formulation of GSCM strategy, based on the above analysis.

Definition of green objectives in multiple views, including measures, indicators, targets, initiatives & tasks.

Describe the Green SCM using event driven process chains.

Using system dynamics model to define the strategic objectives and critical factors.

Linkage of QMEPMS to MIS enables timely collecting data and tracking of performance.

Using simulation technology to forecast Environmental Performance and adjust strategy proactively interest. The totality of the relationships between these components defines the "structure" of the system. Hence, it is said that the "structure" of the system, operating over time, generates its "dynamic behavior patterns." It is most crucial in QMEPMS that the model structure provides a valid description of the real processes. The typical purpose of a QMEPMS study is to understand how and why the dynamics of concern are generated and then search for policies to further improve the system performance. Policies refer to the long-term, macrolevel decision rules used by upper management.

In order to achieve the green supply chain, manufacturing organizations must follow the basic principles established by ISO 14000. In particular, organizations must develop procedures that focus on operations analysis, continuous improvement, measurement, and objectives. An implementation procedure for implementing the green supply chain strategy includes the following tasks:

- **Establishing strategic perspectives:** For each product within the supply chain, identify all inputs, outputs, by-products, and resources.
- **Identifying environmental performance measures:** Defining green objectives in multiple views, including measures, indicators, targets, initiatives, and tasks. Environmental performance indicators are core requirements of a GSCM/PMS when evaluating the environmental performance of activities, processes, hardware, and services. Environmental performance indicators are described in ISO 14031 (environmental management-environmental performance evaluation of the ISO 14001 accreditation guidelines). Environmental performance indicators are needed when evaluating the environmental performance of activities, processes, hardware, and services. Given the complexity of most supply chains, a single performance measure will likely be inadequate in assessing the true performance of the supply chain. Thus, a system of performance measures will be necessary. Such a performance measurement system must include measures for the three environmental categories given above, as well as existing operational measures.
- **Describing green supply chain:** Describe the Green SCM using event driven process chains (EPCs). EPCs are directed graphs, which visualize the control flow and consist of events, functions and connectors. Each EPC starts with at least one event and ends with at least one event. An event triggers a function, which leads to a new event. Three types of connectors (AND, Exclusive OR, OR) can be used to model splits and joins.
- **Establishing cause-effect diagram:** Using system dynamics model to define the strategic objectives and critical factors (Figure 4). Calculate the actual composite performance at each step in the supply chain process for each product. The composite performance, as calculated at each supply chain process step, will be a function of the performance measures developed above. The composite performance, therefore, may be a single numerical value, or (more likely) a vector of numerical values.
- **Linkage to data model and MIS:** Linkage of QMEPMS to MIS enables timely collecting, measuring of data, and tracking of performance. After all processes for all products have been measured, prioritize the process steps in order of increasing composite performance, as calculated above.
- **Development of control model:** Develop alternative simulation models for performance improvement (targeting first those process steps exhibiting the worst composite performance, based on prioritization above), and select a preferred approach. Establish

schedules and procedures for auditing and continuous improvement, including emergency and noncompliance procedures.

QUANTITATIVE MODEL FOR ENVIRONMENTAL PMS

Performance measurement systems usually involve a number of multidimensional performance measures. Neely pointed out that a problem, which arises from that situation is the integration of those several measures expressed in heterogeneous units into a single unit (Neely et al., 2000).

The key techniques of the QMEPMSs are a set of models of business object, coupling operation and system dynamics. These models are proposed based on the object-oriented approach, and are shown in Figure 3.

Business Object Models (BOMs)

Our BOMs are divided from three views and their relationships are also shown in Figure 3.

Organization View

The organizational model is a typical form of representing organizational structures. Person Type (PT) objects can be defined as a 3-tuple:

$$PT = \{(personID, roleName, prsType)\} \quad (1)$$

Where *personID* is the identifier of a human resource; *roleName* is defined as the role of a person in the business process; *prsType* is the type of a person when he processes information resources, such as listener, processor, and dispatcher.

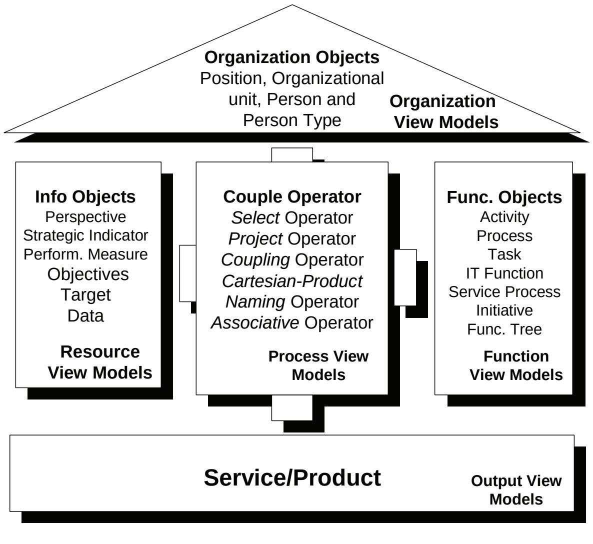
Function View

An enterprise activity (EA) is defined as a 9-tuple:

$$EA = \{(activityID, actFunction, \\ , orgBelongTo) actType \} \quad (2)$$

Where activityID is the identifier of an EA; actFunction is defined as the function of EA; orgBelongTo defines the organization to which activity belongs; actType refers to the type of

Figure 3. Relationship views of the QMEPMS model



activity which can be cataloged as a structured activity and a nonstructured activity.

Info View

An info view model includes a description of the semantic data model of the field which is to be examined. An information resource (IR) can be defined as a 5-tuple:

$$IR = \{(inforResID, content, generationTime, periodOfValidity\ inforType)\} \quad (3)$$

Where inforResID is the identifier of IR; content includes three components: clear definition or meaning of data, correct value(s), and understandable presentation (the format represented to PTs); generationTime refers to the time when the IR comes into being; periodOfValidity refers to the age of the IR remaining valid; inforType is the type of the IR which can be classified as environmental, inner, and efferent.

Output View

An output view model includes a description of the products or services performed in a company. A product service (PS) can be defined as a 6-tuple:

$$PS = \{(ProdServID, Name, Frequency, Costs, Significance, Price)\} \quad (4)$$

Coupling Operation Models (COMs)

The coupling operation consists of a set of operations that take one or two sets as the input and produce a new set as their result. The fundamental operations in the coupling operation are select, project, Cartesian product, and associative.

The Select Operator

The select operation selects tuples that satisfy a given predicate. We use the lowercase Greek letter sigma (σ) to denote selection. The predicate appears as a subscript to σ. The argument relation is in parentheses after the σ. Thus, to select those tuples of the IR in Equation (2) object where the inforResID is "1," we write: σ inforResID = "1" (IR).

In general, we allow comparisons using =, $\neq$, $<$, $\leqslant$, $>$, $\geqslant$, $\nless$, $\ngtr$ in the selection predicate. Furthermore, we can combine several predicates into a larger predicate by using the connectives and ($\wedge$), or ($\vee$), and not ($\neg$).

The Project Operator

Suppose we want to list all names and values of IR, but do not care about the identifier of IR. The project operation allows us to produce this relation. The project operation is a unary operation that returns its argument relation, with certain attributes left out. Since a relation is a set, any duplicate rows are eliminated. Projection is denoted by the uppercase Greek letter pi (Π). We list those attributes that we wish to appear in the result as a subscript to Π. The argument relation follows in parentheses. Thus, we write the query to list all periodOfValidity of IR as: ΠperiodOfValidity (IR)

Composition of Coupling Operator

The fact that the result of a coupling operation is itself a set is important. Consider the more complicated query "Find periodOfValidity of the IR which inforResID is 1." We write:

$$\Pi_{periodOfVality}(\sigma_{\inf or \operatorname{Re} sID=1}(IR)) \quad (5)$$

The Cartesian-Product Operator

The Cartesian-product operation, denoted by a cross (×), allows us to combine information from any two objects. We write the Cartesian product of object o1 and o2 as o1×o2.

The Naming Operator

However, since the same attribute name may appear in both o1 and o2, we devise a naming operation to distinguish the object from which the attribute originally came. For example, the relation schema for R = IR × RI is shown in Box 1.

With this operation, we can distinguish IR.inforResID from RI.inforResID. For those attributes that appear in only one of the two objects, we shall usually drop the relation-name prefix. This simplification does not lead to any ambiguity. We can then write the relation schema for R as shown in Box 2.

The Associative Operator

It is often desirable to simplify certain operations that require a Cartesian product. Usually, an operation that involves a Cartesian product includes a selection operation on the result of the Cartesian product. Consider the operation "Find the contents of all IRs which come into the object of RI, along with the peridodOfValidity and generationTime." Then, we select those tuples that pertain to only the same inforResID, followed by the projection of the resulting content, generationTime, and peridodOfValidity:

$$\Pi_{\text{content, generationTime, periodOfValidity}} (\sigma_{\text{IR.inforResID=RI.inforResID}} (\text{IR} \times \text{RI})) \qquad (6)$$

The associative operation is a binary operation that allows us to combine certain selections and a Cartesian product into one operation. It is denoted by the "join" symbol "⊠." The associative operation forms a Cartesian product of its two arguments, performs a selection forcing equality on those attributes that appear in both relation objects, and finally removes the duplicate attributes.

Although the definition of an associative operation is complicated, the operation is easy to apply. As an illustration, consider again the example "Find the contents of all IRs which come into the object of RI, along with the peridodOfValidity and generationTime." We express this operation by using the associative operation as following:

$$\Pi_{\text{content, generationTime, periodOfValidity}} (\sigma\, (\text{IR} \boxtimes \text{RI}))$$

System Dynamics Models (SDMs)

This section is a detailed discussion of the system dynamics modeling, which allows for simple representation of complex cause-and-effect re-

Box 1.

$$\text{IR} \times \text{RI} = \{(\text{IR.inforResID, IR.content, IR.generationTime, IR.periodOfValidity, IR.inforType,}$$
$$\text{RI.resInputID,RI.receiveTime, RI.activityID, RI.inforResID, RI.personID, RI.IQMeasure})\}$$

Box 2.

$$\text{IR} \times \text{RI} = \{(\text{IR.inforResID, content, generationTime, periodOfValidity, inforType}$$
$$\text{resInputID, receiveTime, activityID, RI.inforResID, personID, IQMeasure})\}$$

lationships. For the discussion that follows, it is important to understand that it is the levels (or state variables) that define the dynamics of a system. For the mathematically inclined, we can introduce this in a more formal way. The following equations show the basic mathematical form of the QMEPMS.

$$measures[i]_t = \int_0^T levels[j]_t dt; \quad \frac{d}{dt} measures[i]_t = levels[j]_t \tag{7}$$

$$rates_t = \mathrm{g}(levels_t, aux_t, data_t, const) \tag{8}$$

$$aux_t = \mathrm{f}(levels_t, aux_t, data_t, const) \tag{9}$$

$$levels_0 = \mathrm{h}(levels_0, aux_0, data_0, const) \tag{10}$$

In these equations g, h, and f are arbitrary, nonlinear, potentially time varying, vector-valued functions. Equation represents the evolution of the system over time, equation the computation of the rates determining that evolution, equation the intermediate results necessary to compute the rates, and equation the initialization of the system.

QMEPMS differs significantly from a traditional simulation method, such as discrete-event simulation where the most important modeling issue is a point-by-point match between the model behavior and the real behavior, that is, an accurate forecast. Rather, for an EPMS model it is important to produce the major “dynamic patterns” of concern (such as exponential growth, collapse, asymptotic growth, S-shaped growth, damping or expanding oscillations, etc). Therefore, the purpose of our model would not be to predict what the total green supply chain profit level would be each week for the years to come, but to reveal under what conditions and capacity planning policies the total profit would be higher, if and when it would be negative, and if and how it can be controlled.

Model Variables

The flow variables represent the flows in the system (i.e., remanufacturing rate), which result from the decision-making process. Below, we define the model variables (stock, smoothed stock, and flow) converters and constants and cost parameters, their explanation, where necessary, and their units. We chose to keep a nomenclature consistent with the commercial software package that we employed; thus, for the variable names we use terms with underscore since this is the requirement of the software package (it does not accept spaces). The stock variables in order that they appear in the green supply chain processes are the following:

- **Raw_Materials:** Inventory of raw materials [items].
- **Serviceable_Inventory:** On-hand inventory of new and remanufactured products [items].
- **Distributors_Inventory:** On-hand inventory of the distributor [items].
- **Collected_Products:** The inventory of collected reused products [items].
- **Collection_Capacity:** The maximum volume of products handled by the collection and inspection facilities per day [items/day].

The smoothed stock variables are:

- **Expected_Distributors_Orders:** Forecast of distributor’s orders using exponential smoothing with smoothing factor a_DI [items/day].
- **Expected_Demand:** Demand forecast using exponential smoothing with smoothing factor a_D [items/day].
- **Expected_Remanufacturing_Rate:** Forecast of remanufacturer rate using exponential smoothing with smoothing factor a_RR [items/day].

- **Expected_Used_Products:** Forecast of used products obtained using exponential smoothing with smoothing factor a_UP [items/day].
- **Desired_CC:** Estimation of collection capacity obtained by exponential smoothing of Used_Products with smoothing factor a_CC [items/day].
- **Production_Rate:** [items/day].
- **Products_Rejected_for_Reuse:** The flow of used products that have not passed inspection and should be disposed [items/day].
- **Controllable_Disposal:** The flow of surplus stock of reusable products to prevent the costly accumulation if there is not enough remanufacturing capacity to handle them [items/day].
- **RC_Adding_Rate:** Remanufacturing capacity adding rate [items/day/day].

Constants, converters are:

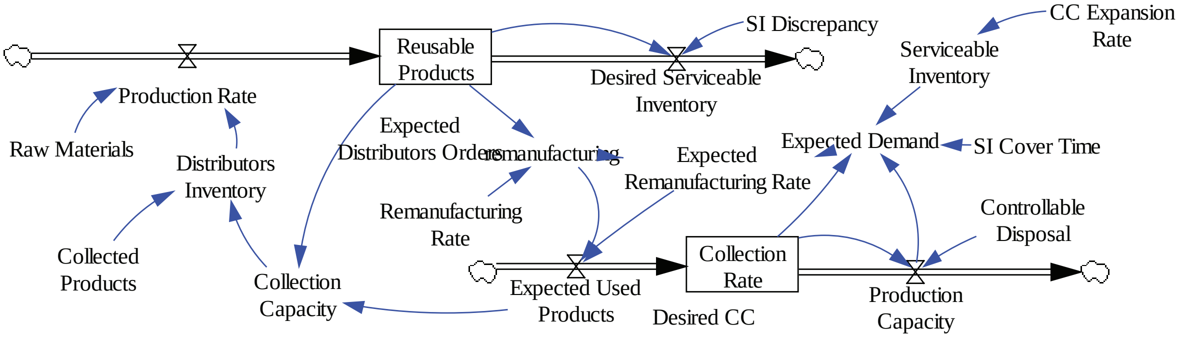
- **CC_Discrepancy:** Discrepancy between desired and actual collection capacity [items/day].
- **CC_Expansion_Rate:** Collection capacity expansion rate [items/day/day].
- **DI_Adj_Time:** Distributor's inventory adjustment time [days].
- **DI_Cover_Time:** Distributor's inventory cover time [days].
- **Pr:** Remanufacturing capacity review period [days].
- **Reuse_Ratio:** The ratio of Expected_Remanufacturing_Capacity to Expected_Used_Products [dimensionless].
- **SI_Adj_Time:** Serviceable inventory adjustment time [days].
- **SI_Cover_Time:** Serviceable inventory cover time [days].

Cause-Effect Diagram

The structure of a system in QMEPMS methodology is captured by cause-effect diagrams. A cause-effect diagram represents the major feedback mechanisms. These mechanisms are either negative feedback (balancing) or positive feedback (reinforcing) loops. A negative feedback loop exhibits goal-seeking behavior: after a disturbance, the system seeks to return to an equilibrium situation. In a positive feedback loop an initial disturbance leads to further change, suggesting the presence of an unstable equilibrium. Cause-effect diagrams play two important roles in QMEPMS methodologies. First, during model development, they serve as preliminary sketches of causal hypotheses and secondly, they can simplify the representation of a model.

The first step of our analysis is to capture the relationships among the system operations in a QMEPMS manner and to construct the appropri-

Figure 4. Cause-effect diagram of the green supply chain



ate cause-effect diagram. Figure 3 depicts the cause-effect diagram of the system under study which includes both the forward and the reverse manufacturing process. To improve appearance and distinction among the variables, we removed underscores from the variable names and changed the letter style according to the variable type. Specifically, stock variables are written in capital letters, the smoothed stock variables are written in small italics and the flow variables are written in small plain letters. These variables may be quantitative, such as levels of inventories and capacities, or qualitative, such as failure mechanisms.

Mathematical Formulation

The next step of QMEPMS methodology includes the development of the mathematical model, also presented as a cause-effect diagram that captures the model structure and the interrelationships among the variables. The cause-effect diagram is easily translated to a system of differential equations, which is then solved via simulation.

The cause-effect diagram is a graphical representation of the mathematical model. The embedded mathematical equations are divided into two main categories: the stock equations, defining the accumulations within the system through the time integrals of the net flow rates, and the rate equations, defining the flows among the stocks as functions of time. In the remaining of this section, we present selected formulations related to important model assumptions.

The equations related to collection green supply chain policy are the following:

$$\mathit{Desired\_CC(t)} = \mathrm{DELAYINF}(\mathit{Used\_Products}, \mathit{a\_CC}, 1, \mathit{Used\_Products}) \quad (11)$$

$$\mathit{Collection\_Capacity}(0) = 0 \quad (12)$$

$$\mathit{Collection\_Capacity}(t + dt) = \mathit{Collection\_Capacity}(t) + dt * \mathit{CC\_Adding\_Rate}, \quad (13)$$

$$\mathit{CC\_Adding\_Rate} = \mathrm{DELAYMTR}(\mathit{CC\_Expansion\_Rate}, 24, 3, 0), \quad (14)$$

$$\mathit{CC\_Discrepancy} = \mathrm{PULSE}(\mathit{Desired\_CC} * \mathit{Collection\_Capacity}, 50, P_c), \quad (15)$$

$$\mathit{CC\_Expansion\_Rate} = \max(K_c * \mathit{CC\_Discrepancy}, 0), \quad (16)$$

Desired_CC is a first order exponential smoothing of Used_Products with smoothing coefficient a_CC. Its initial value is the initial value of Used_Products. Collection_Capacity begins at zero and changes following CC_Adding_Rate, which is a delayed capacity expansion decision (CC_Expansion_Rate) with an average delay time of 24 time units, an order of delay equal to 3 and initial value equal to zero at t = 0. CC_Expansion_Rate is proportional to the CC_Discrepancy between the desired and actual collection capacity, multiplied by Kc. The pulse function determines when the first decision is made (50 time units) and the review period Pc. Similar equations dictate the green supply chain policy.

The total profit per period is given from:

$$\mathit{Total\_Profit\_per\_Period} = \mathit{Total\_Revenue\_per\_Period} - \mathit{Total\_Cost\_per\_Period}, \quad (17)$$

Where

$$\mathit{Total\_Cost\_per\_Period} = \mathit{Investment\_Cost} + \mathit{Operational\_Cost} + \mathit{Penalty\_Cost}, \quad (18)$$

$$\mathit{Total\_Revenue\_per\_Period} = \mathit{Sales} * \mathit{Price}, \quad (19)$$

$$\mathit{Investment\_Cost} = (\mathit{CC\_Expansion\_rate})^{0.6} * \mathit{Col\_Cap\_Construction\_Cost} + (\mathit{RC\_Expansion\_rate})^{0.6} * \mathit{Rem\_Cap\_Construction\_Cost}, \quad (20)$$

$$Operational\_Cost = Collection\_Rate * Collection\_Cost$$

$$\begin{aligned} & Remanufacturing\_Rate * Remanufacturing\_Cost \\ & + Production\_Rate * Production\_Cost \\ & + Reusable\_Products * Holding\_Cost \\ & + Sales * DI\_Transportation\_Cost \\ & + Distributors\_Inventory * DI\_Holding\_Cost \\ & + Shipments\_to\_Distributor \\ & \quad * SI\_Transportation\_Cost \\ & + Serviceable\_Inventory \\ & \quad * SI\_Holding\_Cost, \end{aligned} \tag{21}$$

ILLUSTRATIVE CASE

Owing to the wide set of measures and processes that must often be considered in an EPMS, the implementation of the suggested quantitative models may be complex. To understand the major models of the identified EPMSs, An example that highlights how measures must be structured at the operational level is given. In the following section, the case of FAW Toyota Changchun Engine Co. Ltd. (FTCE) in the automotive industry is analyzed.

First Auto Works (FAW) is the largest Chinese corporation in the automotive industry. It has industrial sites both in Changchun and Tianjin, and over the last few years has adopted a green manufacturing strategy aimed at reducing product costs (through innovative technology) and improving product quality. As a pioneering automobile company, FTCE has initiated multiple dimensions of GSCM practices, including internal environmental management, green purchasing, green marketing, and eco-design.

Since 2000, senior management has been committed to a reduction in the environmental impact resulting from industrial activities, and product usage. In terms of operational policy, such an interest in "green" issues has given rise to two major programmes:

- The F1 program, specifically aimed at improving the environmental performance of the production processes.
- The F2 program, which focuses on the introduction of new environmentally friendly cars. Indeed, in 1999, the group developed a new generation of recyclable cars.

In the light of these issues, it is clear that First Auto has adopted a pro-active pattern of environmental behavior, whereby it has tried to improve its ("green") image.

In the sample application, an EPMS was designed to support operations managers in assessing the results of the Crown model. The car is designed to respect recycling and dismantling techniques, and allows the company to recover all end-of-life components. Materials for engines are recycled into plastics for air ducts in the dashboard, glass is recovered to produce colored bottles; reclining seats are recycled into carpets for furnishing, and so forth. Here, the effectiveness of engine recycling is assessed, since it is the only activity that is implemented internally.

Producing environmentally sound engines is one key dimension FTCE uses to establish their environmental image, and thus gain and keep competitiveness. Within this competitive market, senior managers in the FTCE put forward a call of ‘‘Green plant, environmental engines." They have worked on furthering their environmental image by producing petrol engines with low emissions, low petrol consumption, low noise, as well as high dynamic functions and reliability. To at least maintain and potentially improve its environmental performance, FTCE has invested over 14 million RMB since 2004. The plant purchased equipment for emission purification, noise elimination and wastewater treatment, which greatly improved its internal environmental conditions. In 2006, FTCE initiated a waste water reuse project, and became the first company realizing "zero emissions" for both industrial and municipal waste water in Changchun, which is very important in a municipality that is consistently threatened with water shortages. To complete this program the plant invested 3.26 million RMB for a wastewater treatment project by using flocculation, bio-chemical, ultra-filtration, and reverse osmosis technologies.

Environmental issues are main concerns for FTCE during its product design and development. The Product Development Director in FTCE stated that environmental requirements are quickly becoming primary priorities, even over economic benefits. To help them address this management priority, the plant closely cooperates with our research methodology and models on eco-design projects. As an example of this success, since April 2007, all products produced by the FTCE meet the Europe II emission standards.

The plant has also implemented cleaner production activities in its production stages focusing on source reduction and waste prevention. The plant implements collaborative development efforts with its suppliers, which include environmental considerations, and these efforts and programs are driven by the organization's internal environmental strategy and policy. Customer collaboration is also evident here. For different types of vehicles, road conditions, and consumer characteristics, the plant and its main customer, FAW, jointly develop improved engines that consume less fuel, while maintaining suitable performance standards (including acceleration and cooling systems capabilities).

The significance of outsourcing practiced by FTCE requires them to more closely monitor supplier environmental practices to guarantee both quality and environmental performance requirements. The plant not only collects environmental information related to suppliers, but also establishes a database on environmental situations for main component suppliers. The plant jointly implements research on substitute materials and technologies to improve environmental practices with those partners and even joins in some of these innovation programs with competitors. At the same time, the plant also outsources other nonmanufacturing functions, such as logistics functions to help achieve their goals of just-in-time (JIT) production. This outsourcing requires monitoring of its distribution and transportation environmental and economic performance. JIT provides a managerial challenge since JIT's minimization of waste philosophy is environmentally sound, yet, more frequent delivery requirements weaken transportation energy efficiency, causing environmentally detrimental consequences.

FTCE has improved both environmental and economic performance through GSCM-related practices. It is complying with regulatory and market pressures by offering innovative and environmentally sound products. However, the plant has also faced numerous challenges. Prices for energy and raw materials have continuously increased. Emission standards have become increasingly strict. For example, the federal government recently announced plans to implement Euro III standards on emissions by the end of 2007. These continued pressures and forces will cause not only FTCE to adopt and advance GSCM innovation, but other manufacturers will need to react as well.

In line with the above discussion, the change in the main (physical) environmental performance resulting from the implementation of this program and the main drivers of shareholders' value were calculated.

The implementation of the above initiative results in the modification of design, process efficiency, and volume indices (see Table 3). Specifically, the take-back of engines leads to a reduction in the purchase of plastic raw materials and energy consumption (30% with respect to traditional plants), since the fluff resulting from the grinding of car bodies is cleaner.

From a financial perspective (see Table 4), the program affects expenditure related to the internal efficiency of operations, for example, the reduction of energy, raw materials, and environmental regulations related costs (regarding both waste water and solid wastes), as well as other operating costs associated to the take back and recycling of engines, higher labor costs to implement the recycling process internally, and increased expense for the recycling process itself. In addition, the introduction of new cars produced an increase in volume (50,000 units).

In the light of the above analysis, it can be concluded that the company respected its own targets: indeed, the increase in actual labor costs over standard costs is only marginal and, above all, the result of the growth in production volumes.

The above discussion highlights that there are significant differences in the deployment and assessment of a pro-active or a reactive green supply-chain strategy. In particular, both the design of the EPMS and the gathering of data present different operating problems which depend on the adopted pattern of environmental behavior.

In general terms, the design of an effective EPMS is more complex within pro-active companies than within reactive organizations. It must be noted that the assessment of a pro-active green supply-chain strategy requires identification of physical and economic indicators which well describe a company's potential environment-related sources of competitive advantage. This implies significant changes in the traditional systems adopted to monitor the evolution of environmental performance. Indeed, the latter were

Table 3. Measures expressing a company's impact on the state of natural resources

		Planned value	***Reported measure***
	Time for production	4 hours	3.5 hours
	Time for disassembling	5.8 hours	4.6 hours
	No. of different materials in the product	4	9
Volume index	Quantity of recovered plastics	6.376 tons	8.670 tons
	SOx	523 tons	532 tons
	NOx	412 tons	395 tons
Process efficiency	Electrical energy	445,000 Mwh	430,000 Mwh
	Oil	2,250 tons	2,383 tons
	COD	35,500 tons	33,000 tons
	Sulphates	368,000 tons	369,500 tons

Table 4. The economic items affected by the initiative

	Forecast Value (RMB)	***Reported measure (RMB)***
Revenue		
Total Revenue per Period	2,150,000,000	2,345,000,000
Total Cost per Period		
Total Profit per Period	56,500,000,000	58,450,000,000
Operational Cost	18,250,000,000	17,750,000,000
Energy costs	5,650,000,000	5,537,000,000
Other environmental costs		
Recycling costs	435,720,000	428,780,000
Costs related to environmental regulations	593,500,000	693,000,000

usually designed to verify compliance with existing regulations. A reactive green supply-chain strategy simply demands verification of whether environmental performance of the company's products or processes are consistent with the stakeholders', that is, regulators' or customers', requirements. The implementation of the suggested approach in FA (the reactive firm) did not in fact require the definition of new measures, as the company's EPMS already considered compliance indicators.

It is evident that, apart from managers' skills and the effectiveness of the information system, the deployment of innovation-based green supply-chain strategies (evangelist, pro-active and responsive) is more complex than passive patterns of environmental behavior. A key point in the effective assessment of innovative environmental policies is the identification of measures clarifying how the company positions itself with respect to competitors, and how the adopted programmes affect the company's profitability. In this respect, a growing body of literature highlights that the failure of some ambitious environmental strategies is a direct consequence of an incorrect selection of the indicators to be used in the EPMS.

CONCLUDING REMARKS

The suggested framework is, in our opinion, an effective tool for operations managers wishing to design EPMSs. The operational guidelines on PMS architecture and the appropriate measurement techniques provide support in devising performance indicators that best suit the intended green supply-chain strategy.

The model can be used to analyze various scenarios (i.e., to conduct various "what-if" analyses), thus identifying efficient policies and further to answer questions about the long-term operation of green supply chain using total process profit as the measure of performance. The model could further be adopted and used not only for product recovery, but also for material recycling systems. Thus, it may prove useful to policy-makers/regulators and decision-makers dealing with long-term strategic management issues along with researchers in environmental management. The benefits of the QMEPMS approach may be summarized as follows:

- Factors affecting performance can be identified and then their effects can be quantified
- Effects of multidimensional factors on performance can be aggregated into a single dimensionless unit (priority)
- Help managers to quantify the level of impact of each factor on overall performance and therefore assists in focusing improvement activities
- The relationships between factors can be clearly identified and expressed in quantitative terms
- Models can be easily altered to assists understanding the dynamic behavior of factors affecting performance
- Facilitates the reduction of the number of performance measurement reports

An important benefit gained from the QMEPMS approach is that the interaction of the factors can be clearly identified and expressed in quantitative terms. This identification will bring us one step forward in understanding the dynamic behavior of factors affecting environmental performance.

Moreover, the approach can be used in a "dynamic perspective," that is, to analyze whether to change the adopted pattern of environmental behavior from a passive/re-active to a pro-active strategic attitude. In operational terms, this implies, for example, that a reactive firm has to design an EPMS which includes indicators highlighting how the company's economic value may change with the introduction of innovation-based environmental programmes (i.e., the EPMS suggested for a pro-active manufacturing strategy).

However, the suggested framework does not solve all the problems associated to environmental performance measurement. In this respect, two directions for further research can be identified:

The integration of environmental aspects into the corporate management control system, since, in the above discussion, we considered the control of the implemented environmental programmes as an isolated problem. The design of a comprehensive PMS which includes the environmental dimension as well as the other competitive priorities (i.e., cost, quality, time, flexibility, innovation) may be difficult. A key point for future research is to avoid excessive proliferation of data, since this may hinder the use of PMS to identify how a company performs with respect to the planned objectives.

Decision-making techniques must be developed which allow physical and economical measures to be integrated into a synthetic judgment. The assessment of different "green" options requires the decision maker to identify how each alternative contributes to the reduction of environmental impact and shareholders' value creation. The definition of a synthetic indicator is of fundamental importance if the comparison of the available "green" options shows contrasting results with regards environmental performance and the financial implications of its implementation.

FUTURE DIRECTION

Research in GSCM to date may be considered compartmentalized into content areas drawn from operations strategy. The primary areas of emphasis have been quality, operations strategy, supply-chain management, and product and process technologies, which are collectively beginning to contribute to a more systematic knowledge base. It is reasonable to expect that these research areas will continue to hold the greatest promise for advance in the short term. However, more integrative contributions are needed in the longer term, including green supply chain strategy, intra- and inter-firm diffusion of best practices, green technology transfer, and environmental performance measurement.

One of the biggest challenges facing the field of GSCM is the inherent complexity of environmental issues, such as natural environment limits, multiple stakeholders, uncertain implications for competitiveness, international importance, and so forth. These present significant challenges to researchers, management academicians, and application practitioners. Much research is needed to support the evolution in business practice towards green supply chain strategy. Effective quantitative models for green supply chain need to be developed. Researchers might take advantage of the emergent mathematical modeling technologies for more effective collaboration and cooperation. Although research on intelligent GSCM is still in its infancy, there is no doubt that this will be the hottest topic in the near future. Artificial intelligence techniques, including knowledge-based systems, fuzzy systems, and neural networks, are expected to play a significant role in research and development.

Although many case studies, survey-based empirical methods, and so forth, have been carried out, they have not dealt with strategic management aspect of GSCM. Detailed empirical case studies need to be carried out in such areas as organizational function to GSCM at the firm level, selection of returns and rework facilities in alignment with competitive priorities, the influence of remanufacturing on the supply chain of a particular firm, and how service quality and recovery strategies influence consumer behavior and vice versa. The chance also exists to carry out empirical studies to find how the regulatory environment, economic considerations, and level of function influence the volume of returns. Similarly, studies to find how various uncertainties influence channel relationships within GSCM are also desired.

The product life cycle has been studied in great depth. However, more research is needed in understanding strategic management and its connection to the product life cycle. An important area for investigation would be to see how, in practice, strategic management activities do change over the life of a particular product. More information is needed about returns levels. At a strategic level, there is little published information on product return levels by product type. More study of the impact of marketing on strategies is needed. In general, theory and models need to be developed and consolidated to establish the relationship between new product sales and returns rates. Research is needed into how companies should process, store, and dispose of returned goods. Much more research is needed in understanding secondary markets, and how companies should best sell unwanted products. In addition to traditional brokers, many firms are now selling this material through online and traditional auctions.

Although the current development in GSCM research is encouraging, literature on integrated business strategy (comprising product and process design, manufacturing, marketing, RL and regulatory compliance) in the context of GSCM is at the level of thought papers and frameworks only. More research is needed in determining how companies should best select green strategies for each outlet to maximize returns, while still protecting brand integrity. Further, GSCM deserves special attention in terms of resource function within a firm/ supply chain.

GSCM seems a promising area for trying out new research techniques and for using traditional techniques for overall GSCM Strategy. The problem is complex and challenging, as a very large number of parameters, decision variables, and constraints are involved along with a large number of estimation requirements such as those of expected demands and returns and cost criteria associated with each decision. Perhaps a combination of various tools and techniques may be combined for the purpose of formulation, approximation, analysis, and solution of such complex problems.

Developing and further improving greening strategy concepts means that it will be more beneficial for manufacturing companies to implement recycling, refurbishing, and remanufacturing operations for economic reasons alone besides meeting the consumer pressures and regulatory norms. By determining the factors that most influence a firm's greening strategy undertakings, it can concentrate its limited resources in those areas. Areas and topics such as integrated logistics for network design, under which circumstances should returns be handled, stored, transported, processed jointly with forward flows and when should they be treated separately, comparing cost of remanufacturing with cost of production from virgin materials, potential attractiveness of postponement operations in greening strategy, change in a firm's green strategy for a particular product over the course of the product's life, and modeling for situation when customer returns cannot be cost minimization model may be explored for further research.

ADDITIONAL READING

Flapper, S., Wassenhove, L. V., & Nunen, J. v. (2005). *Managing closed-loop supply chains*. Berlin/Heidelberg: Springer-Verlag. This book provides a framework for analysis and design of closed-loop supply chains including technical, organizational, planning and control, information, environmental and business economic issues, as well as the interactions between them.

Sarkis, J. (2006). *Greening the supply chain*. London: Springer-Verlag. This book is a good introduction for investigating green supply chain management. The chapters of this book include work from a number of international authors from

theoretical and practical backgrounds, sharing their research and experiences in the field to promote a better understanding of the environmental influence of supply chain management.

System dynamics modeling allows researchers to specify stocks and flows of resources, and the relatedness of decisions about those resources (Forrester, 1999). Relatedness may be in the font of direct or indirect feedback loops (with or without time lags) that reinforce or dampen effects from other decisions. The process of modeling strategic decision environments compels researchers to specify assumptions and variables explicitly (Crossland & Smith, 2002).

Dynamic models can be classified as white box and black box (Forrester, 2007b). Black-box models are data driven, and comparing the forecast outcome with actual outcomes can test their validity (Forrester, 2007a). White-box models are descriptive and theory-like in that they try to explain the behavior of a system. System dynamics models, which are of the white-box type, exhibit validity if their internal structure adequately represents the issues relevant to the behavior being described. Further, the internal structure cannot be validated from an entirely objective, formal, and quantitative perspective (Burgelman & McKinney, 2006). Software designed for building system dynamic models assists in clarifying the internal logic of relationships. The responsibility for the accuracy of the description of the system that is being modeled, however, remains with the researcher (Hilmola, Helo, & Ojala, 2003). The availability of system dynamics software facilitates applying concepts, such as the supply chain, to case studies. We chose Vensim® Version 5 software for our study.

Fundamentals of greening as a competitive initiative are explained by Porter and van der Linde (1995). Three strategies in GSCM, namely reactive, proactive, and value-seeking, are suggested by van Hoek (1999) and Johnson (1998). Nasr (1997) and Gungor and Gupta (1999) discuss environmentally conscious manufacturing. Friedman (1992), Guide and Van Wassenhove (2002) and Gupta and Sharma (1996) discuss the changing role of the environmental manager. Interactions among various stakeholders on integrated GSCM and advantages that may accrue to them have been described by Gungor and Gupta (1999).

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Chapter 8.14

A Mediator for Biospatial Information Systems

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ABSTRACT

This article presents a system to enable access to those Information Systems at the National Autonomous University of Mexico (UNAM) that are related to Biodiversity and the Environment. The system in question associates existing Geographic Information Systems (GIS's) as well as standard relational databases in a federation, allows the contents of the individual GIS (or relational databases) to be consulted in a manner transparent to the user, and permits the exports of the underlying systems' data under the corresponding set of permissions. Our approach is based upon three principles: compliance with international standards, reliance upon Open Source Software in implementation, and usage of servers of proven reliability and robustness. [Article copies are available for purchase from InfoSci-on-Demand.com]

INTRODUCTION

Mexico occupies a very high position in biodiversity, especially for reptiles, mammals, amphibians, vascular plants, and birds. The National University of Mexico (UNAM) and other institutions possess a treasure trove of collections gathered since the 19th century, and these unique collections continue to grow exponentially. Several research centers at UNAM as well as other Mexican institutions, such as the National Commission for Biodiversity (CONABIO), the National Polytechnic Institute, or U. of the Americas, have developed Geographic Information Systems (GIS) concerning biodiversity and spatial information. Because they have been developed independently, the GIS's reflect both the idiosyncrasies of the software used in their implementation as well as the peculiarities of each developing institution. A challenge stems from this multiplicity of origins: To allow transparent access to the information of these dissimilar sources to enable their joint exploitation.

To answer this challenge, there has been research on systems' integration (Levy, 2001; McBrien and Poulovassilis, 2003) and on methods to match ontologies (Aumueller et al., 2005), as well as international standards for specifying:

1. Common schemata for defining the fields for exchanging biodiversity information (Graham et al., 2004).
2. Protocols for accessing, via the Internet, data nodes from a diverse array of biodiversity collections (Graham et al., 2004).
3. Spatial data types and their exchange format (OpenGIS, 1999).
4. Canonical operations for accessing spatial data (Clementini et al., 1993; Worboys, 2004).
5. Catalogs of Spatial Reference Systems (OpenGIS, 1999).
6. Query predicates for spatial features in a Web environment (Clementini et al., 1993).
7. The representation of semi-structured spatial information (Lake et al., 2004) by means of a Geographic Markup Language (GML), a standard developed by the Open Geospatial Consortium.

UNAM has established a University Biodiversity System (UNIBIO) that states as its mission: "the generation of a system that allows the capture, organization and public access to Mexico's biodiversity information". Parallel to UNIBIO, UNAM has established the UNIGEO project to unify its geo-spatial information using the standards of the Open Geospatial Consortium (OGC) (Lake et al., 2004). The Mediator system described in this article has been developed by UNIBIO to unify it with UNIGEO, using international standards to bridge the gaps between the different data sources.

The remaining sections of this document describe related work, explain the system's goals and components, present the architecture of the two main constituents of our project to, finally, give results and enumerate conclusions.

REVIEW OF RELATED SYSTEMS

As mentioned in the introduction, the mediator project involves the integration of two types of information systems: the ones concerning biological collections and those related to geo-spatial information. This section describes work in each of these two fields.

Accessing Biological Collections

Two main XML schemata are used for information exchange and data integration on biological collections, namely, the Darwin Core and the schema of the Task Group on *Access to Biological Collection Data* (ABCD) (Sarkar, 2007; Darwin Core, 2003; ABCD, 2005). These schemata have the following characteristics:

Darwin Core specifies elements that describe the domain of an observation. It has 48 elements, five of them required; the longitude, latitude, geodetic datum and coordinate uncertainty are among the non-required elements. Access to Darwin Core sources is commonly accomplished through a protocol called *Distributed Generic Info Retrieval* or DiGIR (DiGIR, 2001); this protocol obtains data by means of HTTP and XML.

ABCD considers more than 2000 elements and may include, apart from the collection's data proper, information on the metadata and on the providers. The ABCD schema is structured in modules and allows the inclusion of new extensions. The expressivity of this schema is greater than the one attainable by the Darwin Core one; however, this complexity translates in a greater difficulty in adapting it to existing collections, thus reducing its popularity. Access to this schema is provided by the BioCase Access Protocol

A protocol called TAPIR (*TDWG Access Protocol for Information Retrieval*) has been proposed in (TAPIR, 2004). This protocol allows the access of both ABCD and Darwin Core schemata.

The collections of UNIBIO use Darwin Core and are accessed through the DiGIR protocol.

Accessing Geospatial Data

There exist two main methods for integrating information systems: using a Warehouse and using a Mediator.

In the Warehouse approach, all data is transferred to a single information system to be handled in a uniform manner; the Mediator, on the contrary, lets the information reside in their original sources and, when receiving a request, orchestrates a series of queries to the original sources and procedures that mix and integrate the results of these queries.

The advantages and disadvantages of each of these approaches are as follows:

A Warehouse provides these benefits: it simplifies the optimization and processing of queries, since both the data files and its statistics are readily available and the physical structure/indexing of the files can be reconfigured for better performance; it allows the administrator to define cleaning/repair procedures to diminish, for instance, data redundancy or false references; and it enables users to add their own annotations to stored data.

On the other hand, this approach must implement mechanisms for updating the information coming from each of the sources and it may present problems with the ownership of information: old data can still be resident in the warehouse even if one of the sources has denied access to its information.

A Mediator has these advantages: it simplifies the retrieval of fresh data, it is easier to connect to new data sources, and it gives the owners of the data more control on the availability of this information.

In a Mediator, however, the cleaning procedures for data redundancy are more difficult since they have to be executed "on the fly", and the efficiency of query processing is generally lower than that attainable in a Warehouse.

Mediators as well as Warehouses must perform both vertical integration, in which the data of several provenances with similar formats are unified, and horizontal integration, in which the results of the query combine data from difference provenances.

In a Warehouse, these integrations are performed while data is being transferred from a source to the Warehouse. A Mediator, however, performs this integration for each individual query.

For the purpose of data integration, a Mediator needs a method to unify, in a global schema, the schemata of the underlying sources. Two main approaches are available: representing the global schema as views of the local schemata (also known as "Global as a View", GAV) or representing the local schemata as views of the global schema (known as "Local as a View, LAV). The GAV approach, most commonly followed, allows a very simple reformulation of a global query in terms of the local schemata; on the other hand, the global schema is difficult to maintain when a local schema changes. This situation is reversed in a LAV approach, in which a simpler maintainability of a schema is achieved at the cost of a more elaborated query preprocessing.

Finally, a Mediator can obey either a Centralized paradigm, in which the mediation is done in a hub and the data sources must comply with pre-fixed data models and command languages, or a Grid Services paradigm, which relies on a cluster of relative independent nodes that register their services for the description, exchange, replication, and processing of data.

The next subsection gives an example of the Centralized paradigm, followed by two examples that illustrate the Grid Services paradigm.

VirGIS

VirGis (Boucelma et al., 2002) is a mediator for geographic information developed at the University of Provence. This system can combine diverse sources of geospatial information and uses a restricted form of the "Local as a View" method to help in this integration.

The data sources of a VirGIS mediation system are accessed using the Web Feature Service of GML, a protocol used to access information with a spatial component represented in a vector format. VirGIS' users pose their queries against the global schema either by employing Keyword-Valued Pairs (KVPs), or by means of GQuery, a language that extends XQuery by adding spatial operators.

VirGIS is internally comprised of four modules doing these functions:

1. The *Decomposition* Module converts the original query (be it in GQuery or in KVPs) into a sequence of elementary requests expressed in terms of the global schema; these queries form an initial version of the execution plan.
2. The *Rewriting* Module considers both the transformations dictated by the global schema and the sources' capabilities, and uses these considerations to rewrite each of the elementary queries generated by the decomposition module, producing subqueries that can be understood by the data sources.
3. The *Execution* Module sends the rewritten subqueries to the corresponding data source and combines the results.
4. The *Recomposition* Module processes the results of the execution module, removes duplicates (if necessary), and returns the results as a GML stream.

In future versions, VirGIS contemplates the development of further query optimization.

Grid Enabled Mediation Services (GEMS)

GEMS (Zaslavsky et al., 2003) is a collection of grid services developed at the San Diego Supercomputer Center, that supports spatial data mediation, ontology and schema conflict resolution, and composite map assembly.

These grid services have been developed within the Geosciences Network Project (GEON), a network that allows its information to be searched using sets of keywords, descriptions, titles, or by means of ontologies.

GEMS allow users to register their datasets and to formulate queries that the system rewrites to suit the idiosyncrasies of the individual datasets, since geospatial sources follow different and often incompatible schemata. To harmonize dissimilar sources, query reformulation requires that the elements of the database schema be associated to concepts in a domain ontology; this association is done at registration time.

The process of a data source's registration involves providing information about the manner in which the source's metadata is to be indexed using a domain ontology, about the source's schemata and the source's exported functions, about the mechanisms to access the source, e.g., ODBC, Web Services, etc., and about the permissions used to specify control restrictions according to a GEMS role-based authentication mechanism

In GEMS, ontology/based queries go through the following four services.

1. A *Concept Expansion* Service, in which the terms and returns the descendents (hyponyms) of the concepts used in the query. Thus, as mentioned in an example in (Zaslavsky et al., 2003), a query that requests formations in the Tertiary age will return the concepts "Neogene", "Pliocene", "Placenzian", "Miocene", etc., all descendents from the Tertiary.
2. A *Concept Resolution* Service, used to provide all values that reference the terms expanded by the previous service. Thus, in the example cited, the returned values may include "Tertiary", "Quaternary/Tertiary", "Tertiary/Cretaceous", etc. The values provided by these service are used to modify the "WHERE" clause of the original request.
3. A *Mediation* Service that forwards each of the data sources its corresponding fragment of the rewritten query, directing their answer to the assembly service.
4. A *Map Assembly* Service that, taking into account the initial query, retrieves into a local staging area the fragments generated by each data source, performs (if required) the necessary transformations and forms a composite map to be returned to the user.

Global Earth Observation System of Systems (GEOSS)

GEOSS (Khalsa et al, 2007) is a project of the Group on Earth Observations (GEO), providing an infrastructure of analytical tools and data for public information.

The systems that participate in GEOSS, though initially developed to suit their individual needs, must adapt their inputs and outputs to be interoperable with other systems. Presently, GEOSS has the IP3 Project (*Interoperability Process Pilot Project*) that concentrates on the interoperability situations that come to light by trying to interface with other systems affiliated to GEOSS via "interoperability arrangements".

For this, IP3 has implemented a Component Register. If a component is to be included in the Register the corresponding organization must complete a registration form, citing all interfaces of the service to be registered. The registering organization is presented with a list of standards existing in the Standards Register, needing to select the ones that apply to the service. If all interfaces to be registered obey one of those standards, the component's registration can be submitted; otherwise, the process is referred to a forum for further consideration.

In the next three sections, the system's goals and general structure will be presented, to then describe in more detail its principal elements.

SYSTEM'S GOALS

Three goals were set prior to the system's design:

1. To form a federation of GIS' that integrates the rich and growing trove of Geographic, Biologic and Environmental information at UNAM into a uniform information system. This system will allow the access of each member's information as if it resided in a single database, transforming, if needed, between coordinate systems. This federation will allow both the vertical and the horizontal integration of data sources.

2. To provide users with access to this information via a graphic interface. The queries will be able to span simultaneously several sources and to utilize spatial predicates (e.g., “give me all species collected in Cajeme County”). The results of the users’ queries will be rendered in GML (Lake et al., 2004); information requests to individual sources will make use of GML’s services, like the *Web Feature Service* (WFS) and the *Web Map Service* (WMS) (OpenGIS, 2002). The query interface will provide all predicates and functions specified by OGC.
3. To provide the client with capabilities to navigate and analyze the results of a query, giving it the option to export them to another system to perform more detailed analysis (e.g., Data Mining).

It was decided to adopt a Mediator (vs. a Warehouse) solution because it allowed more respect to the rights of the data owners and more flexibility in including data sources. Still, the implementation agreed upon is, in a way, a hybrid of both approaches. This is because the system, though capable of mediating among different sources, can still store in a warehouse (a PostGis database) either data that has been entrusted to it or data that has been periodically mined from some selected DiGIR sources; this warehoused information is seen by the mediator as resident in a special kind of source that can resolve more complex queries.

System’s Components

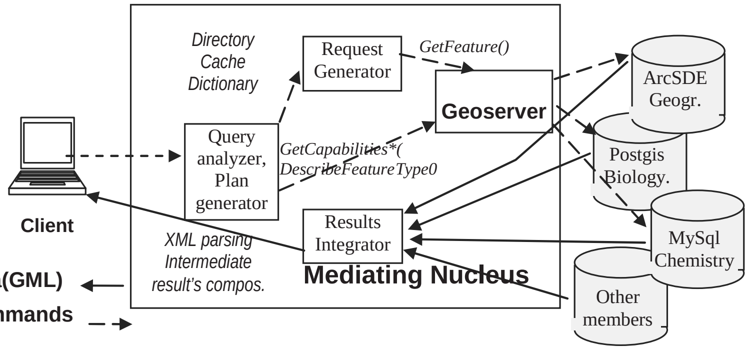
To achieve the three goals above, the system is designed and formed by the three components as shown in Figure 1:

1. A client that produces information requests.
2. A mediating nucleus that receives HTTP commands from the client to then analyze and decompose them into a series of requests to the individual members of the federation. Once the members’ responses arrive, these results are processed and combined, and finally, the response is sent to the client in a GML format.
3. The individual members of the University Biodoversity System (and of UNIGEO). There are two conditions for joining this federation: to permit one or more mediators to access the contents of the potential member’s information contents, and to be capable of rendering these contents by means of a standard service.

Results’ Format and Structure

The client was designed to have the following capabilities: (a) To formulate queries involving

Figure 1. System’s diagram



several sources, using join conditions; (b) to display the spatial component of the results of query and to show, if requested, non-spatial attributes; (c) to store temporarily the results of a query, and to be able define predicates for selecting subsets of the results without resorting to the mediator; (d) to navigate from a selected subset of data elements to a different subset of elements related by the query; and (e) to export using standard formats the results of the execution of a query, so further analysis can be performed on them using specialized tools.

Since the queries posed to the mediator may decree the existence of joins on the information of two or more sources, three alternative format options were considered for returning a query's results to the client:

1. Flatten all results into a relational table.
2. Use a nested representation.
3. Use an ER (Entity/Relationship) model to provide the results in which the relationships are determined by the associations between entities dictated by the join conditions.

The following considerations, related to the types of data sources, were taken into account to decide on one of the previous options: (a) UNIBIO allows information retrieval using DiGIR (DiGIR, 2001) that follows the Darwin Core standard; (b) UNIGEO, in turn, uses two services defined in the GML standard: WMS (Web Map Service) that supplies information in an image format and WFS (*Web Feature Service*) that provides information in a vector format; (c) neither the DiGIR nor the WFS data format allow nesting on any of their non-geometric elements and; both DiGIR and WFS sources provide unique identifiers to each data record (GUIds for DiGIR, Feature Identifiers or FId's for WFS).

The first option was discarded because, in addition to requiring extra data transmission, it would complicate the implementation of the client's ability to navigate between subsets of elements associated by the query. Since the client's design did not prescribe any particular nesting order and since both DiGIR and WFS do not allow nesting, the third option was preferred over the second one and, thus, it was decided to send the entities to the client using a GML format, and the relationships as pairs of FIds/GUIds.

The rest of this article is organized as follows: initially, both the nucleus and the client are described, then some performance results are given and, finally, conclusions and future plans are presented.

DESCRIPTION OF THE MEDIATING NUCLEUS

The mediating nucleus obtains information from three categories of sources:

1. Members that allow the access to their individual servers, either in its native form (e.g., ArcSDE) or using a GML source.
2. Sources that, for performance reasons, deposit their information in a spatial data base server intimately related to the nucleus.
3. Sources that are accessible through DiGIR servers, who, periodically, will have their information migrated to the nucleus' server.

The first category of sources will be accessed by means of a *GeoServer*, an open source platform that uses OGC standards to connect to GIS's in an uniform manner (Geoserver, 2003), while the information of the remaining two categories will be deposited in a PostGIS server.

The nucleus is composed of several environments; these environment are either aimed at supervising the client's connections (the *Connection's* Environment), or at administrating the users' permits (the *Users*' environment), or at handling the DiGIR migrating environment (the *Migrating* environment), or at managing the registration and exposing the contents and metadata of the federation's servers (the *Servers*' environment), or at solving the clients' queries (the *Per-Query* environment).

Figure 2 illustrates the relationships among the nucleus' components.

The next paragraphs will concentrate in the discussion of the per-query environment that optimizes, executes and assembles a user's requests.

The Per Query Environment

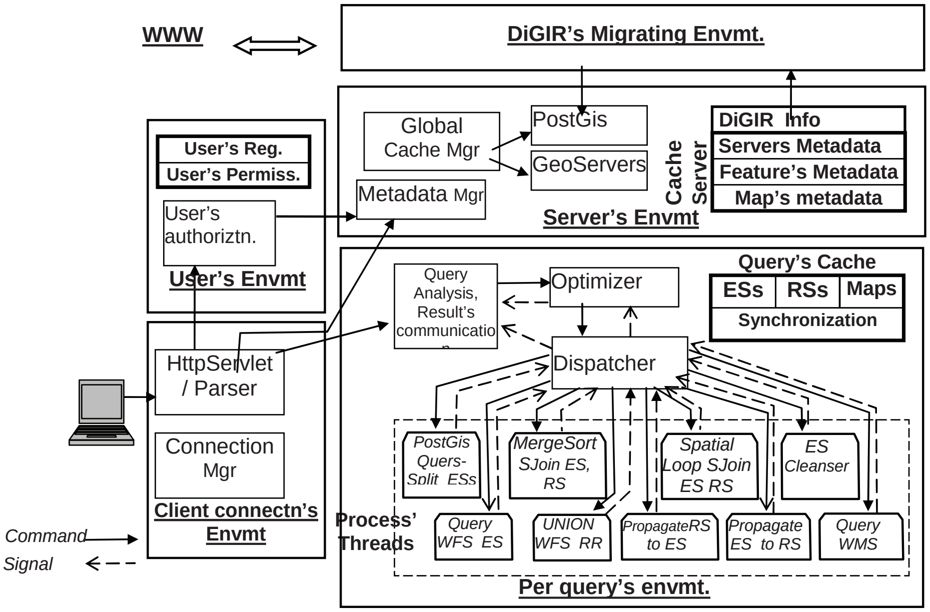
The Per-Query (*PQ*) environment receives two kinds of information requests from the client:

1. Requests asking for background maps using a command of GML that obtains an image of geographic data rendered in a pre-defined style; these requests are merely delegated to a GML server.
2. Requests involving one or more types of spatial features, usually related by join conditions. These requests require a more extensive processing, described in the paragraphs below.

Only the second kind of requests will be discussed here. Inside the nucleus, the PQ environment uses a GML format to handle both the intermediate results and the final solution to these requests. This information is represented by means of two kinds of structures:

1. *Entity Structures* (ES), one for each collection of features involved in the query; according to the GML standard, every component of a feature collection is associated with a FId (Feature Identifier), which is unique within the feature's source.
2. *Relationship Structures* (RS), one for each pair of features involved in a join condition. Each of these structures contains a collection of pairs of FId's that represent the associations created by the join condition involved.

Figure 2. Nucleus' components



In the Per-Query environment, a query is solved in four stages:

1. Parsing and analysis. The client sends, via HTTP, a XML coded request representing a Select-Project-Join-Union query; the format employed reuses WFS's schemas for coding the selects. The request dictates, in addition, the spatial projection in which the results are to be rendered. If the request is correct, query processing continues to the next stage.
2. Optimization. Once the query has been parsed, the set of possible execution alternatives must be explored searching for a good execution plan. To evaluate and generate possible alternatives, several things are needed: (a) methods to formulate sets of equivalent execution plans for the query; (b) formulas to evaluate the performance of candidate plans (these formulas are based on the statistics of the data processed by the query); and (c) methods to retrieve these statistics.
3. Execution of Tasks. The optimizer produces a sequence of operators to be applied to the data; this plan is sent to the Dispatcher for its enforcement. In turn, the Dispatcher launches a sequence of threads, one for each operator whose entry data is ready, starting from the plan's "leaves". When a thread terminates its task, the Dispatcher consults the optimizer's plan and either launches a new operator or sends the results to the client.
4. Submission of results. When the plan completes execution, be it normally or because of an error, the Dispatcher forwards the query's results (or failure notification) to the Query Analyzer. Once this task is completed, the corresponding PQ environment disappears.

The next two entries describe, respectively, optimization and task execution.

Plan Optimization

A good execution plan, specifying both the kind and the sequence of the operators to be applied, is crucial to achieving an adequate performance. Obtaining a proper plan requires quantifying the costs of each alternative. These cost functions, in turn, need numerical and statistical information both on the input and the output data structures. Attaining this information involves, among other issues, obtaining the cardinality and size of the structures and the values (or sets of values) contained in them. In commercial database systems this information is typically acquired by processes that sample the data at idle times.

This statistical information is not available in the kind of servers that integrate our federation (OpenGIS, 2002) that can only provide either full sets of results or the cardinality of them.

As an initial solution, the Mediator dictates the order of the semijoin's plan, giving priority to non-spatial over spatial operations and, when considering semijoins that use the same kind of operators, giving preference to those associated with the structures of least cardinality. Both the propagation and the cleansing operations are delayed until needed.

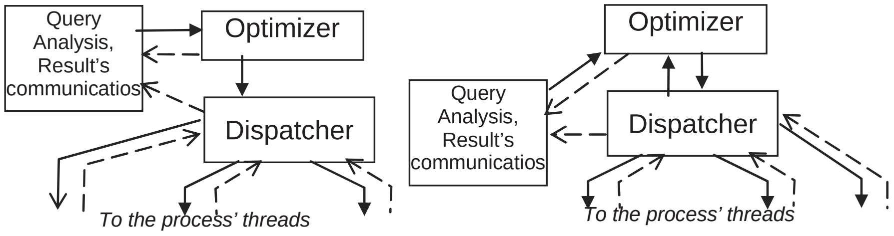
Thus, at present, an architecture in which the optimizer dictates a plan prior to processing is used (Figure 3, Option a).

In line with Deshpande et al., (2007) and lyas et al. (2007), the optimizer and the dispatcher are being redesigned to interact with each other periodically (Figure 3, Option b). In this design, as the operations proceed, the plan is re-examined once certain operations finish; at these points, statistics can be obtained or modified, and a decision made as to whether to continue with the existing plan or to switch to a more promising one.

Task Execution

The threads executed by the dispatcher perform three kinds of tasks:

Figure 3. Two alternatives for the optimizer in the PQ environment



Option a): A-priori plani

Option b): Periodic adaptation

1. Populating the ES's from the data sources.
2. Performing intermediate operators to the ES's and RS's.
3. Cleansing/adapting the results.

In addition to these three tasks, the Dispatcher assigns and manages the memory resources to store the ES and ER structures, orchestrates the synchronization mechanisms needed to coordinate the different threads, and can terminate the execution of a query upon receipt of a client's request. The following paragraphs explore the three kind of tasks cited.

Populating the Entity Structures (ES's)

Presently, the ES's are populated by two methods: (a) by means of a WFS request that retrieves data obeying a certain conditions or (b) as a consequence of the execution of a PostGIS plan. We are planning to include a third method, using DiGIR, a protocol for retrieving structured data from biological collections.

Populating an ES via a WFS command is done by sending a WFS request to the corresponding source; in the case of one accessible by GeoServer, this request includes the "Select" predicates related to the associated Feature.

Populating the structures via PostGIS plan differs from the method above in that the command's execution may fill one or more ES's as well as some RS's. To formulate such a query, the query analyzer processes the query graph, looking for maximal subgraphs that are: (a) connected, and (b) composed entirely of features resident in the Mediator's entrusted data that resides in PostGIS. After these queries are executed, the results are split into the corresponding ES's and RS's, translating them into GML.

Intermediate Operators

Entity Structures are initially populated by sending a request to the corresponding source; the request includes the "Select" predicates associated to the source in question.

The mediating nucleus can perform "Select-Project-Join-Union" queries: Since the "Select" predicates are performed by the data sources, the nucleus implements operators to perform the Union and Join capabilities. The Project functionality will be discussed when describing the cleansing and adaptation of results; the implementation of the Join and the Union capabilities has the following characteristics:

Join Operations. To reduce memory footprint, Joins are implemented as of a program of double semijoins; Suppose, for instance, that two ES's named A and B are semi-joined, perhaps this operation will eliminate some tuples in A and/or in B and also will produce a new RS (R$_{AB}$,) made of pairs of those Fid's of A and B that are associated by the join's condition. If, at a later time, A is needed in a new join with C, the new reductions caused in A will be propagated first from to A to R$_{AB}$ and then from R$_{AB}$ to B. Thus, the nucleus has implemented operators (a) to propagate changes from an ES to an RS and vice versa and (b) to perform semijoins; this latter operator comes in different implementations to consider either spatial or non-spatial predicates.

Union Operations. The version presently implemented by the nucleus requires that all of the ES's involved in it must have the same schema, this being a constraint of DiGIR.

Cleansing and Adaptation of Results

These operations are executed "just in time" by the ES cleaner (Figure 2); this component can concatenate these operations to execute them, if needed, in a single pass. These operations include: (a) Algebraic Projection operators, to remove fields that are no longer included; (b) transformation of spatial coordinates to the cartographic projection desired by the client; and (c) application to individual fields of functions that are required either at the output or to perform some intermediate step, like transformation to upper/lower case, field concatenation, XML type transformations, elimination of accents, etc.

DESCRIPTION OF THE CLIENT

This tool, programmed in C++, has been designed as a semi-light component; this means that, in order to reduce the information flow from/to the mediating nucleus, the Client can maintain state by storing a query's results either to do some exploration on them or to export them to another program.

The Client allows a user to query the members of the federation in graphical form; these queries are sent via *http* to the Mediator. The layout of the client's windows have been inspired by *uDig*, a desktop internet GIS (http://www.refractions.net:8080/confluence/display/UDIG/Home).

The client has four types of windows:

1. *ViewPort*. It is the principal panel that contains both editors and views.
2. *Views*. Their mission is the display of metadata, be it a catalog of the federation members' features, or descriptions of the projects stored in the client, or of the maps generated inside a project, or of the layers that constitute a map. These results in four views: *Catalog*, *Projects*, *Map*, and *Layer*; a layer, in turn, may contain the results of more than one query.
3. *Editors*. They are used to either pose queries or to display data (vs. metadata). There are four of them: (a) *Map* editor. It is used to display the results of queries, represented against background provided by WMS, the map service specified in GML. This editor is the main window of the client and the user may access from it other editors or tools that allow her both to explore the data contents of the results as to navigate through the relationships established by the join conditions; (b) *Query* editor, which poses a request to the mediator, using a graphic interface *a la* Microsoft's Access; (c) *Attribute* editor, which shows the attributes of sets features selected from the map editor; and (d) *Graphic* editor, which allows the definition of polygons, points, lines, etc. in a vector form, to be used in the conditions of Select predicates.
4. *Tools*. They are specialized graphic components, invoked from either views or editors, used to perform certain tasks. Examples of them are: the *Join-predicate* tool, called from the Query editor; the *Map* tool, used by the Map view to prescribe which contents of the map editor are to be shown, as well as their depth order; the *Style* tool, called either from the Layer view or from the Map editor, to select the colors and transparency of the layers within a map, their order of display, and the attribute used to tag a feature; the *Selection and Navigation* tool, to choose subsets of a

certain feature type or to navigate from one subset of features to corresponding subsets in other features related by the query; and a tool used to obtain background maps.

Tables 1 and 2 list the tools, editors and functions accessible from the Map Editor, as well as their icons.

To start a session, the client will connect to a chosen mediator. Once the connection is established, the Catalog view (as well as the icons on shown on the ViewPort) is activated; later clicks on the catalog view will request the metadata of the members of the federation, by issuing to the mediator WFS commands to obtain the data sources available and, for each one of them, metadata describing the source's contents. The system, in turn, will forward these commands to the Geoservers connected to the mediator or to the internal PostGIS database.

To illustrate the usage of the query editor, one can consider a request to localize, within a certain area of interest *A*, the existence of plant species that contain strychnine and are within a certain distance of a river. Suppose that the Institute of Chemistry has a purely relational database (no spatial features) on the contents of plant species (*Compuesto*), that Biology has a spatial table called "*Colectas*" with the collections of plants, and that the Institute of Geography has maps of rivers (*Rios*).

Table 1. Tools/editors accessible from the map editor

Icon	Editor or Tool
🖌	Style tool
✎	Graphic editor
▷	Selection/navigation tool

Table 2. Functions accessible from the map editor

Icon	Function
✖ ↻	Clean/refresh map editor
✥	Adjust to window
⊕ ⊖	Zoom in/out
X	Cancel command's execution

Formulating the query has three steps:

1. Dragging the features involved in the query (Chemical Contents, Collections, and Rivers) from the catalog view to the query editor. Figure 4 illustrates the results of this step.
2. Including into these features the "Select Conditions", e.g., that the collections have to be inside a certain area, or that the plants in the Chemical Contents feature must have strychnine. This step also defines the attributes that are to be retrieved for each feature.
3. Specifying, by means of the Join-predicate tool, conditions to build relationships among the different features of the query.

The client will translate this inquiry to a Query graph, and will send it to the Mediator using a SOAP command.

RESULTS AND PERFORMANCE

The performance of spatial joins in the Mediator, including the Web retrieval from the individual sources, is comparable or superior at times to the one achieved by PostGIS using spatial indices; the performance of non-spatial joins in the Mediator can be three to eight times slower than PostGIS.

Performance, Non-Spatial Joins

Table 3 describes the results of an equijoin between two relations, *cab_mun* that has data about the head cities of the municipalities in Mexico and *marloc95a* that contains information about townships; the table shows the results of queries that return the populations and geometries (the "*the_geometry*" attribute) of the cities and munici-

Figure 4. Adding three features to the query editor

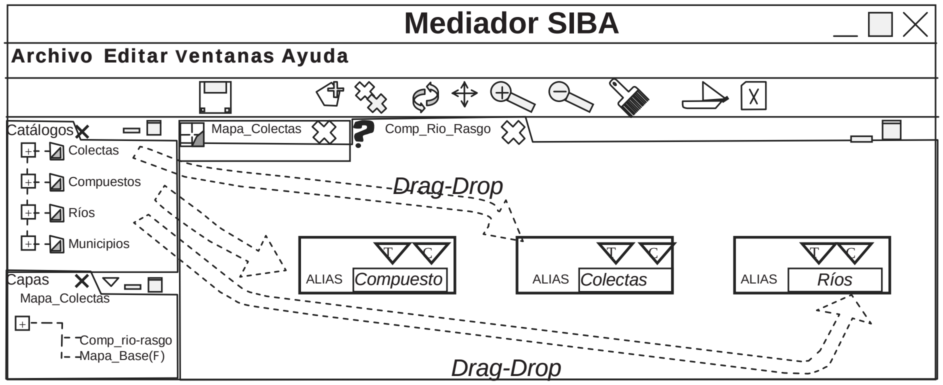


Table 3. Comparison, Mediator vs. PostGIS, non-spatial query

#R1, #R2	# Results	Time, (sec) Mediator Geo-server	Time (sec), PostGIS
2443, 2500	581	1.032	0.172
2443, 5000	1,111	1.328	0.328
2443, 10000	2,340	2.156	0.641
2443, 20000	4,011	3.484	1.094
2443, 30000	6,114	5.172	1.656
2443, 40000	8,123	6.484	2.187
2443, 50000	10,091	8.140	2.703

palities, using different subsets of *marloc95a*; the Mediator used a sort-join algorithm that used an external sort. The PostGis query, in SQL, is:

SELECT R1.gid, R2.gid, R1.total_pop, R2.tot_population,

ASGML(R1.the_geometry), ASGML(R2.the_geometry)

FROM cab_mun R1, marloc95a R2

WHERE R1.tot_population = R2.tot_population

Performance, Spatial Joins

Two example queries are presented to evaluate the performance of spatial joins. Both queries use a mammal's collection extracted from a Darwin Core depository and a weather map of a geographic sub region of Mexico (*clima1mg*); in both data sources, the spatial component is called "*the_geometry*". The first query obtains the rodents that are within the sub region; the second one obtains the rodents that are in an arid climate. The first PostGis query is:

SELECT COUNT (c.gid) FROM clima1mg c, mammals c1

WHERE c.the_geometry && c1.the_geometry

AND CONTAINS (c.the_geometry,c1.the_geometry) AND c1.order='RODENTIA'

The second query adds an extra conjunction (*AND c.clima_llav=23*) to the first one.

The processing times are shown in Table 4:

CONCLUSION AND FUTURE WORK

In its current form, the Mediator does not support cyclic queries or aggregate functions; its implementation of union operators is limited and it only admits conjunctions as join predicates; selection predicates, however, are not restricted. The plan is to allow cyclic queries, using methods similar to those of Kambayashi et al. (1982).

Presently, the Mediator can access information in GML and DiGIR servers. It is planned to

Table 4. Comparison, Mediator vs. PostGIS, spatial query

OPTION	Query 1		Query 2	
	Time, sec.	# Results	Time, sec.	# Results
Mediator	140.2	15550	33.8	486
PostGIS + spatial ind.	949.4	15550	307.6	486

expand the system to access information in Grid Raster format, to be able to include data like that related to the climate information contained in WorldClim (WorldClim, 2008).

GML servers, in their present stage of development, do not support aggregate or sampling functions necessary for obtaining statistics needed by the optimizer. To solve this, a process of designing and implementing an adaptive query processor has been started (Deshpande et al., 2007); Ilyas et al., 2007).

Finally, users have expressed a need to query the mediator about what information is available on certain topics in predetermined regions so that they can pose queries involving non-familiar origins. It would be advantageous to allow the client to provide, for each of the data sources, richer information about the metadata (other than data types, value ranges, etc.), and to allow accessibility to the ontologies that describe these sources, in the lines of Torres et al., (2005) and Bartolini et al., (2006).

Therefore, the Mediator's future developments will be directed by users' needs as expressed in the focus areas of accessibility and information about contents.

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Chapter 8.15

Aligning Six Sigma and ITIL to Improve IT Service Management

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ABSTRACT

Organizations are implementing IT Service Management (ITSM) and creating quality standards to design, deliver, and manage IT services to meet or exceed an agreed level of quality. ITSM uses the best practices of IT Infrastructure Library (ITIL) that informs IT management what needs to be done and how it will get done from the process perspective. However when undertaking an ITSM a project to implement ITIL, ITIL does not provide a method for measuring quality or identifying and completing process improvement projects. By integrating the Six Sigma quality methodology, IT management will have the methodology and tools for measuring quality and improving processes. Adopting Six Sigma principles also helps IT managers focus on their business strategy and customers, manage proactively based on facts, and reinforce collaboration across the enterprise. The framework in our exploratory experience based research has been built upon a deductive study which has been developed through a literature review and synthesis and an exploratory inductive research which has been developed using a qualitative case study methodology in the e-services and mobile applications field. [Article copies are available for purchase from InfoSci-on-Demand.com]

OVERVIEW OF INFORMATION TECHNOLOGY SERVICE MANAGEMENT (ITSM)

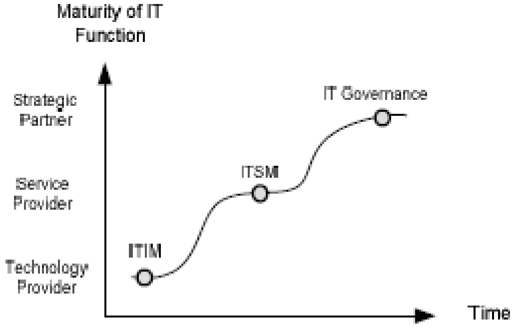
Today's executives are challenged to deliver value to their shareholders in a global market place and to compete, organizations are setting business strategies for the entire organization. This management change presents a significant change for Information Technology (IT) organizations that have historically dealt with individual business units or functional domains. Now IT must support the enterprise's business strategy and the entirety of the enterprise. Technology organizations must deliver interoperation of processes, people and technology to the entire enterprise.

The rise of services oriented architecture, client server computing, virtualization and distributed applications have created a plethora of moving targets in the information technology (IT) organization. IT organizations have had to deal with a business that have historically been siloed by function or department and have been separated from the business. However since organizations have adopted an enterprise approach running their businesses, IT managers can no longer run an IT organization as a technology-based organization. They must be able to migrate to being a value-based service provider and contributor to the enterprise strategy instead of an overhead cost. IT Service Management (ITSM) is a process-based practice intended to align the delivery of IT services with needs of the enterprise, emphasizing benefits to customers. ITSM involves a paradigm shift from managing IT as stacks of individual components to focusing on the delivery of end-to-end services using best practice process models (WhatIs.com, 2008). Information Technology Infrastructure Library (ITIL) is a globally recognized collection of best practices for information technology (IT) service management.

ITSM audits are based on analysis of four key performance indicators in specific ways:

- Growth and value, which involves tracking revenue growth against investment and utilization.
- Budget adherence, which involves optimizing the use of available funds and avoiding unnecessary expenditures.
- Risk impact, which involves identifying and evaluating the consequences of risks taken or avoided.
- Communication effectiveness. IT managers need to adopt a service management approach consisting of well-defined IT processes and a continuous improvement program in order to meet their customer's expectations and contribute to the enterprise's goals.

Figure 1. Evolution of the IT function within organizations (Salle, 2004, p. 1)



ITSM Evolves IT to Achieve Higher Result with Business Focus

To meet the challenge, IT managers in USA are adopting ITSM, a practice that has been used by their European counterparts for over 24 years. According to Salle (2004), the evolution of IT organizations typically mature through three stages: technology provider, service provider and strategic partner.

Continual maturity occurs as the IT organization moves through each stage. In the initial stage the IT organization operates as a technology provider and it is using IT infrastructure management (ITIM). In this stage, the focus is to manage and provide a solid infrastructure to the enterprise by maximizing the return on technical assets and controlling the infrastructure including its hardware and data. As an organization moves to becoming a service provider it will use ITSM which leverages ITIL to identify the "services its customers need and focusing on planning and delivering those services to meet availability, performance, and security requirements. In addition, IT is managing service-level agreements, both internally and externally, to meet agreed-upon quality and cost targets. Ultimately, when IT organizations evolve to IT business value management (IT Governance), they are transformed into true business partners enabling new business opportunities. In that stage, IT processes are fully integrated with the complete lifecycle of business processes improving service quality and business agility." (Salle, 2004, p. 1). Alternatively the Capability Maturity Model Integrative (CMMI) model from the Software Engineering Institute can also be used as the organization evolves in the maturity level of its processes.

This article is structured as follows: the key attributes of ITSM, ITIL and Six Sigma are discussed independently before illustrating some business cases integrating ITSM, ITIL and Six Sigma. This is followed by the discussion of the implications for research and management before the conclusion. The framework in this exploratory experience based research has been built upon a deductive study which has been developed through a literature review and synthesis and an exploratory inductive research which has been developed using a qualitative case study methodology in the e-services and mobile applications field. It makes the case for leveraging ITIL and Six Sigma with ITSM in practice and discusses opportunities for future research and implications for management.

ITIL

What are ITIL and ITIL Service Management Practices?

The U.K. government's Central Computer and Telecommunication Agency created ITIL. It is a framework and does not require a license to practice and it is independent of any commercial solution or platform. In the last 24 years, ITIL has become a de-facto standard and most widely used accepted approach to define processes for IT service-oriented organizations. It aligns IT processes to overall business goals. ITIL is a guide for establishing common processes, roles and activities, with appropriate reference to each other and how communication lines should exist (ITIL, 2007). Although processes dictate how services are delivered, processes are of little interest to customers because they are not visible. ITIL is a public domain set of books that describes comprehensive and consistent best practice guidance in the area of organizing a coherent process for IT Service Management. In the late 1980's when it was originated it consisted of more than 30 books, but the release of ITIL V3 condensed the framework into 5 books.

The latest version is ITIL V3 and it is designed to address the significant shortcomings of ITIL V2. ITIL V3 has a broader scope and contains everything that was included in Version 2. Version 3 pays more attention to the areas of designing services suitable for the business and creating a strategy around this. Version 3 gives more advice on Continual Service Improvement (Damiano & McLauglin, 2005, p. 253). ITIL V3 addresses the life cycle of service management. It embraces a more holistic service management practice that included business and IT at strategic, tactical, and operational layer. While in comparison, ITIL V2 focused just on the operational layer of IT operations. The new version provides best practice guidance to implement a true life cycle of service management in five best practice guides. Version 3 of ITIL library consists of 5 five sets of books (See Table 1).

Benefits of ITIL for Service-Oriented Organizations

ITIL's framework of best practices can be used to assist organizations as their needs and technology evolve around processes. ITIL Service Management Practices offer benefits that demonstrate their value and ROI. Organizations can use ITIL to add more value to their business, be more agile with their responses, define standards, implement new technologies, adopt new trends, regulate compliance, and improve the quality of IT services. Additionally, companies gain higher productivity from both business and IT staff. These best practices for the support and delivery of IT services can help a company document IT processes as required for Sarbanes-Oxley (Worthen, 2005). ITIL is part of the foundation of the COBIT model, which defines control objectives for IT in support of business processes. COBIT was explicitly chosen as the tool of choice for external auditors to use in IT audits for Sarbanes-Oxley. The ITIL process documentation and COBIT control objectives are a powerful combination that can accelerate Sarbox compliance. ITIL allows IT staff to become more innovative in their work. "The results of a recent survey by Axios Systems, show that over one-third of IT professionals have already adopted the ITIL framework, while another one-third plan to roll-out the framework within a year. In the same research, 70% of the Best-in-Class businesses had the ability to measure end-user satisfaction and 60% of the Best-in-Class businesses could compare service delivery standards against SLA provisions" (Brown, 2007, p.5).

Table 1.

Book	Responsibility of Book
Service Strategy	Defines the policies and strategies to implement Service Management in line with the overall business strategy. It focuses on the planning aspect of the policies and strategies.
Service Design	Describes how to use the strategy to create design and specifications for the service. This book has more structure and explains a step-by-step approach to designing services. Much of what was in this book was already addressed by ITIL v2 with the exception of security management.
Service Transition	Covers configuration, change and release management. Change management focuses on how to assess and plan for changes. Configuration management has been extended to include service assets or IT assets, which are important for IT to be aware of. This book also Details how to get the specification into the live environment.
Service Transition	Defines how to best support the support the day- to-day running of the service throughout its life cycle. Provides guidance on running a live production environment.
Service Operation	Provides a framework for Continual Service Improvement. Service performance is measured at each stage ensuring that IT align and continually realign to the needs of the business. This book makes it clear that, for organizations to become more proactive, assessments must be a continual process, rather than one that only happens when a failure occurs.

What Does ITIL not Do?

ITIL does not focus on a specific industry segment or restricted geographically. ITIL does not address who within the organization is going to be in charge of implementing each process. It does not address the how to use the tools that are needed to implement these processes. ITIL does not offer corporate or organization certificates but rather personal certification. Certification does not guarantee service quality and this is a common misconception within IT organizations. Many vendors and consultants offer services in restructuring ITIL, and many customers seek such guidance. However, ITIL does not promote an organizational structure, or require any particular management. Nor does the ITIL mandate any particular workflow design or process. Here is a quote from ITIL: "For each of the processes described in this book, one or more roles are identified for carrying out the functions and activities required. It should be noted that organizations may allocate more than one role to an individual within the organization, or may allocate more than one individual role. The purpose of the role is to lace responsibility rather than to create an organizational structure" (ITIL Organization, 2006)

What you Need to Know before Adopting ITIL?

ITIL's core practice guides are adaptable and applicable within a variety of organizational context. However, every organization is different and should have its own unique requirement. ITIL can be intimidating to understand and organizations should realize that you can not conform to, adopt, comply with or implement ITIL because it is not a set standard and you can not use what ITIL says verbatim.

IT is a service function providing effectiveness, value, and support to the enterprise and its strategy. Organizations should focus on service and business performance improvement first and not processes. An organization should put in place just enough process to answer the question for any given situation to avoid adding processes that don't add value or are not definitive.

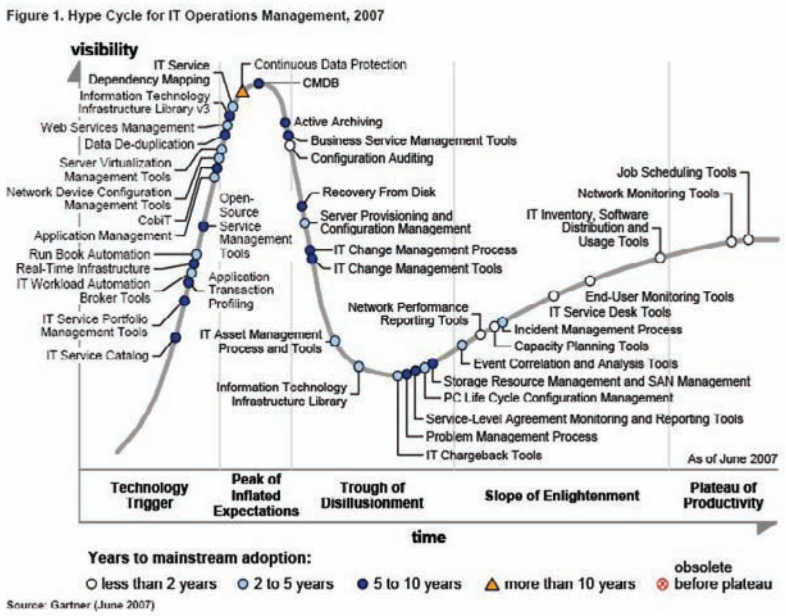
Organizations have been adopting ITIL for approximately 25 years. As illustrated in figure 2, that is consistent with the diffusion theory organizations are moving towards becoming service providers as discussed by Salle in 2004.

SIX SIGMA

Six Sigma was introduced and created by the U.S. based electronics manufacturer Motorola, Inc. In the mid-1980's CEO Bob Galvin established a goal to improve "all products – goods as well as services – by an order of magnitude (e.g. factor of 10) within 5 years" (Klefsjo & Wiklund & Edgeman, 2001, p. 31). During this time, Motorola's field sales force received and reported increased customer complaints about warranty claims. To address the issue, "Bill Smith, a senior engineer and scientist within the Communications Division" invented the new quality method, Six Sigma which standardized the counting defects; by reaching Six Sigma defects would be "near perfect," only 3.4 defects per million. Smith convinced Bob Galvin that this process would be a "key to addressing quality concerns" (McCarty, 2004, p. 1). "Six Sigma clearly focused resources at Motorola, including human effort, on reducing variation in all processes, that is to say manufacturing processes, administrative processes and all other processes. To set a clear measure on the improvement work, the program called Six Sigma was launched in 1988" (Klefsjo et al., 2001).

Antony, (2007) states, "There have been three recognizable generations of six sigma. The first generation of six sigma lasted for a period of 8 years (1987-1994) and the focus was on reduction of defects. Motorola was a great example of a successful first generation company. The second generation of six sigma spanned the period from

Figure 2. Hype cycle for IT operations management, 2007 (Govekar et al., 2007)



1994 to 2000 and the focus was on cost reduction" (p. 17). During this period the methodology was popularized by GE's, CEO Jack Welsh embracing the approach to quality. For example, "AlliedSignal attained savings of $US2 billion during a five-year period while General Electric saved $US1 billion over a two year window" (Klefsjo et al., 2001, Six Sigma origins section). The third generation, according to Antony (2007) started after 2000, and its focus "is on creating value to customers and the enterprise itself. The first companies to embrace third generation of six sigma are foreign. Examples of third generation of six sigma companies include Posco, Samsung, etc." (p. 17).

Six Sigma Themes

Although the beginning of Six Sigma is steeped in quantitative analysis, it is a misperception that Six Sigma is only a statistical measure with a goal of perfection. Pete Pande and Larry Holpp (2002) in the book "What is Six Sigma?" assert Six Sigma is more than a statistical and process methodology and they distribute Six Sigma into Six themes:

- Understand and focus on the customer.
- Be dependent on data- and fact-driven management.
- Master and improve your key processes.
- Manage proactively.
- Collaborate across boundaries within the organization.
- "Drive for perfection, but tolerate failure" (p. 14-16)

Six Sigma Methodologies: DMAIC and DMADV

There are two key Six Sigma methodologies: DMAIC and DMADV. DMAIC is an acronym for Define, Measure, Analyze, Improve, and Control. DMADV is Define, Measure, Analyze, Design, and Verify (DMADV). According to Kerri Simon (2002) in the article, DMAIC versus

DMADV, the DMAIC method is predominant in Six Sigma implementations and "should be used when a product or process is in existence at your company but is not meeting customer specification or is not performing adequately." Practitioners when employing DMAIC, seek to "root out and eliminate the causes of defects" (American Society for Quality). Pande and Holpp (2002) agree that organizations needing to fix broken processes can reap benefits of implementing DMAIC. By using DMAIC organizations will have proven and identified the extent of the problem. By assessing and measuring problems, an organization will be spending time and resources solving high value problems. When the problem is proven and selected for resolution, its root cause is identified using data and facts, not intuition and gut feel. As the DMAIC team works to create a solution, their purpose is to affect real change to the existing problematic process. The resulting solution must be well tested to manage risks to the organization. After the solution is implemented within the enterprise, the organization measures the results validates that the solution is sustaining change (2002, p. 30-31). In the table below, Chieh (2007), outlines in the chart below how DMAIC can be utilized to fix under performing processes….

When designing new processes, the approach used is Design for Sigma Six (DSFF). DSFF uses DMADV not DMAIC in order to design and move to market "new products or services measures by customer-based critical-to quality metrics" (Foster, 2007, p. 463). Simon expands the uses of DMADV beyond the creation of new products or services and advocates using DMADV approach after optimizing an "existing product or process" fails to meet "customer specification or Six Sigma level" (Simon, 2007).

Six Sigma Key Roles

To carry out the work, Six Sigma identifies key roles and responsibilities. The Executives and Champions are responsible for selecting project that will be implemented by the organization. The associates responsible for implementing the projects and process improvements are Master Black Belts, Black Belts, Green Belts, Yellow Belts, and White Belts. It is important to note that successful Six Sigma implementations have a top-down management approach.

Tools of Six Sigma

The teams once formed will use a series of tools, which are employed with the Six Sigma methodology. The expansive toolset, which teams leverage to complete their work, is a primary benefit Six Sigma. Pande and Holpe (2002) recommend teams limit the use of tools to only those that help "get the job done" (p. 67) and categorize the tools as follows (See Table 3).

Criticism of Six Sigma

There is a recent debate of whether Six Sigma has a place in companies embracing the new innovation economy. The argument is that it is difficult for innovation and Six Sigma practices to coexist because by their very nature they are opposite. Six Sigma requires the organization to focus and direct its resources on operational excellence and perfection; it has a very low tolerance for risk because imperfection is increased when risk is introduced. On the other hand, innovation is by its very nature a high risk because it is dealing with new concepts (Rae, 2007). Dr. Thomas Davenport contends that the time for Six Sigma has passed as companies are embracing innovation:

Process management is a good thing. But I think it always has to be leavened a bit with a focus on innovation and [customer relationships]." The discipline was developed as a systematic way to improve quality, but the reason it caught fire was its effectiveness in cutting costs and improving profitability. That makes it a powerful tool—if those are a company's goals. But as innovation becomes the cause du jour, companies are increas-

Table 2. DMAIC in mathematical terms

Steps	Phase	Questions
1. Understand what process is to be improved and set a goal.	Define	> What is the Y or the outcome measure?
2. Measure the current state.	Measure	> What is Y's current performance?
3. Develop cause-and-effect theories of what may be causing the problem. 4. Search for the real causes of the problem and scientifically prove the cause-and-effect linkage.	Analyze	> What are the potential Xs or causes? > What may be causing the problem? > What are the real Xs or causes? > What is really causing the problem?
5. Take action.	Improve	> How can the understanding of the real causes of the problem be exploited to eliminate or reduce the size of the problem? > How can this Y = f(X) understanding be exploited?
6. Measure to verify improvement has taken place. 7. Take actions to sustain the gains.	Control	> Did Y really improve? > How can the Xs be controlled so the gains in Y remain?

(Chieh, 2007, n.p.)

Table 3.

Category	Tools
Gathering Ideas and Organizing Information	√ Brainstorming √ Affinity Diagramming √ Multi-voting √ Tree Diagram √ High-Level Process Map √ Flow Chart (Process Map) √ Cause and Effect (Fish Bone) Diagrams
Data Gathering	√ Sampling √ Operational Definitions √ Voice of the Customer Methods √ Check sheets and Spreadsheets
Process and Data Analysis	√ Process Flow Analysis √ Pareto Charts √ Histograms (Frequency Plot) √ Run (Trend Chart) √ Scatter Plot (Correlation) Diagram
Statistical Analysis	√ Test of statistical significance √ Correlation and regression √ Design experiments
Implementation and Process Management	√ Project Management Methods √ FEMA √ Stakeholder Analysis √ Force Field Diagram √ Process Documentation √ Balance Score Cards and Process Dashboards

Adapted from Pande and Holpe (2002, p. 51- 67) ingly confronting the side effects of a Six Sigma culture (Grow & Hindo, 2007).

The above opinion is supported by Benner and Tushman's research that suggests that Six Sigma will lead to more incremental innovation at the expense of more blue-sky work. The two professors analyzed the types of patents granted to paint and photography companies over a 20-year period, before and after a quality improvement drive. Their work shows that, after the quality push, patents issued based primarily on prior work made up a dramatically larger share of the total, while those not based on prior work plummeted (Hindo, 2007).

Examples of Six Sigma's fall from extreme favor can be seen at many fortune 100 companies including Home Depot, GE and 3M. The new CEO of Home Depot, Blake Frank has scaled back the strictness of the Six Sigma implementation enacted under the former CEO Robert Nardelli by giving more decision making to store managers. After the departure of James McNerney, 3M's leadership has changed its implementation of Six Sigma. Even GE, who under Jack Welsh popularized Six Sigma within the United States, is working to change how Six Sigma is used. Jack Immelt is attempting to move his team to innovate around a theme of "ecomangination" with mixed results (Grow & Hindo, 2007).

This debate does not mean that Six Sigma cannot provide value to organizations. It does mean that Six Sigma cannot be implemented in a vacuum. Multiple methodologies are needed to support the enterprise strategy. For example, companies that are looking to innovate while supporting and improving processes and products are adopting the "Ambidextrous Organization" proposed by O'Rielly and Tushman's (2004) research that shows that successful companies pursue innovations because "they separate their new, exploratory units from their traditional, exploitative ones, allowing for different processes, structures, and cultures; at the same time" (p. 74). The organizations "maintain tight links across units at the senior executive level. In other words, they manage organizational separation through a tightly integrated senior team" O'Reilly & Tushman, 2004, p. 75). To describe these organizations, O'Reilly and Tushman (2004) have coined the term "ambidextrous organizations" and believe that the organizations have provided a "practical and proven model for forward-looking executives seeking to pioneer radical or disruptive innovations while pursuing incremental gains. A business does not have to escape its past; these cases show how to renew itself for the future. Their study showed that 90% of the ambidextrous organizations achieved their goals (O'Reilly & Tushman, 2004, p. 76).

BUSINESS CASES INTEGRATING ITSM, ITIL AND SIX SIGMA

Combining ITIL® and Six Sigma to Improve Information Technology Service Management at General Electric, Fry and Bolt (2004) outline the process that GE undertook in 2004 to improve internal practices for their IT service management. The IT Solutions Enterprise Planning & Strategy consulting group was engaged to develop a process improvement methodology that combined ITIL and Six Sigma to migrate from the current state to "measurable, ITIL-compatible processes" (p. 3). The group used Six Sigma to assess risk, compare current state and processes to the end goal, and then identified the solution which leveraged Remedy's "ITSM Suite to automate and improve ITSM processes" (Fry & Bolt, 2004, p. 3) The five objectives set by the team included 1) Achieve ISO Compliance for ITSM using ITIL for GE IT standards (ITIL is ISO 9000 compliant), 2) Use ITIL framework to define ITSM best practice standards, 3) Assess the current state of IT service by using the Capability Maturity Model (CMM) and Capability Assessment Tool against the ITIL standard, 4) Constantly improve ITSM processes using Six Sigma and Deming's

Total Quality Management (TQM), and 5) Define measurement using Six Sigma to assure control and improvement (Fry & Bolt, 2004, p. 3)

To implement the methodology and meet the objectives set by the team, the team executed the Six Sigma DMAIC. The chart below outlines the project phase, goal or purpose and deliverable as stated by Fry and Bolt (2004) in the case study (See Table 4).

Table 4.

Phase	Goal or Purpose	Deliverable
Phase 1: Define Opportunities	Align ITSM strategy with the business, organizational, and technological strategies. The desired result is to set a definitive vision, scope, and strategic approach for ITSM operations.	> Team charter that describes the purpose, goals, and resources for the project. > Data collection plan that includes such items as interview schedules and questions. > Critical to Quality (CTQ) outline that identifies the critical success factors. > Current situation analysis that was created using the CAT tool. > Customers/Output—Process—Input/Suppliers (COPIS) "as-is" process map outline that provides an understanding of the current processes to which the solution
Phase 2: Measure performance	Create a current-state assessment of how well the current environment supports the ITSM strategy. The desired result is to determine current processes, issues, and the critical success factors—or Critical To Quality factors (CTQs)—of the desired future state environment.	> An accurate assessment of current process performance. > Detailed "as-is" process maps derived from the COPIS outline created in Phase 1 > Critical Success Factors (CTQ) summary chart
Phase 3: Analyze factors impacting performance	Examines the data collected in the Measure phase to generate a prioritized list of the sources of variation. The Analyze phase focuses improvement efforts by separating the "vital few" variables (those most likely responsible for the variation) from the "trivial many" (those least likely responsible for variation).	> Opportunities Table: Solutions mapped to process gap > Critical Success Factors (CTQs) benchmarked against ITIL best practices to identify opportunities for improvement > Cause and Effect Diagram > Pareto Chart of Opportunities
Phase 4: Improve Performance	Define and refine recommended tactical solutions based on information determined in phases 1-3. The desired result is a documented recommendation based on strategic fit, cost, and benefits.	> Risk Assessment/Failure Modes and Effect Analysis (FMEA)/Contingency Plan. > Prioritized potential solutions > Solution Pilot > "To Be" process maps
Phase 5: Control Performance	Propose a plan for designing and implementing the ITSM process improvement solution. The desired result is a true life cycle ITSM solution that allows for continuous improvement.	> Multi-Generational Product Plan (MGPP) > Process metrics defined > Full solution implemented > Control/Response Plan implemented > Risk mitigation actions complete

Source: Fry & Bolt, 2004, pp. 4-8

GE's project to improve their IT service management demonstrates that ITIL and Six Sigma can be leveraged together to implement and maintain ITSM within an organization. The benefits that GE found included 1) reducing cost by minimizing "potential downtime and the adverse effects of system, network, and application failures and install, move, adds, change and decommission implementations". 2) "Improve decision-making ability by facilitating access to information throughout the organization, and by enabling the enterprise wide use of outputs from an integrated framework of processes and tools through such devices as cross functional IT service dashboards" and 3) "Improve IT service levels by creating operational efficiencies and enabling a linked IT Service Management process loop for defining, measuring, analyzing, improving, and controlling service performance" (Fry & Bolt, 2004, p. 9).

Liberty Mutual, a diversified global insurer and sixth largest property and casualty insurer in the U.S., has introduced Lean Six Sigma and ITIL to dramatically reduce cycle times, improve quality and reduce cost. Although it is still in the early days of introducing Lean Six Sigma to the overall organization, preliminary results have been encouraging. Since 1994, the Boston-based company has almost tripled net revenue, to $23.5 billion, while shedding noncore businesses like financial services and health care. For example, in one of the company's underwriting groups, process reengineering has helped reduce cycle time by as much as 70 percent. Within the IT group, Lean Six Sigma is the foundation for all process-improvement efforts. Stuart McGuigan, CIO and senior VP of Liberty Mutual Group, calls ITIL a "common-sense model" and believes it can empower a large organization like Liberty Mutual by helping the organization break work into meaningful components and achievable goals. He also says that ITIL gives him a common language that was missing during the days when each technology silo had its own terms and conventions. "ITIL," he says, "has given us an end-to-end vocabulary." (Brown, 2008).

In another case study, Integrated Mobile delivers end-to-end life cycle management of an enterprise's entire inventory of wireless assets through a single management interface. With capabilities built on the lean Six Sigma, ITIL and CMM principles, Integrated Mobile eliminates the obstacles, challenges and distractions of managing wireless services resulting in a highly efficient and effective mobile enterprise. The issue was managing mobile services and assets of more than 925 retail outlets across major metropolitan markets in 49 states with more than 76,000 employees. Adding more than 17,000 new employees annually and several new stores, including international outlets, could lead to a mobile environment that is overwhelming. The company needed to find an efficient way to handle the multitude of inquiries, tasks and transactions associated with their mobile communications since there was too much time and money being spent on maintaining wireless devices. In this state of chaos there was no time to identify ways to drive efficiencies and improve the end-user experience.

This specialty retailer turned to Integrated Mobile's iManage solution, a feature-rich, managed service that helped eliminate the chaos and excessive costs often associated with a mobile enterprise (Integrated Mobile, 2007). Integrated Mobile's iManage solution includes:

- A Single Interface for All Wireless Management for All Carriers
- Supply Chain Automation
- Custom Kitting
- Provisioning and Fulfillment
- Standardized Handsets and Catalog Management that Supports Business Rules
- Approval Workflow
- Cost Allocation
- Credit Card Transaction Processing

- 24x7 Bilingual Administrative and Technical Tier 1 Support
- Asset Management
- Comprehensive Reporting, Transactions, Trends, Defects
- Validation of Transactions on the Carrier Bill
- MACD Processing
- Rate Plan Optimization
- Defect Elimination
- Optional iCare and iBill services for application and device support and invoice processing

This is how the specialty apparel retailer in this case study was able to improve satisfaction and productivity while driving down the cost of wireless with capabilities built on the lean Six Sigma, ITIL and CMM principles.

Lessons for IT Managers

It was to be expected that GE, an organization whose culture under the direction of Jack Welsh became entrenched in Six Sigma, leveraged Six Sigma when it implemented a project to use ITIL to improve its IT Service Management. But even organizations that are not Six Sigma implementations can benefit from using Six Sigma principles, methods, and tools. For example, the purpose of ITSM is to align the IT organization with the enterprise. This aligns to Pande and Holppe (2000) contention that within the Six Sigma implementation that there should be an emphasis and focus on the customer. Additionally, Six Sigma recommends collaborations across boundaries within the organization which is important to IT management because they need to determine service many divisions and functions and must provide enterprise level not silo level support and service. Using the DMAIC project management approach provides the IT organization a methodology to establish a vision and strategy for ITSM within the organization, assess the current state and its effectiveness in supporting the ITSM strategy, determine what is most likely for not meeting the defined strategy, identify a solution and propose a plan for implementation ITSM. Alternatively, if ITSM and ITIL are currently in place within the organization, the Six Sigma approach to organizing and getting work done including identifying and selecting problems to be solved could be used. Additionally, the Six Sigma tool kit provides tools that assist IT staff identify problems, determine root causes, and recommend ITIL solutions to fix existing problems. To provide sound IT service management, organizations should use ITIL and Six Sigma combined to ensure strategic alignment with their organization.

IMPLICATIONS FOR RESEARCH

The framework in our exploratory research has been built upon a deductive study which has been developed through a literature review and synthesis and an exploratory inductive research which has been developed using a qualitative case study. It makes the case for leveraging ITIL and Six Sigma with ITSM in practice and opportunities for future research.

IT operations, as the production arm of IT departments, have been mostly ignored by IT research. There is a growing body of research on isolated aspects of operations services; but there is little research that is explicitly ITSM related. Despite the significant growth of ITSM practice in industry, there is no academic work or community of scholars that shares a common mission to understand how to advance it. Services are emerging in separate areas of academic, industry and government but few attempts to integrate them (Conger et al, 2007, p. 50). Since the early versions of ITIL lacked truly quantifiable business values, IT organizations are not interested in and supportive of IT Service Management processes. ITIL faces an uphill battle for acceptance and creditability that needs to be won across the entire organization.

Six Sigma is a measurement-driven approach to continuous process improvement that focuses on reduction of variation, consistency and high product quality. Therefore, in terms of IT service oriented industry, combining Six Sigma with ITIL can migrate current processes toward usable, measurable, ITIL-compatible processes as mentioned above with the case study on GE, however there is no research on version 3 because it is relatively recent, i.e., released in May 2007. Based on this we have shown the Six Sigma tools, which can be used to improve ITSM processes using the DMAIC model.

IMPLICATIONS FOR MANAGEMENT

At this point we have provided background on ITSM, ITIL and Six Sigma individually. But the question is can an organization's ITSM implementation benefit by integrating ITIL and Six Sigma? We conclude that ITIL and Six Sigma should be leveraged in tandem by IT organizations. Together with the ITIL best practices model and Six Sigma continual improvement and measurement, IT will be able to set boundaries and provide control elements for the senior IT management. ITIL is needed to provide the framework and best practices for ITSM. ITIL provide a set of guidelines to specify what an IT organization should do based on industry best practices. ITIL best practices process model is a key item to drive IT to meet the enterprises expectation.

However, ITIL does not define for an organization how it should be accomplished. According to Fry and Bolt (2004) "Six Sigma provides a process improvement approach that is based on statistical measurement, drives quality improvement, and reduces operational costs. It helps in developing detailed work instructions, and it defines a methodology for continually mapping, measuring, and improving the quality process. Six Sigma tells how, but it doesn't tell what to do nor does it specify any best practices specifically for ITSM…ITIL defines the "what" of service management and Six Sigma defines the "how" of quality improvement. Together, they make a great combination for improving the quality of IT service delivery and support" (p.2). ITSM, ITIL and Six Sigma combined can also assist IT govern itself and ensure that it is meeting and sustaining the enterprises strategies and objectives (Colbeck et al., 2005).

CONCLUSION

Over the next decade, executives will continue to be challenged to deliver value to share holders and other stakeholders. To support the organization, IT executives and managers will be challenged to transform their organization from delivering technology to providing service and ultimately becoming a business partner within the organization. To meet the challenge, we encourage the use of ITIL in combination with Six Sigma in IT Organizations with an ITSM implementation. IT managers need to leverage ITSM to develop, deliver and manage IT services to agreed upon quality standard. To have a sound IT management, managers should use ITIL v3 as best practices. Six Sigma DMAIC should be used to make certain that ITSM is aligned with the customer and to provide the mechanism to deliver and monitor all the IT service management processes. The case study at GE shows that ITIL and Six Sigma can be used in tandem to deliver ITSM and meet the organization's business objectives. Nevertheless, delivering ITSM using ITIL and Six Sigma is a one building block for building a world-class company. World-class competitors do not achieve the status because they adopted a "tool or technique." They achieve the status because they are good in "performing the fundamentals "including understanding their customers, products, employees, competitors' landscape, the market they are competing in and the enabling technologies. The world-class competitors succeed because they are creative and know how to make use of operations processes to their best advantages (Foster, 2007, p. 509). ITIL and Six Sigma are just two tools that should be used for the IT organization to deliver world class IT Service Management and meet quality targets. As the IT organization successfully delivers ITSM, it will become a business partner within the organization

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APPENDIX A: ROLES WITHIN SIX SIGMA

The hierarchy and the roles within a Six Sigma organization are described by the American Society for Quality (http://www.asq.org) and Thomas Pyzdek as follows:

Roles	Description of Role
Executives/Leadership	Must be lead by the CEO because "Six Sigma involves changing major value streams that cut across organizational barriers (Pyzde, 2000). Provides overall alignment by establishing the strategic focus of the Six Sigma program within the context of the organization's culture (ASQ).
Champions	Champions are the next level within the organization. These are "high-level individuals who understand Six Sigma and are committed to its success." In a Six Sigma implementation there will also be "informal leaders" who are daily practitioners and are communicating the "Six Sigma message" within the organization (Pyzde, 2000). The role of a champion is to "translate the company's vision, mission, goals and metrics to create an organizational deployment plan and identify individual projects." They are also to "identify resources and remove roadblocks" (ASQ).
Sponsors	Sponsors own processes and systems that can be improved using the DAIMC process. They "help initiate and coordinate Six Sigma improvement activities in their areas of responsibilities" (Pyzde, 2000).
Master Black Belts	Within the project hierarchy, the Master Black belt is "highest level of technical and organizational proficiency." The Master Black Belt is responsible for providing technical leadership, including statistical training and assistance to Black Belts, developing key metrics, and strategy within the Six Sigma program. The Black Belt must have the same knowledge as the Black Belt; additionally, they must "understand the statistical mathematical theory on which the methods are based… There is usually about one Master Black Belts for every ten Black Belts, or about 1 Master Black Belt per 1,000 employees" (Pyzde, 2000). They are similar to a Program Manager within the Project Management hierarchy
Black Belts	Black Belts are respected leaders and technically inclined; they "receive 160 hours of classroom instruction, plus one-on-one project coaching from Master Black Belts or consultants." An organization will have on average "about one percent of their work force as Black Belt." A Black Belt, Project Manager, will complete between 5 to 7 projects each year. (Pyzde, 2000). Black Belts are responsible for leading "problem solving projects and the training of and coaching of project teams" (ASQ).
Green Belts	Green Belts are the equivalent of a project lead within the Six Sigma program. They are capable "of forming and facilitating Six Sigma teams and managing Six Sigma projects from concept to completion" (Pyzde, 2000). Green Belts are also responsible for assisting "with data collection and analysis for Black Belt projects" (ASQ).
Yellow Belts	Yellow Belts are project team members. They review "process improvements that support the project" (ASQ).
White Belts	White Belts "can work on local problem-solving teams that support." overall projects, but may not be part of a Six Sigma project team. They understand "basic Six Sigma concepts from an awareness perspective" (ASQ).

Adapted from American Society for Quality (http://www.asq.org) and Thomas Pyzdek (2000)

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